Concept of Operations for I-376 Parkway East Corridor Transportation Network

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List of Acronyms and Abbreviations

ATDM……..……..Active Transportation and Demand Management
ATM…….…….Active Traffic Management
ATMS……..……..Active Traffic Management Software
AVIDS……..……..……..Automated Video Incident Detection System
AWWVD……..……..……..Automated Wrong Way Vehicle Detection
AI…….……...Artificial Intelligence
CCTV……Closed Circuit Television
ConOps……..Concept of Operations
DMS…….……Dynamic Message Sign
FHWA……...Federal Highway Administration
FOC…….….Fiber Optic Cable
GUI…….Graphical User Interface
HAR…….……Highway Advisory Radio
ITS……..Intelligent Transportation Systems
LCS…….…….Lane Control System
LUCS……..……Lane Use Control Signal
MVDS……Microwave Vehicle Detection Sensor
OSP……..Outside Plant
PennDOT……...…..Pennsylvania Department of Transportation
PSP……...…….Pennsylvania State Police
RCRS…….Road Condition Reporting System
RTMC……Regional Traffic Management Center
RWIS …….……Road Weather Information System
SEA……...……Systems Engineering Analysis
SPC……..……..…Southwestern Pennsylvania Commission
SWRI…….....South West Research Institute
TMC……..Transportation Management Center
TSMO……...….Transportation Systems Management and Operations
VSLS……..….Variable Speed Limit Sign
VSS……..……Video Sharing Solution
WWDS……Wrong Way Detection System
WRTMC……..Western Regional Traffic Management Center

1. Overview

The Concept of Operations (ConOps) is a foundation document that frames the overall system and sets the technical course of the project. A high-level conceptual overview of the intended system will be explained in a way that each stakeholder can understand. The ConOps attempts to answer the Who, What, When, Where, Why and How (**Figure 1**) for the system in general terms for major system capabilities and functionality.

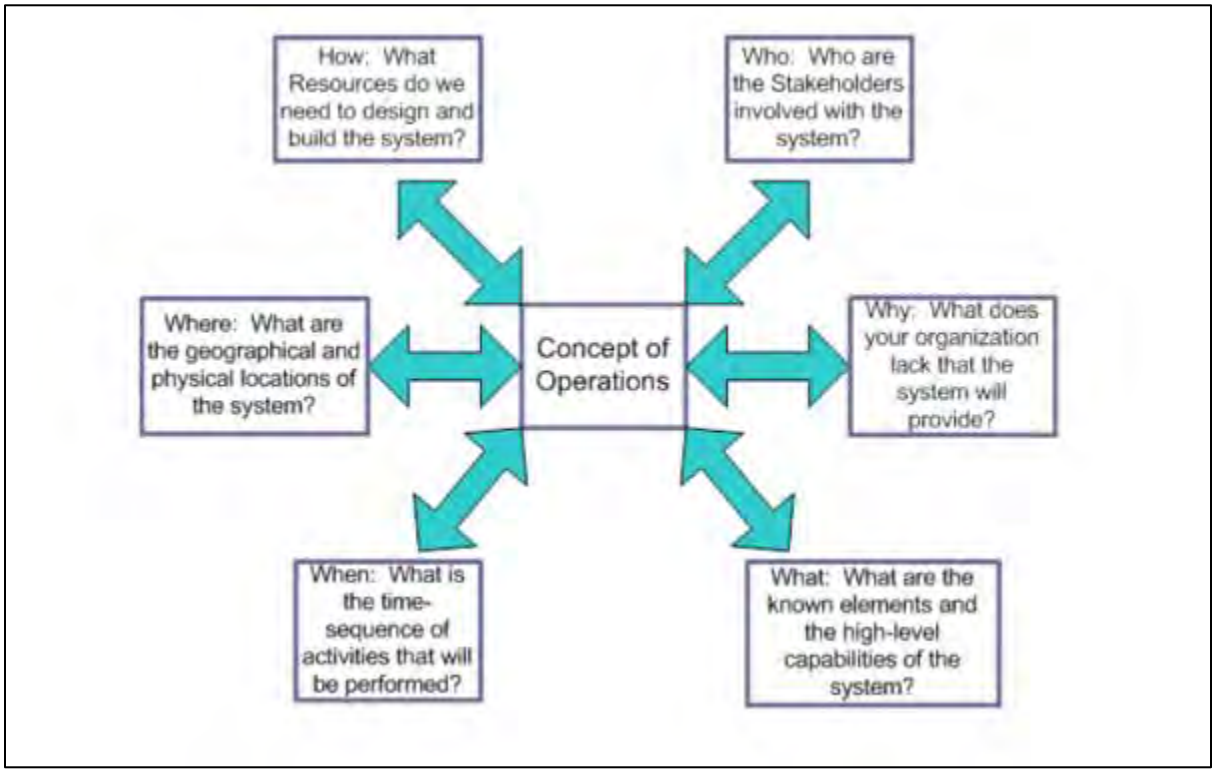

Figure 1: Concept of Operations

Additionally, the document is part of the Federal Highway Administration (FHWA) policy that requires Systems Engineering Analysis (SEA) for all Intelligent Transportation Systems (ITS) projects using federal funds, by FHWA Rule 940. The first section of the ConOps document provides six elements: system identification, purpose, an overview of this document, a high-level overview of the proposed system, stakeholders, and references. These elements are described in the following sections.

2. System Identification

The Parkway East (I-376) is a major transportation link in Southwestern Pennsylvania, extending from downtown Pittsburgh to Monroeville. The Parkway consists of multiple interchanges (**Figure**

2) between downtown Pittsburgh and Monroeville, and also includes intersecting arterial routes. The Parkway East Corridor serves automobiles and trucks on the roadway network; pedestrians and bicyclists on an adjoining network of sidewalks, trails and bike lanes; transit riders on the Martin Luther King, Jr. East Busway and on a network of express and local bus routes.

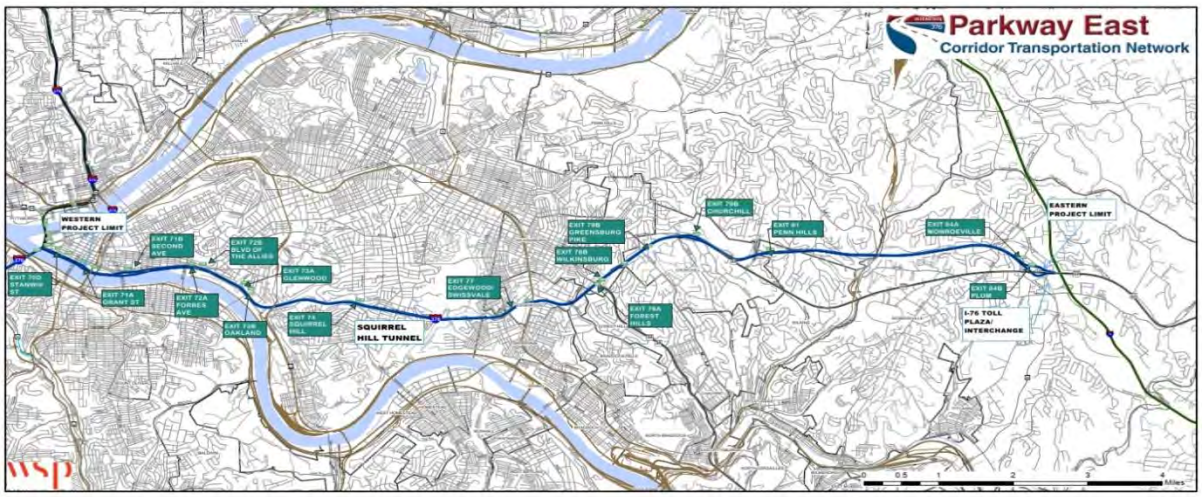

Figure 2: Parkway East Corridor Transportation Network

The Parkway East, primarily a six-lane highway with an Average Annual Daily Traffic (AADT) of 96,000 is the primary route between the Pennsylvania Turnpike (I-76), the eastern suburbs, city neighborhoods and downtown Pittsburgh. While serving as a major transportation connection throughout the Southwestern Pennsylvania Region, the Parkway East is severely congested with above average crash rates.

Alternate routes are limited and similarly congested. Additionally, due to topographical constraints of the region, the Parkway East roadway geometry does not meet current design criteria, contributing to it being one of the most congested in the state. The corridor suffers from unreliable travel times, as well as significant non-recurring congestion due to incidents and other contributors.

3. Objectives

Pennsylvania Department of Transportation (PennDOT) is looking to advance the deployment of an Active Traffic Management (ATM) System for I-376 Parkway East in Allegheny County, Pennsylvania.

One of the first and most important elements of the "systems engineering process", often depicted as the "Vee" diagram (**Figure 3**), is the Concept of Operations.

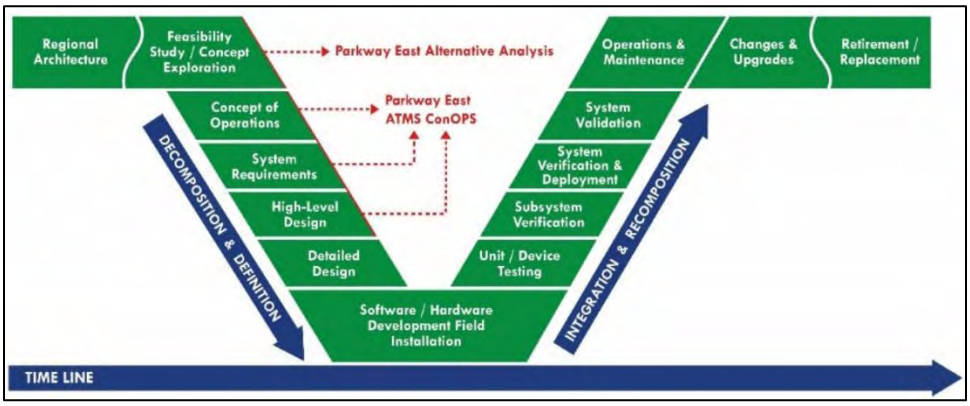

Figure 3: Vee Diagram of Systems Engineering Process

The purpose of this ConOps document is to provide conceptual ATM System implementation strategies along the I-376 Parkway East corridor, including the Squirrel Hill Tunnel traffic control system.

The ConOps is a foundation document that frames the overall system and sets the technical course of the project. Its purpose is to clearly convey a high-level view of the system to be developed that each stakeholder can understand.

The ATM System ConOps is built upon the previous I-376 Parkway East Corridor Transportation Network Phase 2 Alternatives Analysis. It identifies ATM System safety improvements that will enhance the corridor by reducing crashes, improving travel time reliability, reducing congestion and providing or enhancing travel options. A range of improvements are identified that could provide additional benefits throughout the corridor and wider-area network as part of future projects.

The Parkway East ATM System project aligns with the Regional Operations Plan (ROP), which utilized the statewide Transportation Systems Management and Operations (TSMO) framework to identify the needs for this project. The ConOps outlines ATM strategies to better implement statewide TSMO strategies to manage traffic. The purpose aims to improve efficiency, safety, reliability, and system performance while reducing travel time variability. Overall, a proposed ATM project will support incident management, Fire-Life Safety response coordination, regional economies and communities that rely on freight mobility, on-time logistics, and improved commuter availability for continued growth. As this project progresses, PennDOT will evaluate trending mobility technologies that would enhance connections to multimodal options, deploy innovative technologies such as connected vehicle technology, and implement corridor-wide integrated systems for intersecting arterial control to support a cohesive transportation network.

Focusing on implementing critical strategies to address major congestion, improve motorist advisory efforts, and reduce closures, the Parkway East ATM project proposes improvements such as:

- Implementing ATM technologies and strategies that provide enhanced situational awareness, real-time monitoring, and automated traffic control devices.
- Supporting future intersecting arterial roadway coordination and operational strategies.
- Improving timeliness of communications to motorists of Parkway East conditions through a variety of technology tools and sources to support both pre-route decision-making and real-time dynamic routing decisions.
- Reducing the impact of non-recurring congestion and improving travel time reliability on the Parkway East.
- Improving the regional economy through better freight mobility and by enhanced connectivity between the communities, businesses, technology hubs, and research institutions along the Parkway East.

The Parkway East ATM System will coordinate with projects on connecting freeway as the system design progresses.

4. High-Level ATM System Overview

The goal of the proposed Parkway East ATM System is to implement ATM strategies to improve safety, reduce congestion, improve travel time variability, inform motorists, and increase throughput along the Parkway East (I-376). The 14.5 mile highway provides a connection from the Eastern suburbs and Pennsylvania Turnpike I-76 to the City of Pittsburgh. Constructed in the 1950s, the Parkway East (I-376) has struggled to keep up with increasing traffic demand. The space available for geometric improvements is limited, so innovative solutions to improve safety and reduce congestion are being developed.

This ConOps follows FHWA ATM System strategies for conceptual deployment along the Parkway East and the Mitigating Congestion solutions from PennDOT Pub 851, TSMO Guidelines.

Dynamic Lane Use Control This strategy involves dynamically closing or opening of individual traffic lanes as warranted and providing advance warning of the closure(s), typically through dynamic lane control signals, to safely merge traffic into adjoining lanes. Dynamic lane use control (**Figure 4)** is often installed in conjunction with dynamic speed limits and also supports the ATM strategies of dynamic shoulder lane (flex lanes) and dynamic junction control.

Figure 4: Example of Dynamic Lane Use Control. Photo and Illustration. Example of full gantry ATM deployment in Washington State (Source: WsDOT).

Additional Dynamic Message Signs This strategy will provide additional dynamic message signs (DMS) along the Parkway East corridor, and incorporate or replace existing DMS signs as appropriate. Additional DMS will be installed in the Corridor, either on proposed gantry posts or on stand-along supports. On the Parkway, the additional signs will be part to of the queue detection and warning system; along the arterials, they will be used to inform motorists of travel time, traffic or roadway conditions and other information.

Dynamic Speed Limit This strategy, also called variable speed limit **(Figure 5)**, adjusts speed limits displays based on real-time traffic, roadway, and/or weather conditions. The strategy can either involve enforceable (regulatory) or advisory speed limits, which can be applied to either an entire roadway segment or individual lanes. The result is a "smoothing" process which helps minimize the differences between the lowest and highest vehicle speeds, also called "speed harmonization."

Figure 5: Example of Dynamic Speed Limit Sign. Photo. VSL sign in Wyoming (Source: WYDOT)

Merge Control This strategy, also known as dynamic late merge or dynamic early merge **(Figure 6)**, consists of dynamically managing the entry of vehicles into merge areas with a series of advisory messages approaching the merge point that prepare motorists for an upcoming merge and encouraging or directing a consistent merging behavior. Applied conditionally during

Figure 6: Example of Merge Control. Photo. DMC application in Texas, Phase 2 (Source: TTI)

congested (or near congested) conditions, such as a work zone, merge control can help create or maintain safe merging gaps and reduce shockwaves upstream of merge points.

Queue Warning This strategy involves real-time displays of warning messages (typically on dynamic message signs and possibly coupled with flashing lights) along a roadway to alert motorists that queues or significant slowdowns are ahead, thus reducing rear-end crashes and improving safety. Queue warning (**Figure 7)** may be included as part of Dynamic Speed limit and Dynamic Lane Assignment strategies.

Figure 7: Queue Warning (Source: Missouri DOT)

Incident Ramp Management (**Figures 8** and **9)**, this solution provides the ability to close ramps to traffic, potentially using a series of signs and automatic gates, in response to incidents or roadway conditions.

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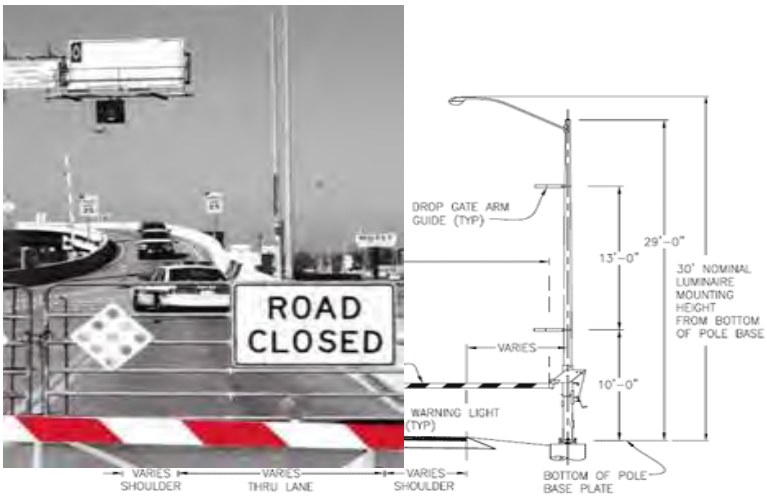
Figure 9: Sample Gate Closure Detail (Source: Colorado Department of Transportation. Standard Plan M-607-15, Road Closure Gate Drop Detail.)



Adaptive Traffic Signal Control: This strategy continuously monitors arterial traffic conditions and the queuing at intersections and dynamically adjusts the signal timing to optimize one or more operational objectives (such as minimizing overall delays). Adaptive Traffic Signal Control (**Figure 10)** monitors traffic flows upstream of a signalized intersection or signalized corridors, , anticipating volumes and flow rates in advance of reaching the first signal, then continuously adjusting timing parameters (e.g., phase length, offset, cycle length) during each cycle to optimize operational objectives.

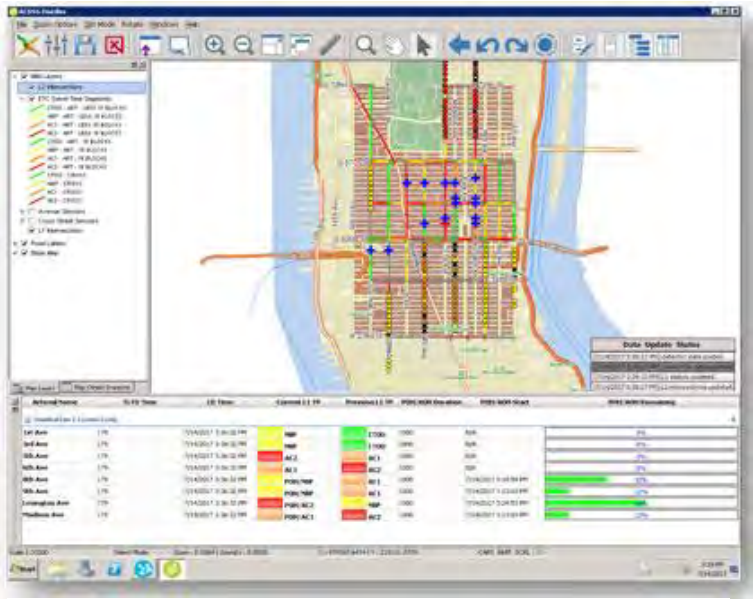


Figure 10: ATSX application in New York City (Source: New York Department of Transportation)

Dynamic Junction Control This strategy consists of dynamically allocating lane access on mainline and ramp lanes in interchange areas where high traffic volumes are present, and the relative demand on the mainline and ramps change throughout the day **(Figure 11)**. For off- ramp locations, this may consist of assigning lanes dynamically either for through movements, shared through-exit movements, or exit-only. For on-ramp locations, this may involve a dynamic lane reduction on the mainline upstream of a high-volume entrance ramp.

Figure 11: Simulation graphic. Dynamic junction control implementation. (Source: Federal Highway Administration.)

Automated Wrong-Way Vehicle Detection and Warning This strategy uses sensors or video analytics to detect vehicles traveling in the wrong direction and provide real time messages and ramp management strategies to prevent additional motorists from entering the freeway in high danger locations **(Figure 12)**. This technology also sends real time alerts to the TMC.

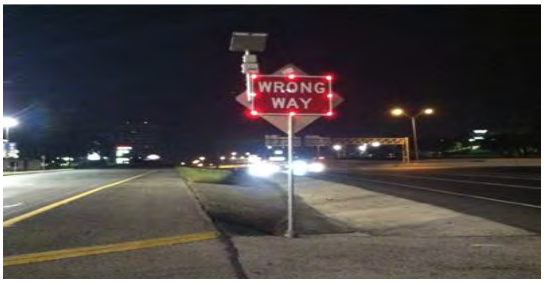


Figure 12: Automated wrong way vehicle detection. (Source: San Antonio District of the Texas Department of Transportation (TxDOT)) (Source: Traffic and Parking Control Co., Inc).

5. Stakeholders

Table 1 in Appendix C, identifies the stakeholders that are system users and may be involved in the project's development. An important goal of this ConOps is to ensure interagency collaboration and project awareness between agencies along the corridor.

6. Current Roadway System

Background

The Parkway East (I-376) is a major transportation link in Southwestern Pennsylvania, extending approximately 14.5 miles from the Fort Pitt Bridge in downtown Pittsburgh to an interchange with the Pennsylvania Turnpike (I-76) and US Route 22 in Monroeville. The Parkway East, as referred to in this ConOps, is the highway, its ramps, and the immediately adjoining segments of the connecting arterials.

The Parkway East serves a broad range of users including residents, commuters, visitors, shoppers, transit users and commercial traffic. The extended corridor is multimodal in nature, serving automobiles and trucks on the roadway network; serving pedestrians and bicyclists on an adjoining network of sidewalks and trails; and serving transit riders on the Martin Luther King, Jr. East Busway and a network of express and local bus routes.

The limited access interstate is connected to the adjoining highway and street network by exit and entrance ramps.

In the eastbound direction, beginning at downtown, Pittsburgh, there are 13 exit ramps and 10 entrance ramps:

- Three (3) exit ramps are linked by lane drops (Forbes Avenue, Squirrel Hill / Homestead and I-76 PA Turnpike)
- 10 exit ramps are linked by deceleration lanes.
- Three (3) entrance ramps are linked by add-lanes (Fort Pitt Boulevard, Boulevard of the Allies and Churchill Road)
- Seven (7) entrance ramps are linked by acceleration lanes.

In the westbound direction there are 12 entrance-ramps, and 11 exit ramps,

- Four (4) entrance ramps are linked by add-lanes (I-76 Pennsylvania Turnpike, Old Gate Road, Forward Avenue and Boulevard of the Allies)
- Four (4) exit ramps are linked by lane drops (Churchill, Wilkinsburg, Boulevard of the Allies, Grant Street and the lane drop to I-279 North Fort Duquesne Bridge / North Shore). (**Table 2 in Appendix C**).

Major intersecting arterials include the downtown streets feeding into Fort Pitt Boulevard, SR 885 Boulevard of the Allies, Bates Street, Beachwood Boulevard, South Braddock Avenue, US-30 / PA-8 Ardmore Boulevard, Greensburg Pike, PA-130 / Churchill Road, US Business 22, PA-791 Rodi Road, Haymaker Road, US-22 and I-76 Pennsylvania Turnpike.

The Parkway East typical cross-section shown in **Figure 13,** varies between four (4) and six (6) lanes. There are six (6) lanes on the city side (west side) of the Squirrel Hill Tunnel, four (4) lanes in the tunnel, four (4) to five (5) lanes on the suburban side (east side) of the tunnel and six (6) lanes east of Churchill Road to the I-76 Turnpike Interchange.

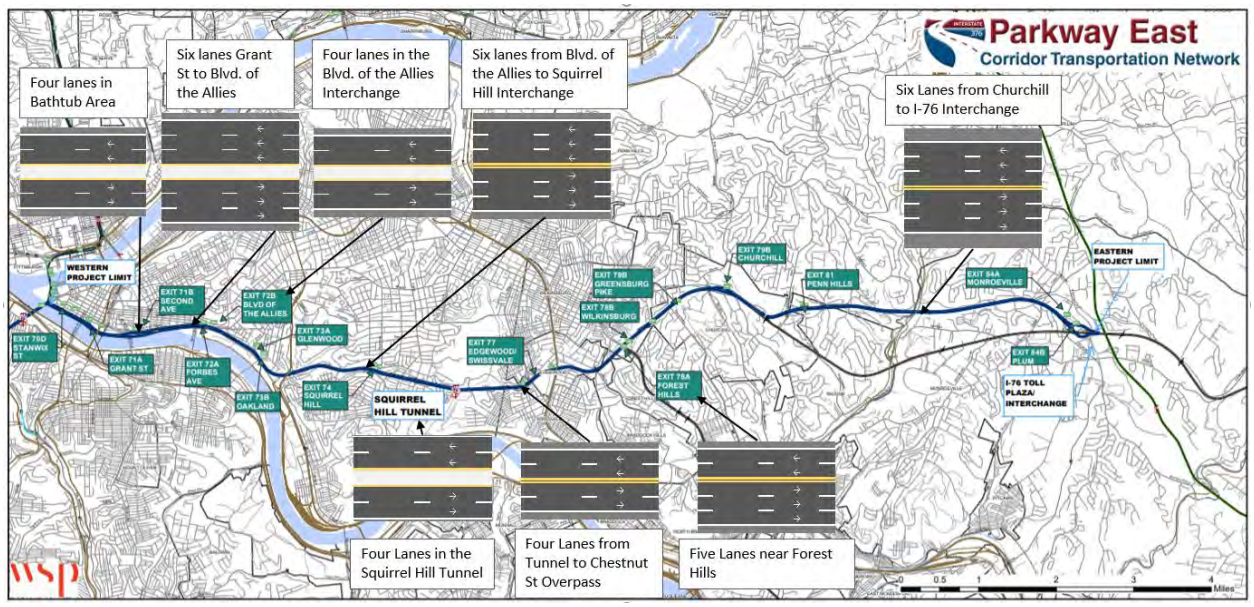


Figure 13: Typical Number of Lanes on the Parkway East

More specifically, working from west to east from downtown towards Monroeville there are:

- Four (4) lanes from Stanwix Street to Grant Street, in the "bathtub" area;
- Six (6) lanes from Grant Street to SR 885 Boulevard of the Allies, four (4) lanes within the Allies interchange;
- Six (6) lanes between Boulevard of the Allies and Squirrel Hill;
- Four (4) lanes in the Squirrel Hill Tunnel, two (2) lanes in each tube;
- Four (4) lanes from the Squirrel Hill Tunnel to the add-lane 500 feet east of the Chestnut Street overpass totaling five (5) lanes, three (3) eastbound and two (2) westbound.
- The 5-lane section continues for 1.7 miles until the eastbound lane ends, east of Greensburg Pike, merging into the through lanes, resulting in a brief 4-lane section.
- From the Churchill interchange the typical section is six (6) lanes to the Pennsylvania Turnpike I-76 interchange.

The highway is constrained by the rolling terrain of the Appalachian Plateau section of the Appalachian Mountains, part of the most rugged landscape in Pennsylvania. As a consequence of topography and adjacent development, the highway geometry is substandard; medians are too narrow and many of the deceleration and acceleration lanes to and from interchange ramps are substandard. Many of the exit ramps are posted with advisory speeds ranging from 15 MPH to 40 MPH. For the major part of the Parkway East, the mainline posted speed limit is 55 MPH. A truck speed limit of 35 MPH is posted for the westbound (inbound) direction near MP78, between Forest Hills and Edgewood Swissvale because of the 2 ½ mile steep downhill grade. The Squirrel Hill Tunnel is constrained with posted height restrictions of 15'-6" in the westbound (inbound) direction and 14'-9" in the eastbound (outbound) direction. All restricted placards loads are prohibited from the tunnel and must exit upstream. Five (5) emergency pull-off areas are provided in the westbound (inbound) direction and four (4) in the eastbound (outbound) direction, primarily in the urban section where shoulders and median are narrower or absent.

The Parkway East is highly constrained by hillsides, valleys, and adjacent development. Planning for the highway began in the 1930s. The first segment opened to traffic in 1953, and the remainder (**Figure 14**) was opened in phases until 1963. Squirrel Hill Tunnels are located on the Parkway East at the eastern border of the City of Pittsburgh; the tunnels dominate traffic flow on the Parkway East, cutting through a ridge where no alternate major highways are available. As a result, severe congestion regularly occurs on approaches to the tunnel, and traffic queues exist during many hours of the day. Peak period queues extend for several miles.

Figure 14: Parkway East Construction in the late 1950s.

7. Operational Constraints

The limitations of the operational characteristics of the Parkway East corridor are due to many substandard geometric roadway features and bottlenecks. These features, identified in the Phase 2 Alternatives Analysis, include substandard horizontal and vertical curvature, ramp design speeds, shoulder widths, and interchange ramp spacing. The roadway bottlenecks and capacity constraints are outlined in Section 10. Regarding the existing operational and aging ITS infrastructure components e.g., CCTV's, DMS, LUCS, ITS cabinets, OSP fiber optic cable, electrical services and underground systems along the Parkway East, many of these systems are beyond their life cycle and should be replaced. A detailed evaluation of the existing ITS infrastructure should occur during the design phase in order to determine whether the existing infrastructure is suitable for reuse or full replacement. A proposed ATM System along the Parkway East would require additional operational technical updates from hardware/software and human/AI interaction perspectives. Operational integration into PennDOT's Western Regional Traffic Management Center (WRTMC) and Statewide Advanced Traffic Management System (ATMS) virtual software platform would be required for operational functionality of the entire corridor to provide a seamless ATM System.

8. Roadway Capacity Constraints

Various locations along the Parkway East were identified as bottlenecks in the Technical Memorandum #7 Bottleneck Analysis, January 2015. Drivers experiencing queueing at these bottleneck locations may benefit from ATM strategies such as advance queue warning and dynamic speed limits. Images of the referenced bottleneck locations can be found in **Appendix A: Bottleneck Locations.**

Eastbound:

- Forbes Avenue Interchange
- Squirrel Hill Interchange
- Edgewood/Swissvale Interchange
- Greensburg Pike Interchange
- Churchill Interchange

Westbound:

- Forest Hills/Wilkinsburg Interchange
- Edgewood/Swissvale Interchange
- Squirrel Hill Interchange
- Bates St/ Glenwood Interchange
- Boulevard of the Allies Interchange
- Downtown Interchanges

The Squirrel Hill Tunnel is the main bottleneck point, in both directions, along the Parkway East. This is primarily due to the two-lane cross section through the tunnel in each direction, with three or more lanes, including ramps, feeding traffic into this area. In the westbound direction, there are two (2) through lanes plus the Edgewood and Swissvale on-ramp just upstream of the tunnel. In the eastbound direction, there are three (3) through lanes (the right lane drops at the Squirrel Hill Interchange) plus the Beechwood Boulevard on-ramp immediately upstream of the two-lane tunnel section. Traffic flow through the tunnel is constrained by the limited horizontal and vertical clearances, which lead some drivers to slow or to increase following distances when entering the tunnel. Due to the combination of these factors, the bottleneck operation is complex and encompasses not only the tunnel itself but also the Wilkinsburg, Edgewood/Swissvale, and Squirrel Hill interchanges. In the eastbound direction, the lane drop 900 feet past (east of) the Greensburg Pike off-ramp, and the left and right side onramps from William Penn Highway (Churchill)create another bottleneck. Traffic entering from the left side onramp from William Penn Highway (Churchill) is known to weave over three lanes of traffic to exit at the Business 22 (Exit 80) off-ramp. The weaving action creates turbulence in this section and queues often form. The preferred route would be to use the right side onramp from Churchill Road to Exit 80, however the limited sight distance and short acceleration lane make this merge uncomfortable for motorists.

A solution to the Churchill-Monroeville weave conflict may be to close the left side Churchill on-ramp (from William Penn Highway), and then shift eastbound Parkway East mainline to one lane to the left to provide an exclusive add-lane for the Churchill Road on-ramp on the right side. This may require additional improvements on surface roads and signals as traffic on William Penn Highway, normally destined to the closed on ramp, would need to divert right onto Buelah Road then left onto Churchill Road (opposite Helen Drive) and finally left to the right-side onramp, opposite Holland Road. A traffic signal may be warranted at Churchill Road and Holland Road intersection. Local residents may object to the increased traffic.

The lane shift on the Parkway Eastbound would require a 330' minimum distance. A cursory analysis indicates there is about 450' of available distance between the left on-ramp gore from William Penn Highway and the right on-ramp gore from Churchill Road.

The Parkway East carries an AADT of approximately 53,000 vehicles per day in the eastbound direction and 45,000 vehicles per day in the westbound direction. Travel times along the 14.5 mile corridor range from 14-55 minutes in the westbound direction and 14-45 minutes in the eastbound direction.

9. Crash Analysis

Crash data was analyzed along the entire length of the I-376 Parkway East Corridor to identify crash hot spots and trends. The results showed that “rear end crashes”, “hit fixed objects”, and

"same direction sideswipes" were the most common occurring crash types. These types of crashes can partially be attributed to the substandard geometry of the Parkway and interchanges.

Rear-end crashes accounted for 51% of the reported crashes. The recurring queueing and congestion approaching the Squirrel Hill Tunnel and adjacent interchanges play a large role in the number of rear end crashes. Along the eastbound side of the Parkway east, rear-end collisions occur mainly in the PM peak hours since this is the main outbound roadway from the city to the eastern suburbs. In the westbound direction, rear-end collisions are more evenly spread through the daytime hours. This is due to congestion and queuing at both the Fort Pitt and Squirrel Hill Tunnels.

Hit fixed object crashes accounted for 33% of the reported crashes along the corridor. Although some of these crashes are from vehicles hitting impact attenuators, the bulk of hit fixed object crashes consist of vehicles hitting the longitudinal concrete barrier in the median of the roadway. This is most likely due to the substandard interior shoulder width through a majority of the corridor.

Same direction sideswipe crashes were the third most prevalent at 6% of the reported crashes. The high volume of merging movements in the peak periods contributed to the same direction sideswipes. Substandard ramp geometry at many of the interchanges was identified as a contributing factor to this crash rate.

ATM strategies have been shown to reduce crashes, and with the recurring and nonrecurring congestion at the Squirrel Hill Tunnels and throughout the corridor, there are opportunities to improve safety.

10. Existing WRTMC and ITS

Traffic Management of the Parkway East Corridor is regionally controlled from PennDOT's Western Region Traffic Management Center (WRTMC) at 45 Thoms Run Road, Bridgeville, Pa. 15017. The WRTMC is part of PennDOT's Statewide Advanced Traveler Information System, providing information that is gathered from the highways in the metropolitan area to customers, media, and transportation partners. PennDOT utilizes multiple ITS devices/elements and on-line applications coordination e.g. INRIX-Waze to provide situational awareness of the Parkway East. There are approximately 273 closed circuit television (CCTV) cameras, overheight truck detection sensors, 5 Bridge Anti-icing Systems, Squirrel Hill Tunnel Overheight Detection System, (LCS) and 90 Dynamic Message Signs (DMS) to keep traffic flowing in the ten-county area of southwestern Pennsylvania. The management and command/control of the ITS device infrastructure is transmitted via a combination of OSP Trunk and Distribution Fiber Optic cable infrastructure and wireless links. Real time video feeds from the CCTV cameras are provided to the PA State Police, local TV stations newscasts and the 511 system statewide. PennDOT WRTMC operators at the Western Regional Traffic Management Center monitor conditions on I-79, I-279, I-376, I-579, PA 51, West End Bridge and other major arterials through the use of strategically placed closed-circuit television cameras. With a bird's eye view of traffic, staff at the WRTMC can quickly spot problems and immediately alert the Freeway Service Patrol and Pennsylvania State Police of an incident. Local traffic services, such as KDKA AM and Metro Traffic staffed at the WRTMC during AM and PM rush hour periods, are also alerted so they may pass along traffic news updates to drivers. Emergency responders are also alerted in cases of fire or serious incidents. The PennDOT Freeway Service Patrol is a roadside service provider that responds to incidents along the Parkway East in Pittsburgh. The fleet consists of tow trucks equipped with emergency lights and arrow boards. Crash trucks with mounted attenuators are part of tunnel operations. Tunnel staff respond 24 hours per day 7 days per week year-round to any incident in the corridor. The trucks continually patrol I-79, I-279, I-376, I-579, and any other roadway as directed by the Department between the hours of 6 AM to 9 AM and 3 PM to 6 PM. The existing Parkway East ITS infrastructure is maintained through an on-call maintenance contract and the WRTMC is staffed and operated by PennDOT staff. **Figure 15** illustrates the existing ITS infrastructure in a section of the Parkway East Corridor and for more detail See **Appendix E (Existing ITS Infrastructure)**.

Figure 15: Existing ITS Infrastructure (Larger image in Appendix E)

The current WRTMC traveler information to the public is provided for the I-376 East corridor using the PennDOT's 511 system. www.511pa.com and mobile applications provide traveler information that includes live traffic conditions, incidents, active roadwork, weather forecast and alerts, and live camera feeds where available. **"Know before you go"** is the goal of the current traveler information systems, which allows travelers to make informed decisions to choose their route or time to travel.

Real time traffic is monitored from the WRTMC using available traffic data feeds. INRIX provides incident alerts using speed data collected along the corridor and PennDOT has a current TSMO Performance Program Dashboard **(Figure 16)** that provides traffic performance measure, alerts and additional analytical information. Freeway Service Patrols are roving on the Parkway East during peak hours to assist motorists with incidents such as breakdowns, flat tires, and crashes. The service patrols are dispatched to an incidents' location when needed. The WRTMC staff utilizes the DMS boards throughout the corridor to communicate information about incidents ahead.

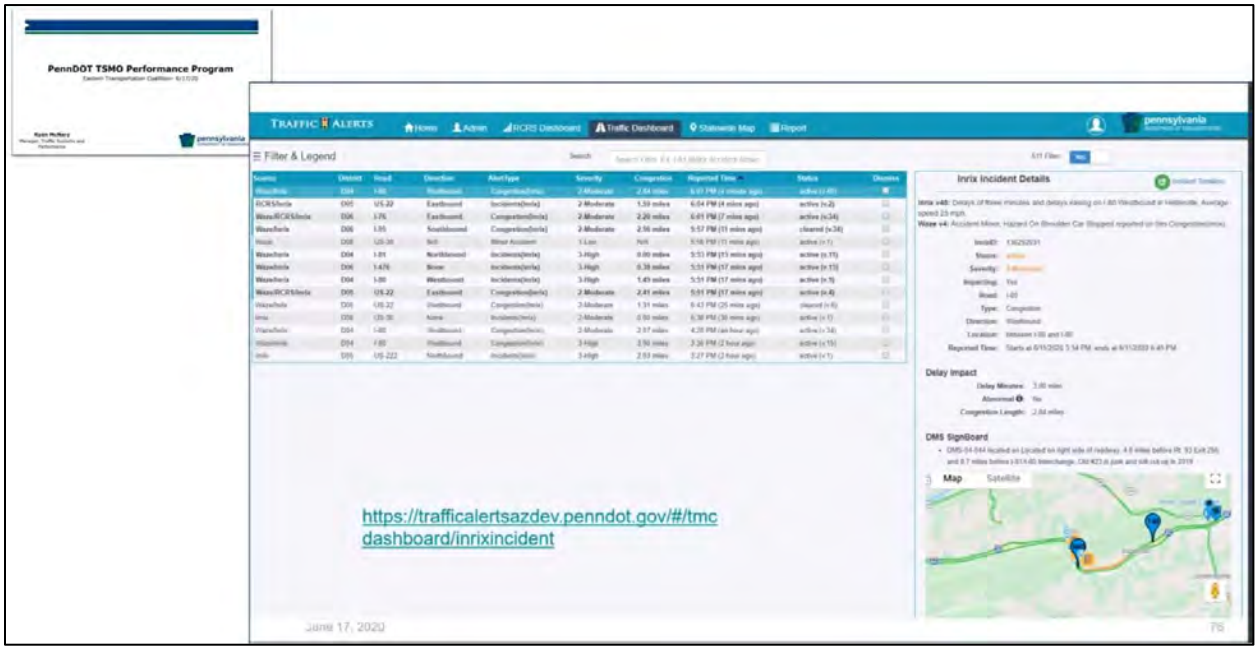


Figure 16: INRIX Traffic Alert Dashboard

The ITS sub-systems below describe the existing ITS field devices that are in operation within the Parkway East corridor.

Squirrel Hill Overheight Detection System The Overheight Detection System for the Squirrel Hill Tunnel is comprised of Overheight Sensors, Flashing Beacons, LCS and Traffic signals all controlled fiber optically through a PLC Scada System from the Squirrel Hill Tunnel. The system operates automatically to detect an overheight vehicle 1–mile in advance of the tunnel. Real time status is provided to the Tunnel Staff of an actual overheight vehicle and in turn take appropriate actions on intercepting the overheight vehicle. In addition, the PLC Scada System allows the Tunnel Staff to manually control the lane control signals for maintenance purposes and to permit the Freeway Service Patrol Vehicles to enter the roadway, respond to an incident around or within the tunnels, or allow maintenance crews access to the tunnel facilities

Figure 18: Example of Over Height Truck Detection System

Lane Control Signs (LCS)

(**Figure 17**) display lane status for pending tunnel closures as vehicles approach the Squirrel Hill Tunnel in both the eastbound and westbound directions. Prior to closing the tunnel, Be Prepared to Stop Signs bordered by yellow flashing lights activate to give warning to approaching motorists, Traffic signals at the tunnel entrances also provide a regulatory stopping point prior to the tunnel entrances.

Overheight sensors leading up to the Squirrel Hill Tunnel in both directions detect overheight vehicles (**Figure 18**) and then activate a flashing sign system notifying overheight trucks to exit and providing real time alerts to the Tunnel Staff.

Travel Time System

Travel times are displayed on various DMS displays along the corridor (**Figure 19**) and are updated in real-time. The information originates from INRIX traffic system and sensors along the corridor.

Figure 19: Example of Travel Time System

Dynamic Message Signs

DMS displays dynamic messages (**Figure 20**) such as travel times along corridor, advance notice of incidents/crashes, status of Monongahela Wharf parking area, information about routing to sporting events, AMBER alert messages, and inclement weather notifications.

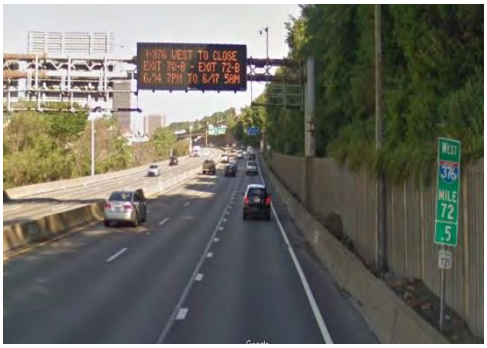


Figure 20: Example of Dynamic Message Signs

Roadway Flood Closure System I-376 WB "Bathtub"

Guide Signs prior to the "bathtub" (I-376 WB between the Grant Street Off ramp and the Stanwix Street On-ramp) (**Figure 21**) contain insert matrix DMS signs that display CLOSED indications when the westbound section of I-376 is closed between the Grant Street Off ramp and the Stanwix Street On-ramp, due to flooding of westbound

Figure 21: Example of Flooded Roadway Closure System

CCTV

CCTV cameras (**Figure 22**) are installed along the corridor which transmit live video feeds to the WRTMC. PA State Police, Local news stations, Pennsylvania State Police, and 511PA have access to these live feeds for emergency response, traffic reports and the public to view respectively.

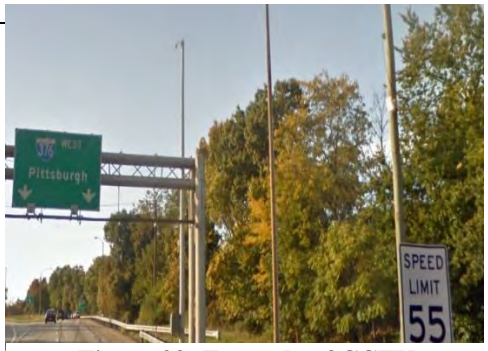


Figure 22: Example of CCTV

Other ITS in the Region

Microwave Vehicle Detector Sensors

Microwave vehicle detectors (**Figure 23**) in the region provide traffic data collection including lane presence, volume, occupancy, and speed data. To accomplish this, the MVDS uses a radar signal for vehicle detection.

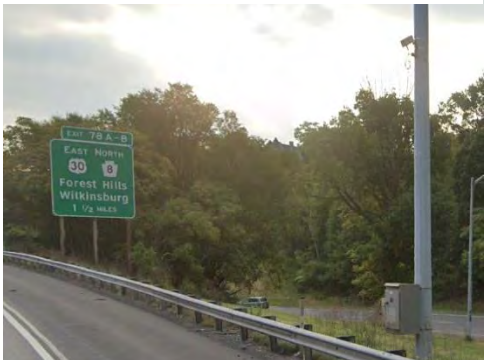


Figure 23: Example of Microwave Vehicle Detector Sensors

Road Weather Information Station

I-376 W/B @ Exit 10A Churchill Allegheny Co**.** RWIS (**Figure 24**) station measures real-time atmospheric parameters, pavement conditions, water level conditions, and visibility and provides this data to PennDOT.

Figure 24: Example of Road Weather Information Station

Liberty Bridge Reversible Lane System

The Liberty Bridge Reversible Lane System has the ability to automatically reverse a number of travel lanes based on time of day. This system is comprised of LCS's and DMS's throughout the bridge span that change in sequence to allow for safe reversal of traffic in both directions. Overhead Dynamic Message Signs (**Figure 25**) provide changing status for each individual lane on the bridge from beginning to end of the reversal process during peak hours. Additional ITS features were recently upgraded as part of the Liberty Bridge Reversible Lane project.

Figure 25: Liberty Bridge Reversible Lanes and Overhead Message Signs

Adaptive Traffic Signals

Traffic signals along the US-30 and Business 22/US-22 corridors have been upgraded to adapt to fluctuating traffic conditions (**Figure 26**). The current system extends from the Business US-22/Rodi Rd intersection through Delmont. The US-30 corridor adaptive signals currently extend from the Ardmore Blvd/Brinton Rd intersection to the Ardmore Blvd/Avenue B intersection. This example of Adaptive Traffic Signal Systems may be proposed to integrate with the ATM System in future PennDOT and County Integrated Corridor Management solutions. The Adaptive Signal Systems alongside the corridor are currently owned, maintained, and operated by the respective municipalities, not PennDOT. Communications between the TMC and signal systems are currently paid for by the municipalities via internet drops with the Adaptive Software Systems residing on the Department's secure servers. Although the Department TMC has the software (MaxView) to interface and control these adaptive systems, the Department currently lacks the staff and training to monitor and operate these systems in the event of incidents for implementation of diversion timing patterns. Expansion of the TMC both in terms of personnel and extension of the Department's fiber backbone to directly connect to these arterial signals may want to be considered as part of the future planning effort. It would be recommended that a future ConOps be performed for integration of these adaptive traffic signal systems into the Parkway East ATM System.

Figure 26: Example Adaptive Traffic Signal Corridors

11. Advanced Traffic Management System (ATMS) Operating Platform

The Pennsylvania Department of Transportation's (PennDOT's) Statewide Advanced Traffic Management System (ATMS) Operating Platform (**Figure 27**) is a computerized transportation communication system that employs communication technology to gather traffic information from field devices. The ATMS also provides Command/Control of the Traffic Management Systems and distributes information to the Traffic Management operators at the WRTMC for actions to

incidents or other traffic management. The ATMS uses traffic sensors, environmental sensors, cameras, and other devices deployed along the Parkway East roadside to monitor real time traffic conditions. The system enables control center managers and operators to detect traffic incidents and congestion rapidly, and subsequently dispatch resources to the incident scene.

Additionally, the ATMS seamlessly integrates with PennDOT's Road Condition Reporting System (RCRS) and Video Sharing Solution (VSS). It also provides virtual shared control of all ITS devices throughout the Commonwealth.

A proposed ATM System along the Parkway East Corridor would need to integrate with the existing ATMS and provide monitor/control interconnections with the Squirrel Hill Lane Control System. The current version of PennDOT's Statewide ATMS is OpenTMS and is maintained by Southwest Research Institute (SWRI).

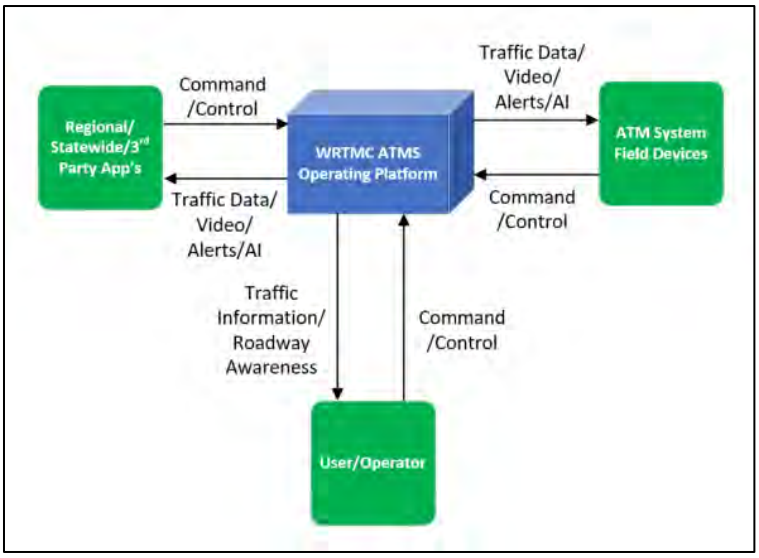


Figure 27: ATMS Operating Platform with ATM System

12. Existing and Proposed Multimodal Systems

Proposed Bus Rapid Transit

The Port Authority of Allegheny County is the primary transit service provider in Allegheny County and operates bus, light rail, inclines (funiculars) and paratransit (for elders and people with disabilities) service. A major Bus Rapid Transit (BRT) project is scheduled to begin service in the Parkway East Corridor Transportation Network in autumn of 2023. The BRT lanes will be on Forbes Avenue and Fifth Avenue in the Downtown, Uptown and Oakland (university and hospital district) neighborhoods of the City, about ¼ to ½ mile to the north of the Parkway East. Construction bids are anticipated to be awarded in September 2021 and followed by two years of

construction. The BRT project will provide a high quality transit connection from downtown Pittsburgh to Oakland and points east. The service will also connect to Wilkinsburg via the Martin Luther King Jr. East Busway and to the Highland Park and Greenfield neighborhoods on city streets. The system will feature upgraded transit stops (Layer 2 switch, CCTV, Validators, Ticket Vending Machines, Code Blue Emergency and Real Time Bus stop Displays), specially branded buses, 15 of which will be all-electric power, and special lanes and upgraded traffic signals to facilitate bus priority at critical intersections. This system may alleviate some congestion by diverting some traffic traveling between downtown and Oakland that otherwise uses I-376. Currently, two bus routes operate on the Parkway East that could be affected by the proposed BRT service: 52L Homeville Limited and 53L Homestead Park Limited (weekday commuter and weekday local, respectively, both running between exit 74 and 71B). Three additional routes operate on the eastern section of The Parkway and would not be affected by the proposed BRT service: P12 Holiday Park Flyer (weekday commuter running between Exit 84 and Exit 78), P67 Monroeville Flyer (weekday commuter running between Exit 84 and Exit 80), 67 Monroeville (local route running between exit 79B and exit 80).

Other Multi-Modal Facilities

East Busway

The Martin Luther King Jr. East Busway (East Busway) provides a transit connection from Swissvale to downtown Pittsburgh with 10 stations and several well-used park-and-ride lots along the way. Fourteen Port Authority of Allegheny County routes and a few Westmoreland County Transit Authority routes travel the East Busway. The East Busway gives transit riders an efficient congestion-free route to and from the downtown. Express peak hours "Flyer" routes also use the East Busway to give commuters an alternative to driving on the Parkway East. Park-and-Ride facilities throughout the region aim to provide motorists with transit options. The East Busway follows the Norfolk Southern Railroad Pittsburgh Line on two former sets of railroad tracks through the densely populated eastern neighborhoods.

Park and Rides

Currently there are approximately 15 park-and-ride lots in the East that serve the Parkway East Corridor. Several adjoin the MLK East Busway. The lots are named:

- Duquesne
- Alpine Village
- Forest Hills
- Beulah
- Hamnet (Along MLK East Busway)
- Harmar
- Hebron
- Holiday Park Volunteer Fire Department

- McKeesport Transportation Center
- Monroeville Mall
- North Versailles
- Olympia
- Plum
- Swissvale (Along MLK East Busway)
- Wilkinsburg (Along MLK East Busway)

Smart Park and Ride Systems

While there may not be imminent park-and ride expansions planned, it would be helpful to have provisions in place for future "Smart Park and Ride Systems" as referenced in the National ITS Architecture and its associated Service Packages. While these types of systems may extend outside of the Parkway East Corridor, the opportunity exists for partnering with the Port Authority of Allegheny County on their current Port Authority Park and Ride Space Availability TSMO project on their goals and objectives for an efficient and well-managed Park-n-Ride facility.

Pedestrian Facilities

A widespread network of sidewalks, public staircases and related facilities accommodate pedestrians throughout the corridor. Quality, density and usage of pedestrian facilities vary throughout the corridor, but generally speaking, walking trips are greater in the more densely populated neighborhoods where destinations and transit stops are more plentiful. The mean walking-trip length and duration in the U.S. population have been estimated to be 0.62 miles and 16 minutes. As travel on the Parkway East becomes more reliable, there may be a reduction in cut-through trips, or trips attempting to bypass congestion on the Parkway on local streets through business districts and residential neighborhoods. Otherwise, the quality of the Parkway East travel experience will likely only indirectly affect the pedestrian mode in the corridor.

Bicycle Facilities

A growing network of bicycle facilities serve bicycle and other human-powered vehicle trips in the corridor. According to the City of Pittsburgh Bike(+) Master Plan, June 2020,

> *"Pittsburgh's bicycle network has grown from about 11 miles in 1999 to roughly 93 miles in 2019, 40% of which are bike lanes. The City's extensive network of over 35 miles of paved riverfront trails forms a strong backbone of the bicycle system and culture in Pittsburgh. After launching in 2015 with 50 stations, Pittsburgh Bike Share (a.k.a. "Healthy Ride") now has over 500 bikes at 113 stations and over 66,000 active users".*

A prominent component of the network is the Eliza Furnace Trail (aka Jail Trail), a paved 5.7 mile trial that closely parallels The Parkway East and connects downtown with Oakland (roughly

between Exists 70 D and 73 A/B). Similar to the pedestrian facilities, the bike network will be improved as motor vehicle traffic avoids cut-through trips on neighborhood streets.

13. Stakeholder Profiles

City of Pittsburgh

The City of Pittsburgh is a medium size metropolitan city, with a population of 300,281 (2019 American Community Survey) serving as the primary source and destination of most travel within the surrounding metropolitan region, which has a population of 2.32 million (2019). Transportation departments operating ITS include the Engineering and Construction Department (Bureau of Engineering's Division of Traffic), Department of Public Safety (bureaus of police, fire, EMS, and emergency management), and the Parking Authority. Pittsburgh is the county seat of Allegheny County with a population 1.22 million (2019 American Community Survey).

FHWA

According to the FHWA website, "*The Federal Highway Administration (FHWA) is an agency within the U.S. Department of Transportation that supports State and local governments in the design, construction, and maintenance of the Nation's highway system (Federal Aid Highway Program) and various federally and tribal owned lands (Federal Lands Highway Program). Through financial and technical assistance to State and local governments, the Federal Highway Administration is responsible for ensuring that America's roads and highways continue to be among the safest and most technologically sound in the world."*

The FHWA staffs a local Pennsylvania Division field office in Harrisburg, PA which collaborates with PennDOT.

PEMA

The Pennsylvania Emergency Management Agency (PEMA) helps communities and citizens mitigate against, prepare for, respond to, and recover from emergencies including natural disasters, acts of terrorism, or other human-made disasters. The agency works with both government and volunteer agencies like the American Red Cross. The agency is required to prepare and maintain the state emergency management plan; assist state and local governments with the design of emergency management plans and training programs; coordinate commonwealth, federal and local emergency management activities and plans; identify areas most vulnerable to disasters and recommending zoning, building and land-use controls to eliminate or reduce the impact of disasters; and provide notice on disasters and information and instructions to the public. The western field office in Indiana PA, acts as a liaison between organizations in Allegheny County and 23 other counties in Western Pennsylvania.

Municipalities/Boroughs (Monroeville, Penn Hills, Churchill, Wilkins, Forest Hills, Wilkinsburg, Edgewood, Swissvale)

Pennsylvania cities (excluding Pittsburgh), boroughs, or townships are incorporated for local governments throughout the Region. Municipalities are responsible for various local operations within their limits, including public safety (police, fire, and EMS) and traffic signal systems.

Emergency services from bordering municipalities may respond to incidents along the I-376 Parkway East. Coordination efforts between PennDOT Western Regional TMC and local emergency services will help identify incidents and dispatch appropriate entities.

PennDOT Western Region Traffic Management Center

The Western Region Traffic Management Center is located in the Pennsylvania Department of Transportation Engineering District 11-0 Office in Bridgeville PA. The Western Regional TMC is responsible for PennDOT traffic management services, incident detection, emergency response coordination and traffic response to maintenance and construction activities throughout the ten-county SPC region covering PennDOT Districts 10-0, 11-0 and 12-0. PennDOT traffic sensors are focused on the most-heavily traveled portions of the interstate network. The WRTMC operates and maintains PennDOT's extensive network of ITS field devices; monitors and supports work zone safety (where equipped); and facilitates traveler information services by providing road network status, roadway and weather conditions, incidents and construction, and travel time information for various information applications. The WRTMC also provides external users and the media with video feeds from traffic surveillance cameras. The WRTMC manages the Freeway Service Patrols on I-79, I-279, I-376, and PA-28.

TMC operations staff coordinates with the District Offices and other agencies for emergency response resource coordination and disaster planning, work zone and maintenance planning. There are plans for future involvement with local governments, including traffic signal coordination in priority regional corridors. TMC operations staff also coordinate the Inbound/Outbound opening and closing of the I-279 HOV Lanes and provide HOV Freeway Service Patrol with the I-279 Freeway Service Patrol.

Pennsylvania State Police

The Pennsylvania State Police is a full service statewide law enforcement agency that fulfills the law enforcement needs of the general public across the Commonwealth of Pennsylvania. Transportation services provided by the Pennsylvania State Police include: (1) incident response, (2) commercial vehicle inspections, and (3) law enforcement on state highways. A Wireless ethernet link is provided to the Pennsylvania State Police Barracks in Moon Twp. from the WRTMC in order to provide them CCTV feeds for incident management update and response. Pennsylvania State Police has a remote workstation at the Squirrel Hill Tunnel to support incident response and improve response times to the East suburbs.

Pennsylvania Office of Homeland Security

Homeland Security is an executive office of the Governor which works to secure Pennsylvania against acts of terrorism and other criminal activities affecting the public. The staff typically works with the Pennsylvania National Guard, and local EMS, firefighters and the Pittsburgh Emergency Management Agency. The Homeland Security director is appointed by the governor.

Port Authority of Allegheny County

The Port Authority of Allegheny County (PAAC) operates light rail, bus (bus way systems), two inclined plane railways, and paratransit (for elders and disabled). The PAAC operates about 1,000 buses, 55 light rail vehicles (28 more ordered), and about 100 paratransit vehicles. The authority also operates about 50 Park-n-Ride lots within the Region. There are about 15,000 bus stop shelters and transit stations interfaced with the street system. The PAAC also has an extensive public safety force providing security and responding to incidents involving PAAC vehicles or facilities.

Southwestern Pennsylvania Commission

The Southwestern Pennsylvania Commission (SPC) is the regional planning agency and serves the Pittsburgh and surrounding 10-county area (Allegheny, Armstrong, Beaver, Butler, Fayette, Greene, Indiana, Lawrence, Washington, and Westmoreland Counties). As the official Metropolitan Planning Organization (MPO), SPC directs the use of all state and federal transportation and economic development funds allocated to the region. SPC manages the Commute Info Ridesharing Program and provides additional ride-matching and traveler information services for the region's residents. SPC also maintains Pennsylvania's Southwestern ITS Regional Architecture in conjunction with PennDOT District 11 and other major stakeholders

14. Current ITS Infrastructure Maintenance

The current Parkway East ITS hardware infrastructure is maintained through an on-call ITS Maintenance contract with Bronder Technical Services. The current ITS technology that is maintained includes digital CCTV, vehicle detectors, DMS, HAR, RWIS, ITS cabinets, fiber optic cable and electrical infrastructure. Bronder also maintains the roadway flood closure systems and the I-279 HOV System. The Squirrel Hill Tunnel Overheight Truck detection system is maintained by PennDOT Tunnel electricians and Wellington Power.

Bronder also maintains the Video Wall, associated Video equipment, network/communications equipment, PC/Servers, and Uninterruptible Power Supplies (UPS) and associated infrastructure to maintain operational readiness for the WRTMC.

15. Justification for Change

The Parkway East ATM system is proposed to improve safety, reduce congestion, increase reliability, inform motorists, and increase throughput along the Parkway East. Recurrent congestion exists along the Parkway East due to peak period demand exceeding available capacity. The corridor contains bottlenecks and substandard geometric features which would be very expensive to mitigate. The ATM system can provide benefits corridor wide versus localizing benefits to an interchange. The traveling public will be able to use information provided by the ATM system to make informed decisions on how they travel and react to incidents throughout the corridor.

The proposed ATM system has the potential to reduce crash frequency and severity using variable speed limits and queue warning that react to changing roadway conditions. Modes such as maintenance or emergency service preemption will allow for closures of lanes making a safer construction/maintenance working environment or allowing expedited passage of emergency vehicles. Increased information given to motorists may allow for better trip planning and detours if necessary due to incidents.

The I-376 Parkway East corridor is a strategic route through the City of Pittsburgh to the east connecting with I-76 Pennsylvania Turnpike. Commuters, commercial traffic, public transit, and recreational traffic all rely on the I-376 corridor and would benefit from the proposed ATM strategies.

16. User Needs

User needs have been defined in **Table 3 in Appendix C**. The needs are broken down by user need ID, user and the desired result of the ATM system.

17. Concept of the Proposed System

Background

The concept of the proposed ATM System and the strategies that are recommend to be utilized for the Parkway East followed the FHWA ATM Feasibility and screening guide. The Phase 2 Alternatives Analysis was reviewed to identify concepts that may be incorporated into the ATM System project. Some of the concepts are proposed to be implemented in the conceptual design, while some additional concepts may be implemented in the future with interfaces to the proposed Parkway East ATM System.

The current proposed system incorporates concepts identified in the following alternatives from the Phase 2 Alternatives Analysis.

The concepts below, taken from the Alternatives Analysis, had a benefit cost ratio greater than 1. Concepts with B/C ratios less than 1 were not included. Concept 1 - Managed Lanes, 1A - Active Traffic Management, Concept 2 -Additional VMS Signs, and Concept 4 variable speed limits will all be incorporated into the conceptual design of the Parkway East ATM system.

Discussions with the PennDOT District 11-0 Traffic, WRTMC, and Tunnel Operations staff were held to discuss conceptual ATM system implementation. Concepts such as Dynamic Junction Control, Advanced Merging, and Ramp Management were discussed during these meetings. The direction from the PennDOT staff was that Dynamic Junction Control, Advanced Merging, and Ramp Management would not be an appropriate fit for the Parkway East Corridor. These concepts were not investigated or proposed further.

Objectives

The fundamental objective of the proposed ATM system is to meet the overarching mission of PennDOT's Transportation Systems Management and Operations (TSMO): "To move people and goods from point A to Point B safely and efficiently." The proposed Parkway East ATM system should implement ATM strategies to improve safety, reduce congestion, increase reliability, inform motorists, and increase throughput along the Parkway East (I-376). More specific elements supporting this objective are:

1. Implementing ATM technologies and strategies that provide enhanced situational awareness, real-time monitoring, and automated changes to traffic control.

2. Supporting future adjacent arterial roadway coordination and operational strategies.

3. Improving timeliness of communications to motorists of Parkway East conditions through a variety of technology tools and sources to support both pre-route decision-making and real-time dynamic routing decisions. In this way, travelers will get critical trip-planning information when they need it.

4. Reducing the impact of non-recurring congestion and improving travel time reliability on the Parkway East.

5.Improving the regional economy through better freight mobility and by enhanced connectivity between the communities, businesses, technology hubs, and research institutions along the Parkway East.

Description of the Proposed System Concepts

The ATM strategies proposed for implementation along the I-376 Parkway as defined by FHWA are dynamic lane use control, dynamic speed limits, wrong way vehicle detection, additional dynamic message signs, and queue warning. These strategies are defined in detail below. **Figures 28 through 31** are examples of possible ATM system implementation.

The proposed ATM system includes overhead sign structures or gantries spaced every ¼-½mile along the corridor. The sign structures include lane use control signals over each lane, with auxiliary dynamic message signs spaced throughout the corridor. Variable speed limit signs/ variable speed limit displays may replace existing static speed limit signs along the corridor. Variable speed limit signs/ variable speed limit displays may be regulatory and enforceable refer to 75PA cod 3363 and Title 75, Chapter 61 for more information.

Queue detection and warning may be automated using data available from location based data analytics providers and microwave vehicle detection sensors (MVDS). Real-time data would enable the lane use control signals and variable speed limit signs/ variable speed limit displays to respond to changing conditions appropriately. Queue detection and warning, along with variable speed limits, may reduce rear-end crashes by alerting drivers to slow or stopped traffic ahead. The speed limits approaching the back of the queue may be stepped down gradually.

Automated wrong-way vehicle detection and warning would detect vehicles traveling the wrong way and alert the offending motorists with flashing lights and messages. The right-way traveling motorists would be alerted that a vehicle has entered the roadway traveling in the wrong direction by overhead messages. Emergency services would also be alerted to intercept the wrong-way vehicle. The Conceptual Wrong-Way Detection System (WWDS) could provide alerts in many different scenarios. The WWDS instantly detects any wrong-way vehicle with sensors, immediately flashes alert signal at the MUTCD-Compliant blinkersign “Wrong Way” field sign, sends alert notifications directly to the operators of the RTMC or other stakeholders. Additional, options could also be SMS/Email alerts notifications to virtual recipients

Video analytics may monitor traffic conditions and identify incidents in real time, enacting preapproved operations plans.

The Squirrel Hill Tunnel overheight truck detection system and lane use control signals would be integrated into the complete ATM system. The integration would allow both Tunnel Staff and WRTMC operators to control the associated components around the Squirrel Hill Tunnel when required. Local control at the Tunnel Operations Center would remain and be able to override WRTMC control when required.

Tunnel systems Fire, life and Safety systems would be exclusive to tunnel management. Tunnel Traffic control devices (Tunnel LUCS, Tunnel DMS, VSLS) and RTMC/Statewide monitoring for the ATM system devices are beneficial for a cohesive ATM system throughout the Parkway. Additionally, with a RTMC/Statewide interconnection to the tunnel traffic control system, the Parkway ATMS solution can provide an optional backup control functionality if needed.

The proposed ATM system design is recommended to be completed in one phase, but construction/integration may be broken into five (5) separate roadway segment phases. The proposed roadway segment phasing is as follows:

- Segment 1 – City Bifurcated from MP 70.5 (Grant St) to MP 72.3 (Allies),
- Segment 2 – City United from MP 72.3 (Allies) to MP74.7 (City Side),
- Segment 3 – Squirrel Hill Tunnel,
- Segment 4 – Suburban Side part I MP 75.5 to MP 79.4 (Churchill),
- Segment 5 – Suburban Side part II MP 79.4 (Churchill) to MP 84.5 I-76 PA Turnpike.

Dynamic Lane Use Control: Shown in **Figures 28 and 29**, this strategy involves dynamically closing or opening of individual traffic lanes as warranted and provides advance warning of the downstream lane closure(s) through the use of lane use control signals, in order to safely merge traffic into adjoining lanes. In an ATDM approach, as the network is continuously monitored, real-time incident and congestion data is used to control the lane use ahead of the lane closure(s) and dynamically manage the location to reduce rear-end and other secondary crashes.

Components:

Support Structure - Overhead structures spanning all traffic lanes and in certain locations half span or cantilevered structures. Existing structures to be analyzed for reuse of supporting LUCS.

Display Device - Lane use control signals are typically matrix displays centered over each travel lane. The signs are able to display both text and symbols. Full matrix lane control signals would allow for posting weather restrictions such as requiring all commercial vehicles to use right lane.

Communications and Power Infrastructure - Lane use control signals are low power devices that may be powered by solar or hard wire sources. Ethernet, serial, cellular, or leased line data are options for communication.

Command and Control System – The dynamic lane use control will be integrated into the existing OpenTMS software to ensure functionality between the WRTMC and PennDOT's statewide TMC.

Video Coverage – Dynamic lane use control systems require complete coverage of the roadway and sign indications. The complete coverage allows for verification of incidents and that lane control signals are working as intended.

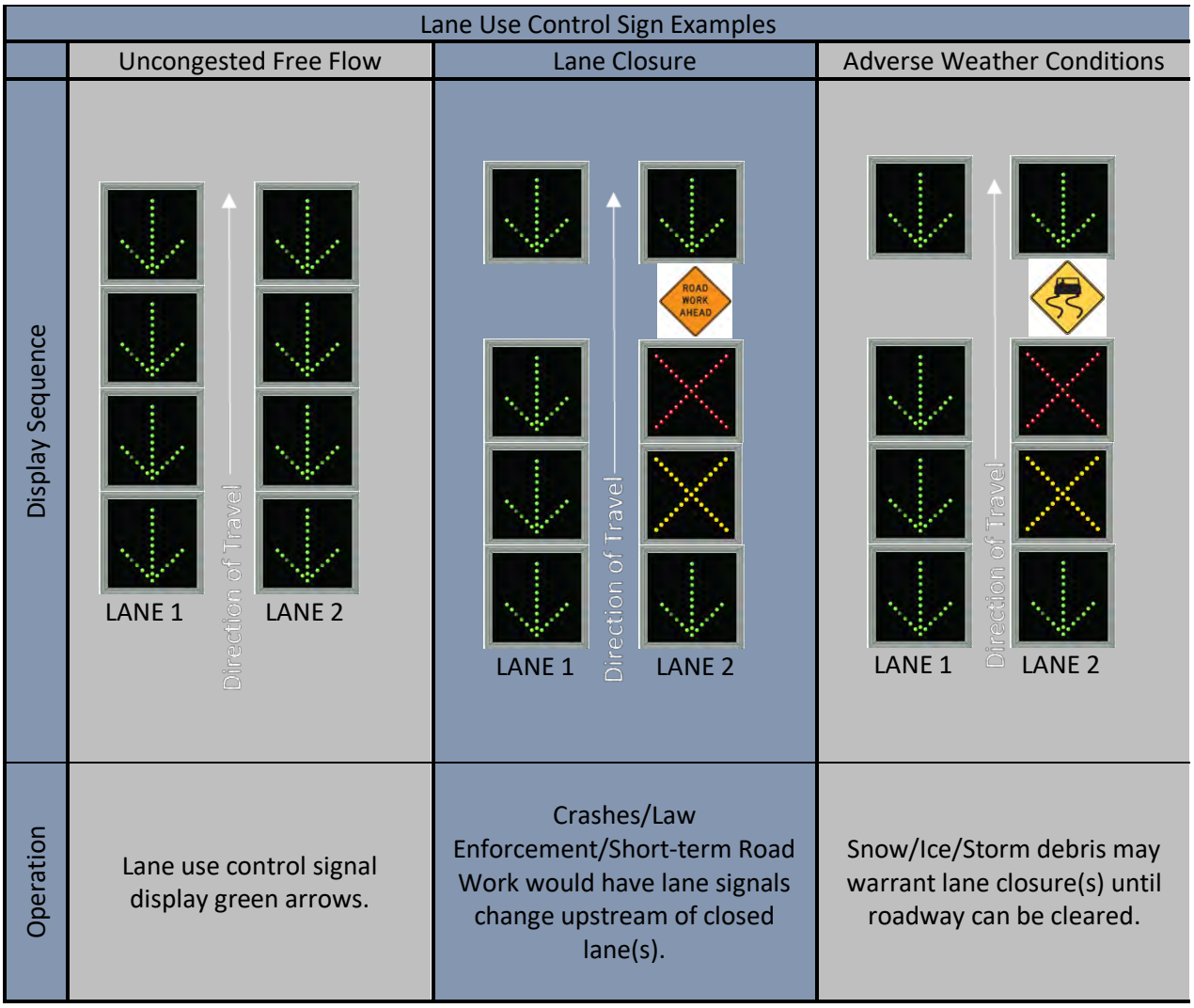


Figure 28: Example of Dynamic Lane Use Control

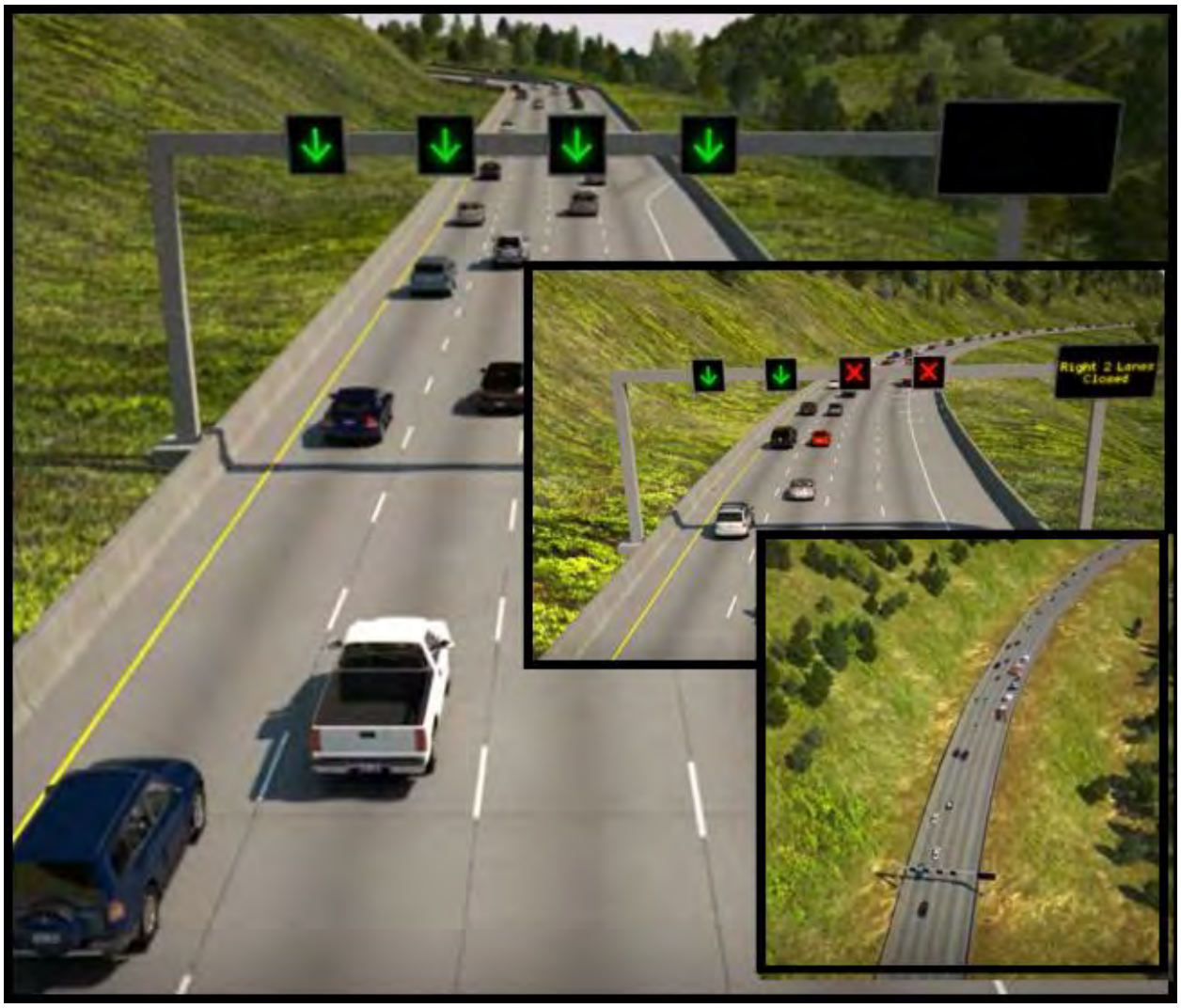


Figure 29: Example of Dynamic Lane Signs

Dynamic Speed Limits: Shown in **Figure 30** this strategy adjusts speed limits based on real-time traffic, roadway, and/or weather conditions. Dynamic speed limits can either be enforceable (regulatory) speed limits or recommended speed advisories, and they can be applied to an entire roadway segment or individual lanes. In an ATDM approach, real-time and anticipated traffic conditions are used to adjust the speed limits dynamically to meet an agency's goals/objectives for safety, mobility, or environmental impacts. The legal use of Variable Speed Limits is authorized in 67 PA Code 212.08 and the PA Vehicle Code.

Components:

Support Structure: The dynamic speed limit signs may be mounted on standalone posts similar to existing speed limit signs, or attached to the sign gantries that support the lane use control signals.

Display Device – The dynamic speed limit signs may be a full matrix display that includes the sign image, or a static sign that includes a changeable two digit speed limit numeral area. The image displayed would adhere to the MUTCD design standards for regulatory signs.

Video Coverage – Dynamic speed limit signs benefit from complete coverage of the sign indications for verification.

Communications and Power Infrastructure – Variable speed limit displays are low power devices that may be powered by solar or hard wire sources. Ethernet, serial, cellular, or leased line data are options for communication.

Command and Control System – The variable speed limit signs/ variable speed limit displays will be integrated into the existing OpenTMS software to ensure functionality between the WRTMC and PennDOT's statewide TMC.

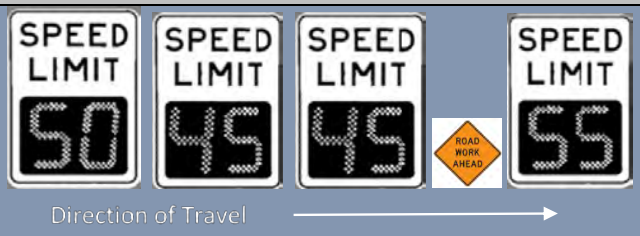
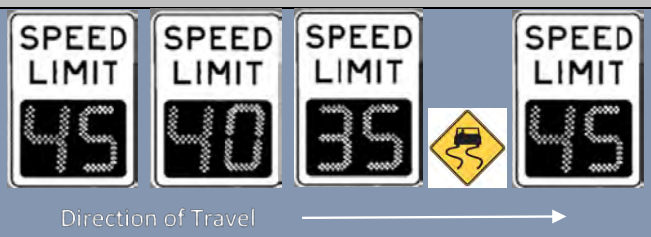
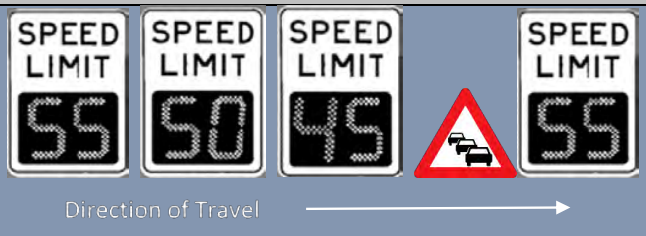
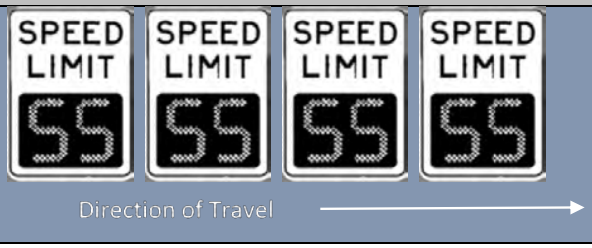
Operation	Display Sequence
Uncongested Free Flow	
Normal posted speed limit displayed.	
Lane Restriction	
Crashes/Law Enforcement/Short-term Road Work would have speeds stepped down upstream of a lane blockage.	
Adverse Weather Conditions	
Snow/Ice/Fog/Heavy Rain may warrant speed reductions.	
Recurrent/Non-Recurrent Congestion	
Speed Limit reduced approaching congested area, then increased past congestion point.	
Complete Closure	
Speed Limit reverts to normal posted speed limit.	

Figure 30: Examples of Dynamic Speed Limit Signs

Queue Warning: This strategy involves real-time displays of warning messages (typically on dynamic message signs and possibly coupled with flashing lights) along a roadway to alert motorists that queues or significant slowdowns are ahead, thus reducing rear-end crashes and improving safety. In an ATM System approach, as the traffic conditions are monitored continuously, the warning messages are dynamic and automated, based on the location and severity of the queues and slowdowns.
In addition to the existing PTZ cameras, the Queue Warning System should include implementation of full static CCTVs coverage. This would introduce great benefits, including: dedicated automated incident detection and automated wrong-way vehicle detection. This would operate 24/7, even when the PTZ cameras are being utilized for other purposes.

Components:

Support Structure: The queue warning signs may be attached to the sign gantries that support the lane use control signals.
Display Device – The queue warning signs may be full matrix displays that display the queue warning, or a static blank out sign with a predetermined message. The message displayed may be automated based on roadway sensors or traffic data from location based data analytics providers such as INRIX.
Video Coverage – Queue warning signs benefit from complete coverage of the sign indications for verification.
Communications and Power Infrastructure – Queue warning signs may be low power devices that are powered by solar or hard wire sources. Ethernet, serial, cellular, or leased line data are options for communication. Larger size DMS that are also used for queue warning messages may require a larger power supply.
Command and Control System – The queue warning signs will be integrated into the existing OpenTMS software to ensure functionality between the WRTMC and PennDOT's statewide TMC.

Automated Wrong-Way Vehicle Detection (AWWVD): This strategy uses sensors or video analytics to detect vehicles traveling in the wrong direction and provides real time messages and ramp management strategies to prevent additional motorists from entering the freeway in high danger locations.

Components:

Support Structure: The AWWVD devices, signs and cameras may be attached to upright supports on off-ramps.
Display Device – The AWWVD signs may be wrong way signs with flashing borders or attached rapid flashing beacons to alert wrong way drivers. DMS devices may display messages to oncoming drivers warning of an approaching wrong way vehicle.

Video Coverage – AWWVD systems may utilize forward looking infrared cameras to detect wrong-way vehicles. Video analytics with edge processing may automatically alert roadway operators and emergency services.
Communications and Power Infrastructure – AWWVD devices may be low power devices powered by solar or hard wire sources. Ethernet, serial, cellular, or leased line data are options for communication.

Command and Control System – The AWWVD system will be integrated into the existing OpenTMS software to ensure functionality between the WRTMC and PennDOT's statewide TMC.

Additional Dynamic Message Signs: Shown in **Figure 31**, this strategy includes installing dynamic message signs on intersecting roadways at interchanges along the Parkway East corridor. Dynamic message signs will give motorists information about roadway conditions and incidents prior to entering the Parkway East. Locations have been proposed in **Appendix B** – **Conceptual Device Layout**.

Components:

Support Structure: DMS devices are supported by sign structures and foundations, sized to accommodate each DMS appropriately.
Display Device – The DMS signs may vary in size depending on location and available right-of-way. The DMS may be a full color matrix display with the ability to display sign graphics and text.
Video Coverage – DMS systems may have video coverage to verify sign messages displayed.
Communications and Power Infrastructure – DMS devices may require a larger power source than overhead lane use control signs. The DMS may be powered by existing or new load centers. Ethernet, serial, cellular, or leased line data are options for communication.
Command and Control System – The dynamic message signs will be integrated into the existing OpenTMS software to ensure functionality between the WRTMC and PennDOT's statewide TMC.

Figure 31: Example of Additional Dynamic Messaging Signs

Additional CCTV cameras: – Shown in **Figure 32**, CCTV camera coverage will be a large component of the ATM system implementation. There is currently complete corridor coverage by pan-tilt-zoom CCTV cameras. The proposed ATM strategies may benefit most from complete corridor static video camera coverage. CCTV cameras will allow ATM system operators to verify DMS messages, Queue warning messages, lane use control signal messages, and variable speed limit signs/ variable speed limit displays in real time. CCTV cameras may also support emerging technologies such as automated video incident detection system (AVIDS), stopped object detection, and automated queue detection.

Components:

Support Structure: The CCTV cameras may be attached to existing or new gantries and existing or new CCTV camera support poles.

Video Coverage – Complete corridor wide static camera video coverage would support the proposed ATM strategies.

Communications and Power Infrastructure – CCTV devices may be low power devices that may be powered by solar or hard wire sources. Ethernet, serial, cellular, or leased line data are options for communication.
Command and Control System – The CCTV cameras will be integrated into the existing OpenTMS software to ensure functionality between the WRTMC and PennDOT's statewide TMC.

Cybersecurity and Remote Access to the Network The proposed ATM system will follow PennDOT Cybersecurity Regulations and Standard Operating Procedure (SOP) if there is a system network breach or critical failure on the ATM system network. Additional system SOP's will be needed and developed that provide interoperability through PennDOT's statewide software application and the ability to remotely log-in to the system via a secured Virtual Private Network (VPN) connection. Cybersecurity is critical to the resiliency of a regional system, and a well-developed and comprehensive security plan will need to be developed by collaborating with technical partners and the participating agencies to set up proper security designs, standard operating procedures (SOP's) and protocols as well as contingency plans.

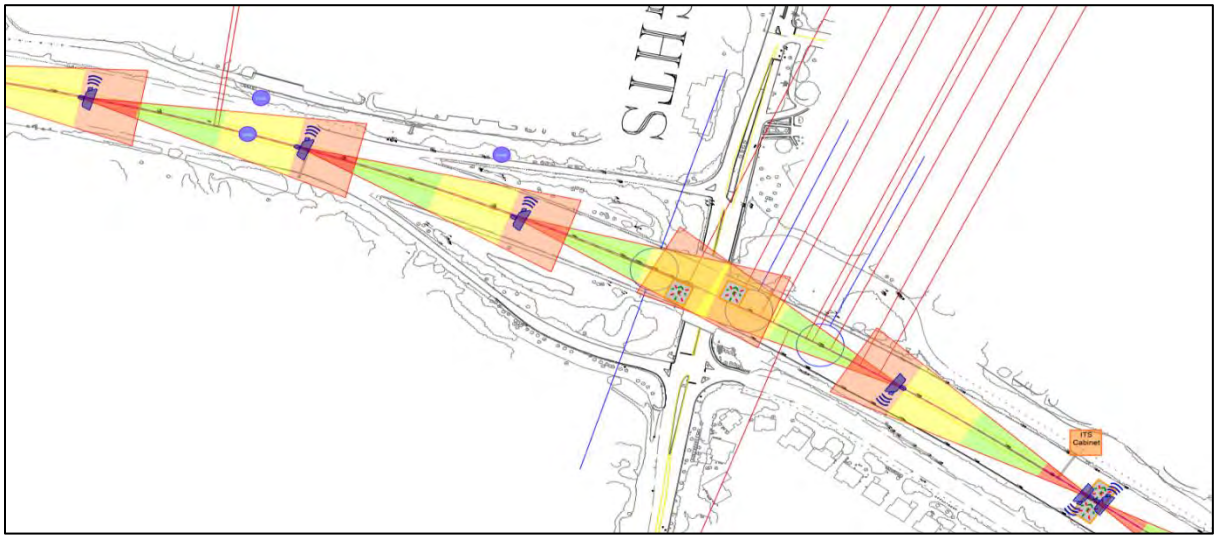


Figure 32: Example of Camera Coverage for AVIDS

18. Planned ITS Required Changes

The proposed I-376 Parkway East ATM project is intending to design and use technology and strategies not currently in use in the Southwestern PA region. Some of the proposed strategies include automated variable speed limits with speed harmonization, dynamic lane management, automated queue detection, automated video incident detection system (AVIDS)shown in **Figure 32.**

These elements are not currently part of the Southwestern Pennsylvania Commission's Regional ITS Architecture. Data sharing and interconnection across stakeholders and infrastructure will be integral to the success of the Parkway East ATM project. Compliance with the Southwestern Regional ITS Architecture will help to ensure data exchanges and interfaces are identified to satisfy all needs of the ATM project.

The description of the National ITS Architecture service packages by FHWA are shown in **Table 4 in Appendix C**.

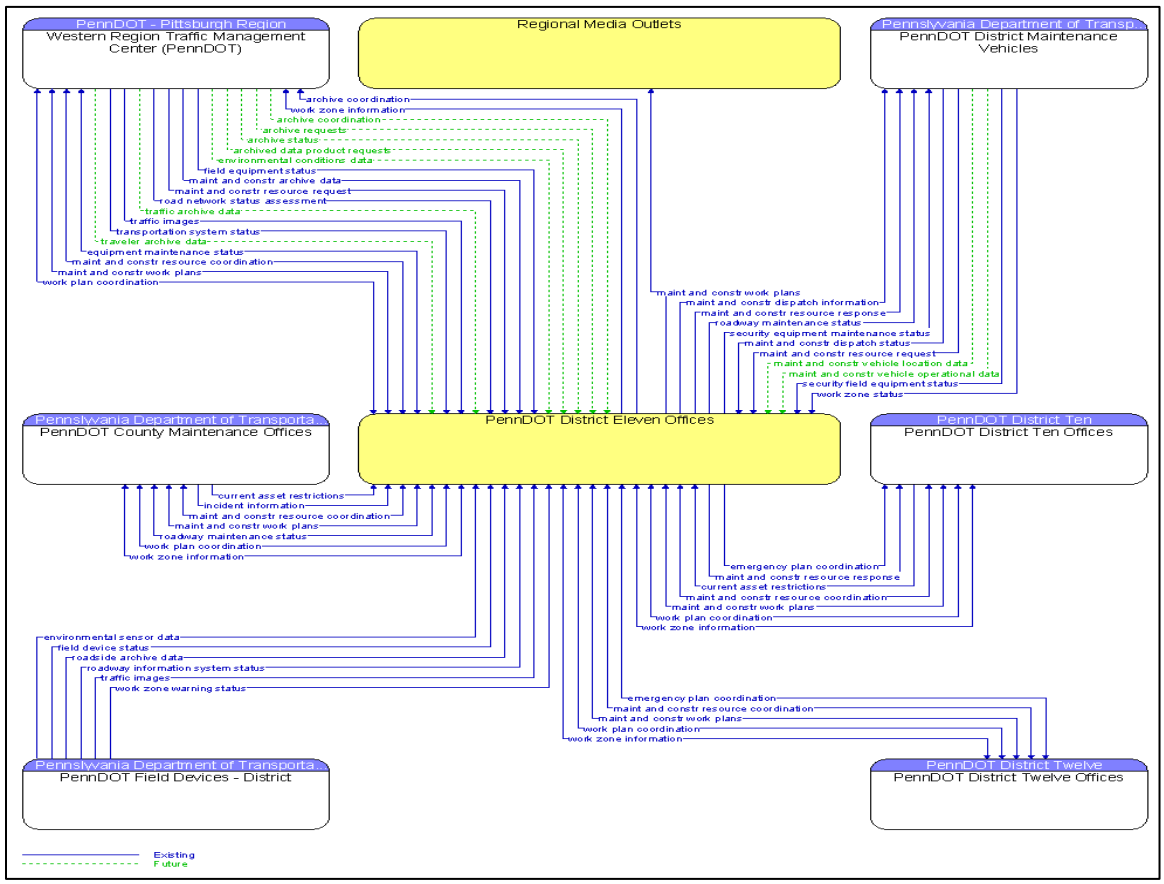


Figure 33: PennDOT District 11 ITS Architecture Informational Flow Diagram

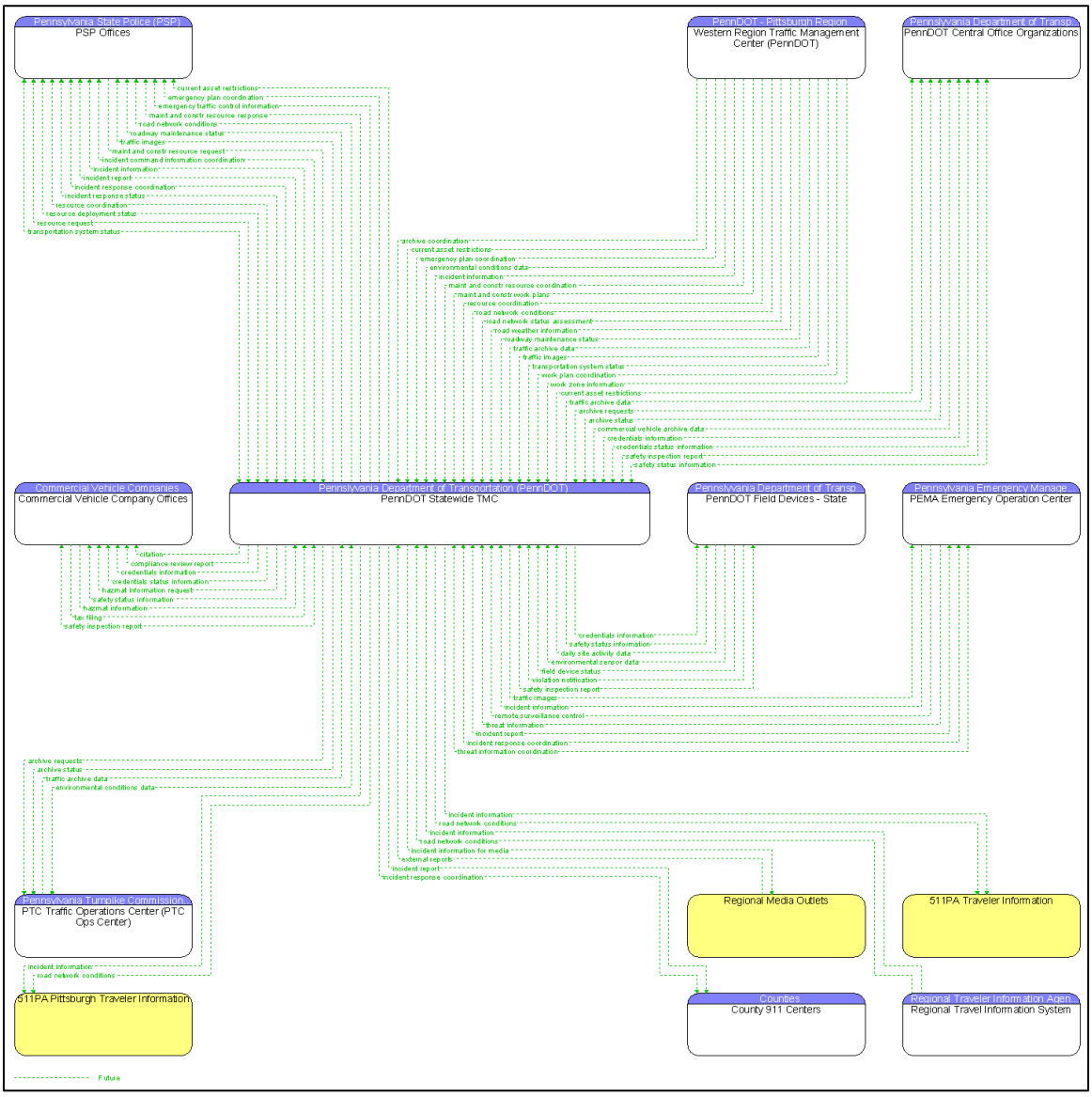


Figure 34: PennDOT Statewide Traffic Management Center ITS Architecture

Figures 33 and 34 illustrate the current Statewide Traffic Management Center ITS Architecture that will need to be revised for the proposed ATM System.

The following national ITS service packages that are applicable to ATM system strategies will need to be added to the regional and statewide architecture.

- **ATMS22**, Variable Speed Limits – sets variable speed limits along a roadway to create more uniform speeds, to promote safer driving during adverse conditions (such as fog), and/or to reduce air pollution; also known as speed harmonization. VSL can improve safety, delay the onset of stop-and-go conditions and decrease emissions and fuel consumption. There are two general reasons to utilize Variable Speed Limits: first, they can help reduce the frequency of rear-end crashes at the back-of-queue and other crashes due to inclement weather and poor road surface conditions. Second, VSL can be used for speed harmonization when demand volumes are increasing, and density is nearing breakdown conditions (resulting in traffic congestion). The goal is to achieve more efficient flow at a slower, but not stop-and-go, speed. These two use scenarios can lead to a reduction in the frequency of crashes (and resulting congestion) which could, in turn, reduce air pollution.

- **ATMS23**, Dynamic Lane Management and Shoulder Use – provides for active management of travel lanes along a roadway, including the associated hardware and control electronics that are used to manage and control specific lanes and/or the shoulders.

- **ATMS24**, Dynamic Roadway Warning – includes systems that dynamically warn drivers approaching hazards on a roadway (e.g., roadway weather conditions, road surface conditions, traffic conditions including queues, obstacles or animals in the roadway and any other transient event that can be sensed).

The major entities operating in the I-376 Parkway East corridor area are as follows: PEMA Emergency Operations Center, PennDOT Western Regional Traffic Management Center, PennDOT District 11, and the PennDOT Statewide TMC. Strategies such as variable speed limits, dynamic lane management, and dynamic roadway warning are not currently identified for future implementation in the SPC Regional ITS Architecture. Additional service packages may be required to be developed due to the emerging technology trends and automated/artificial intelligence (AI) system that are being applied to ITS/ATM systems.

Architecture interfaces and data exchange with ITS devices such as variable speed limit control, lane management operation, automated video incident detection system (AVIDS) and automatic queue detection throughout the corridor have not been identified in the current system architecture diagrams.

In summary, the existing Southwestern PA Regional ITS Architecture contains many of the ITS service packages that would be required to support the Parkway East ATMS project. This section outlined the existing service packages and stakeholders that will be an integral part in the proposed Active Traffic Management System. There are, however, some missing service packages and stakeholders that would be required in the system architecture for the ATMS project. The following service packages are not included in the current ITS Architecture; ATMS22 (variable speed limits), ATMS23 (dynamic lane management and shoulder use), and ATMS24 (dynamic roadway warning). The Squirrel Hill Tunnel Operations and Maintenance would be a vital ATMS stakeholder, and interconnection to the regional architecture should be represented in the architecture diagrams. These additions through the development of an I-376 Project Specific ITS Architecture would bring the ATMS in compliance with Southwestern PA Regional Architecture and support the I-376 Parkway East ATMS project. The I-376 Project specific ITS Architecture can then be merged into the Southwestern ITS Regional Architecture through the use of the FHWA Regional Architecture (RAD-IT) Tools. The update and merging of the I-376 Project Specific ITS Architecture into the Southwestern ITS Regional Architecture will need to be performed by the Southwestern Planning Commission as part of their routine update to its Regional ITS Architecture.

In addition to the existing Southwestern PA Regional ITS Architecture subsystem and PennDOT's Regional Operations Plan, the general ATM System/Functional requirements for the proposed ATM system and are identified in **Table 5 in Appendix C.**

Additionally, the proposed ATM System desired changes (**Table 6 in Appendix C**) in general terms are listed below and may require updates during the lifecycle of the ATM System project.

19. Modes of Operation

This section describes the intended modes of operation for the conceptual Parkway East ATM system. The conceptual intent is that the Parkway East ATM system, Squirrel Hill Tunnel and PennDOT TOC operations will be integrated into one common software platform and the operating modes will include all applicable system components within the project area.

Standard Operations Scenario

During standard operations, the system can perform all desired functions and all the systems and subsystems are operational. ATM system infrastructure are activated as scheduled to address recurring traffic volumes and congestion. Pre-determined sign plans are activated as necessary in response to non-recurring congestion and minor incidents.

The standard ATM System operation mode will automatically respond to incidents and congestion that are identified within the corridor. Protocols such as dispatching service patrols or emergency services to vehicles stopped along the corridor will be possible. Sensors and cameras mounted on the gantries can provide up-to-date traffic conditions.

Variable speed limits enable stepping down the speed limit approaching a standing queue or other incident such as inclement weather. Speed limits may be regulatory or advisory that the Pennsylvania State Police would have the ability to enforce.

Automated wrong-way vehicle detection will have sensors or video analytics to alert vehicles traveling in the wrong direction and approaching vehicles of unsafe conditions using signage and messages in high risk locations.

Auxiliary dynamic message signs will give motorists information about changing traffic conditions that will help inform their travel decisions.

Maintenance Scenario

During maintenance operations, traffic patterns are altered to accommodate maintenance needs. This can include single or multiple lane closures. Speed limits may be temporarily reduced to address queueing from lane closures.

Weather Event Scenario

This operating mode is enacted when inclement weather is identified throughout the corridor. The speed limits would be reduced as appropriate until weather events have passed. Obstructed lanes, areal flooding or untreated lanes could be closed until maintenance has cleared the roadway.

Emergency/Closure Scenario

This operating mode is enacted if an emergency (such as major incident, flooding or fire) that require blockage and/or evacuation of traffic in and around downtown or Squirrel Hill tunnel facilities.

Evacuation Scenario

This operating mode is enacted if there is a major emergency that requires a large-scale evacuation of the area. The focus of system operators is ensuring that all traffic is routed safely out of the area via opening eastbound(westbound) lanes to westbound(eastbound) traffic. PennDOT and emergency operations personnel work to block/control access to eastbound(westbound) facility ramps during contraflow operation. Evacuation scenarios could prioritize certain on-ramps further from the city that have acceptable ramp geometry for vehicles to exit onto local roads. All ramps would be controlled by PennDOT/emergency services during this scenario operation. Evacuation scenario plans could be developed along with the ATM system design

Failure Scenario

This operating mode is enacted when a failure in the ATM system is detected or communication to ITS devices is disrupted. The system would revert to a predetermined program if partial communication exists otherwise the system would not be operational until status and connectivity is reestablished. Backup generators or uninterruptable power supplies may be available to supplement power loss issues. The default system failure scenario would restore speed limits to the normally posted speed limit. Overhead LUCS would not be operational during the failure.

Special Event Scenario

This operating mode is enacted during special events such as the Pittsburgh Marathon, Great Race, and Light Up Night that would affect the corridor. Ramp closure information for such events could be displayed on DMS signs. Traffic information and detours could be shared using DMS signs for sporting events or college move in/move out days.

20. Proposed ATM System User Involvement and Interaction

The primary users of the ATM system will be the WRTMC staff, Squirrel Hill Tunnel operations staff, safety patrols, emergency responders, and the traveling public. These users and their interaction are described in the following section.

WRTMC staff will oversee day-to-day operations of the ATM system, including existing traffic management activities. Maintenance of ITS devices will be overseen by WRTMC operations. Traffic condition changes will alert WRTMC staff who will verify conditions or incidents and set in motion the approved traffic control plans. WRTMC staff will dispatch the appropriate responders such as the safety patrol, maintenance forces, or emergency responders to the location of the incident.

Squirrel Hill Tunnel Operations Staff will retain control of the tunnel lane use control signals. This will permit the safe operation of the tunnel facilities and safe egress from the portal buildings. Tunnel traffic control activities will display in the overall ATM system but final override control will rest with the Squirrel Hill Tunnel Operations Staff.

Safety patrols will remain in contact with the WRTMC to provide on the ground support where required. Queue detection throughout the corridor could provide early alerts of incidents and crashes.

The traveling public will interact with the ATM system by receiving the additional information provided from the dynamic message signs, lane use control signals, queue warning signs, wrong way vehicle detection alerts, and variable speed limit signs/ variable speed limit displays. The ATM system will be integrated into the 511-PA website to provide **"Know Before You Go"** information of current traffic conditions.

21. Assumptions and Constraints

Upcoming construction projects along the Parkway East corridor were identified as possible constraints to the ATM system implementation. The bridge that carries I-376 over Commercial Street to the east of the Squirrel Hill Tunnel (Commercial Street Bridge) is slated for replacement possibly starting in the year 2023. Completed in 1951, the historically significant concrete arch bridge will be reconstructed over a multi-year period during which traffic interruptions will be minimized. The bridge replacement project may provide opportunities for use of the ATM system if the ATM system is completed prior to construction of the bridge. Should the ATM system not be constructed prior to the bridge replacement, the addition of power/conduit/fiber optic cables (FOC) connections to the new structure should be considered.

The Bates Street interchange Oakland 73B/Glenwood 73A Exits will be under construction to widen the westbound mainline structure to permit an exit only lane to be constructed. The ATM system may be integrated to emphasize the exit only lane. Improvements for the westbound Bates Street/Glenwood interchange will be completed in the near future which will widen the I-376 structure allowing for an exit lane. This area was previously identified as a candidate for the ATM system to designate the right lane approaching the exit ramps as exit only due to queueing that backs up on to mainline I-376.

A section of the Mon/Fayette Expressway connecting PA Route 51 to I-376 is proposed to be constructed once right-of-way acquisitions are completed. The final segment of the Mon/Fayette Expressway will complete the 68 mile roadway from I-376 to northern West Virginia. The interface with the Parkway East may provide an opportunity for more ATM devices as there would be a new interchange.

The Squirrel Hill Tunnel lane use control signals will require the ability to be overridden by the tunnel maintenance operators. The WRTMC will integrate the associated tunnel LUCS into the overall corridor ATM system, however ultimate control will remain at the tunnel operations center. Technology evaluations will be completed during design of the system. As technology advances and the ATM system design progresses, there may be additional options or features that may be implemented in the Parkway East ATM system. Edge processing and video analytics will be evaluated for possible integration into the ATM system.

22. Risks

Identifying risks associated with the Parkway East ATM System will be instrumental in the success of this project. **Table 7 in Appendix C** outlines risks, the risk owner, risk rating, and mitigation strategies. Risks have been identified and rated based on both likelihood of occurring and impact of the risk. Mitigation strategies have been described for each risk in the Risk Register below.

23. Support Environment

PennDOT operates its current WRTMC ATMS application utilizing the OpenTMS software from Q-Free. The OpenTMS software contract has recently been changed to be managed and updated by Southwest Research Institute (SWRI). OpenTMS software application will provide a coordinated traffic management and operations environment across the state. The proposed ATM System will need to integrate with the ATMS software application to provide the regional desired functionality for the Parkway East ATM System. Additional support for the ATM System would require Parkway East field, Squirrel Hill Tunnel and WRTMC infrastructure upgrades.

Agencies that would provide support for the ATM system include Transit, Fire/Life/Safety Service Patrol, 511, emergency management, law enforcement, maintenance and operations. The traveling public will use the system under a lane management strategy which will provide situational awareness during an incident. Other third party agencies and companies like INRIX, Waze and Google would benefit from the proposed ATM system by knowing the real time condition of traffic along the Parkway East. Holding public forums and civic meetings to inform citizens of the benefits of the proposed ATM System would also provide buy-in, support and encourage dialog of the proposed technology advancements for the Parkway East.

24. Summary of Impacts

Traffic Impacts During Construction

Construction impacts may include short term shoulder closures outside of peak hours to facilitate roadside or shoulder work to install additional communications hardware and power supply to the ITS devices. Erection of overhead sign structures and sign gantries may require weekend or nighttime short term lane closures or short term directional traffic stoppages. After installation, the ATM system would undergo an extensive testing process to ensure correct system operation.

Traffic Impacts During System Maintenance

Maintenance impacts may include short term shoulder or lane closures to facilitate maintenance of overhead ITS devices. Parts of the ATM system may be temporarily disabled during maintenance activities. The affected ATM system components may revert to pre-programmed messages during maintenance.

Organizational Impacts

From the WRTMC user perspective, there will be operational training required. Existing staff may be temporarily away from their regular duties to complete training and orientation. Arrangements may need to be made to cover normal staff obligations, either temporarily while in training or on a more long-term basis if assigned to a new role supporting the ATM system. Likewise, during the integration with existing systems, staff regularly dealing with other existing systems may become occupied with the integration activities. Then, in the operational phase, new staff may

need to be hired to help operate the ATM system and to assist the increased workload of TMC operations, incident responders, ITS maintenance and roadway maintenance resources. This additional workload will require additional funding for the operation and maintenance of the proposed system. Nomenclature will need to be developed and learned and a database of equipment will need to be created, updated and maintained through the life and expansion of the system.

Other Regional Projects

Several projects are planned within and near the Parkway East right-of-way, and each will affect the ATM system to different degrees. The SPC 2019-2022 Transportation Improvement Program (TIP) includes over $1.755 billion in state, federal, and local funds to be invested in Allegheny County and the City of Pittsburgh. Several of these projects are on the Parkway East and listed in **Table 8 in Appendix C**.

The most significant infrastructure project affecting the ATM system will be the I-376 Commercial Street Bridge replacement. This bridge sits just a ¼ mile east of the Squirrel Hill Tunnel's east portal and carries 100,000 ADT on all four lanes of the Parkway East over Nine Mile Run and Commercial Street, in the City of Pittsburgh. Construction is anticipated 2023-2025 and utilizing a slide-in method that would entail construction of the proposed bridge immediately to the north, on an adjacent set of abutments and then sliding this proposed structure into place just as the existing structure is demolished. Both directions of the Parkway East would be closed and detoured for a two-week period during the demolition and sliding and connecting process.

Another Parkway project affecting the ATM system is the E104228 Glenwood, Bates Street, Second Ave interchange upgrades currently in design. This is one of a several projects discussed in the SPC's Second Avenue corridor traffic study which recommends a variety of multimodal improvements spanning the length of Second Avenue and Irvine Street from the Glenwood Bridge past Bates Street to the Armstrong Tunnel. The study was conducted in anticipation of the Hazelwood Green (aka ALMONO, the former LTV coke works site) land development. The improvements will include widening the structure carrying I-376 over Bates Street so that the existing substandard deceleration lane to Exit 73A Glenwood is lengthened and intersection widening at several signalized intersections along Second Avenue near Exit 73 Bates Street.

Several other planned projects are outside of the Parkway East right of way but still affect traffic in the Parkway East Corridor Transportation Network:

Mon-Fayette Expressway from Jefferson Hills to Monroeville

The Mon-Fayette Expressway is a tolled, 4-lane divided, limited access freeway connecting I-68 near Morgantown, WV to PA-51 in Large, PA. The Pennsylvania Turnpike Commission plans to extend the highway, signed as PA TURNPIKE-43, from its existing terminus in Large, PA through the Monongahela River and Turtle Creek valleys to connect with I-376 in Monroeville (18 miles to the north of its current terminus). This extension is the last remaining unconstructed section of

the project and is divided into two segments, south of and north of the Monongahela River. The future of the northern segment of the highway – the portion slated to connect to I-376 The Parkway East between exits 81 and 84 – is uncertain because of revenue shortfalls created by the COVID-19 pandemic.

Route 28-Highland Park Bridge Interchange

Running approximately parallel to and 4 miles to the north of The Parkway East, SR 0028 is a limited access highway that follows the north shore of the Allegheny River out of Pittsburgh. A significant reconstruction is slated to relieve the single-lane bottleneck currently on SR 0028 at the Highland Park Bridge interchange. Two through lanes will be re-established on SR 0028 through the interchange to help mitigate conflicts, smooth flow and increase safety and reliability through this heavily traveled segment.

In addition to these projects, SPC's draft long rang plan is slated to include $31.7 billion worth of transportation projects through year 2045 in the 10-county southwestern Pennsylvania region. These long range projects include highway, bridge, transit projects and place an emphasis on technology such as smart traffic signals. The long range plan also includes a wish list of projects that aren't funded (listed as Projects Currently Beyond Fiscal Capacity). The unfunded long-range Parkway East-related projects in this long range plan include:

- $750 million extension of the Martin Luther King Jr. East Busway to Monroeville, a project that could help reduce demand on The Parkway East,
- SR 22 at SR 48: Reconstruction and Drainage, a major signalized intersection adjacent to Parkway East Exit 84A,
- the I-376: Bridge Preservation over Rodi Road (Exit 81).

Finally, there is potential for redevelopment of an abandoned Westinghouse Research Center site into an online retail distribution warehouse in Churchill Borough, between Exits 79A and 79B. The Churchill borough council has voted to move forward and amend the Borough zoning code, allowing a Conditional Use of a Distribution Center in the Borough's C-1 and C-2 Commercial Districts. the 133-acre parcel known as Churchill Crossing, formerly the George Westinghouse Research Park. With this zoning change, any applicant can now submit plans to the Borough for a conditional use with required studies. Development of the site could bring additional motor vehicle traffic, including truck traffic to the Churchill interchange. At the time of this writing, plans indicate the former Westinghouse buildings will be demolished, and the site remediated before any proposed construction occurs. A proposed plan includes new roads, parking storm water management and locations of buildings. A slip ramp from I-376 Exit 79A (for eastbound traffic) and a dual lane modern roundabout at the intersection of William Penn Highway and Beulah Road SR 0130 or improvements to the existing signal were studied as part of this plan.

25. Analysis of Proposed ATM Strategies

Alternatives

The proposed ATM system may incorporate operational alternatives including crash mitigation scenarios, speed harmonization, video analytics, wrong-way vehicle detection, queue detection and warning, dynamic lane assignment, and automated ramp, tunnel and freeway closures to handle traffic during emergencies. Each of these operational scenarios is considered for its usefulness in mitigating operational challenges along the Parkway East:

Crash Mitigation Scenarios

According the FHWA, *"TIM [Traffic Incident Management] consists of a planned and coordinated multi-disciplinary process to detect, respond to, and clear traffic incidents so that traffic flow may be restored as safely and quickly as possible. Effective TIM reduces the duration and impacts of traffic incidents and improves the safety of motorists, crash victims and emergency responders".* As crashes occur, lanes and or shoulders are temporarily closed due to the stopped crash vehicles and to facilitate the emergency responders, tow trucks and Hazardous materials contractors moving to and from the scene. Currently, these lane closures are communicated to the traveling public via existing DMS, in-vehicle applications like Waze and 511, and by the flashing waring lights of the emergency vehicles. If a crash occurs and block a lane in or near the Squirrel Hill Tunnel, the existing tunnel system of traffic signals and overhead lane use control signals are used to indicate the temporary lane closure to the approaching motorists. With the proposed ATM system, a clearer, wider-reaching message can be communicated via the proposed DMS and overhead LUCS. The crash could be detected by video analytics and edge computing outside of the TMC and then verified at the RTMC. In summary, the variable speed limits and lane status information would help to warn drivers of backups ahead and smooth out traffic as it approaches a lane-blocking incident.

Speed Harmonization

This operational strategy is implemented through VSL signs, sensors and the optimal speed calculating algorithms connected thereto. Benefits include smoother traffic flow with less delay, safer speeds through work zones and during hazardous weather events like flooding or where sight distance and the driver's ability to safely operate the vehicle is diminished. Under normal conditions when demand and density are increasing, highway capacity can be managed by setting vehicle speeds to slower than what some individual drivers may otherwise prefer. In this way the system can provide a higher flowrate with the slower speed. **Figure 35** helps to illustrate this principle. While enforcement and compliance are still issues given the state of existing technology, CAV technology could help to improve compliance and therefore effectiveness of the strategy.

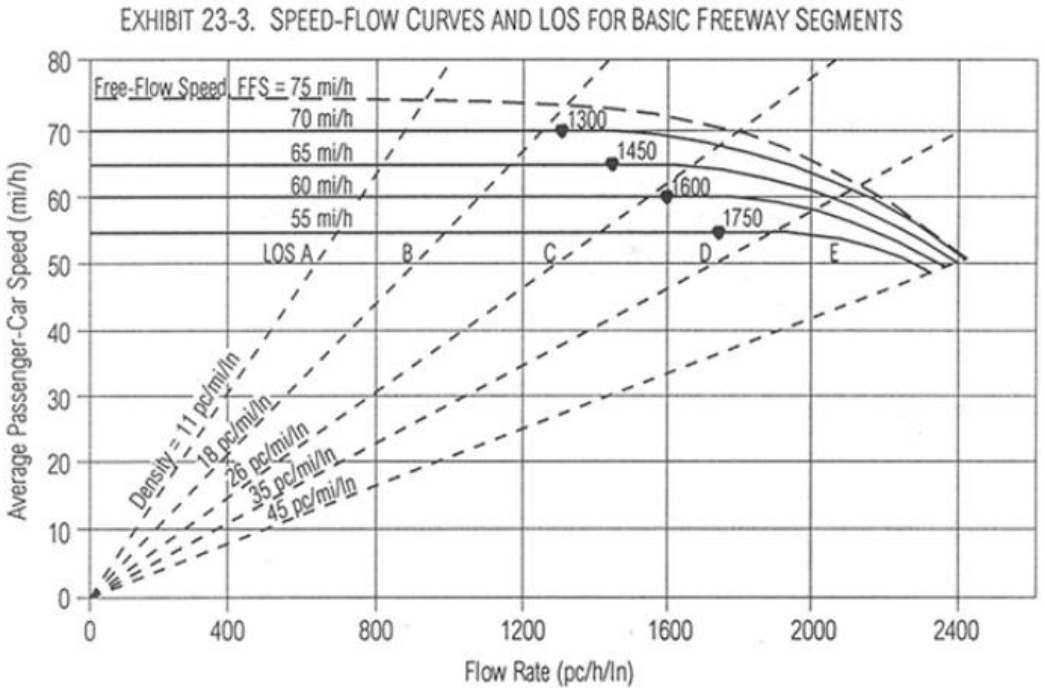


Figure 35: Speed-Flow Curves for Basic Freeway Segments

Video Analytics Scenarios

Working with regular video cameras already mounted along the highway, machine vision software can detect wrong way drivers, stopped vehicles, objects on the road, volume increases/decreases, or frequent slowdowns and proactively alert WRTMC staff. The cameras and analytics allow system operators to verify and respond to automated alerts so responses can be set in motion more quickly to clear the incident.

Wrong Way Video Detection

Similar in function to video analytics, wrong way video detection can trigger flashing lights on stationary warning signs along ramps and can proactively alert WRTMC staff. If on the freeway, the system can trigger automated messages on DMS and to activate LUCS to warn other motorists to be alert and to stop or avoid the errant vehicle.

Queue Detection and Warning

Standing queues are a regular occurrence approaching either portal of the Squirrel Hill Tunnel and at other critical bottlenecks throughout the corridor related to high volumes at critical interchanges and sub-standard highway geometry. These queues can extend for miles and last several hours during weekdays commuter peaks and during certain weekend special event-related peaks. Queues may also form during lane restrictions associated with crashes, highway construction, tunnel

cleaning and other maintenance events. A queue warning system can be installed to warn approaching motorists of the slow-moving or stopped vehicles that may suddenly appear. Sensors are installed downstream of DMS. When stopped or slowing vehicles are detected by the sensors, warning messages are displayed on the upstream DMS alerting motorists of the conditions ahead.

Dynamic Lane Assignment

Parkway East closures and lane restrictions, both scheduled and impromptu, occur daily throughout the corridor. Through a series of Dynamic lane control signs supported on overhead gantries, motorists can be directed to merge out of a closed lane in a planned, more orderly fashion. According to the FHWA, Agencies can realize numerous benefits with active traffic management. General operational benefits include:

- A decrease in primary incidents by alerting drivers to congested conditions and promoting more uniform speeds;
- A decrease in secondary incidents by alerting drivers to the presence of queues or incidents and proactively managing traffic in and around incidents;
- Increased throughput by reducing the delay associated with the number of primary and secondary incidents reducing speed differential in traffic flow, and reducing the shockwave effects of excessive breaking;
- Increased overall capacity by adding shoulder use during congested periods when it is needed most;
- Overall improvement in speed uniformity during congested periods; and
- Increased trip reliability by increasing capacity and throughput and reducing incident delay and improving vehicle throughput.

Automated Ramp, Tunnel and Freeway Closures

During emergencies and other more routine incidents, it may be necessary to temporarily close a ramp, tunnel or portion of the freeway while the incident (crash, wrong way vehicle, hazardous spill, errant person).

A few examples local to the I-376 The Parkway East might include:

A westbound directional closure at the “Bathtub” area. This 1900-foot- stretch of the westbound Parkway East floods when the Monongahela River exceeds 24 feet and overtops a wall constructed to hold the river back. This depressed section passes under the Smithfield, Wood, Market and Stanwix Street overpasses and is occasionally closed due to flooding. Vertical clearance issues and other roadways in this tight area make affordable, workable solutions infeasible. A Parkway East Flood Gate system in the bathtub area needs to be implemented and have emergency pre-entry gates installed to protect the bathtub area and close off ramps that can enter the parkway. This Flood Gate System needs coordinated with the Planned Flood Wall project.

Squirrel Hill Tunnel Interior washing takes place regularly, with weekday nighttime lane restrictions, typically from 10 p.m. to 5 a.m.

Heavy snowstorms rarely but occasionally limit each direction to just one passable lane before snowplows can clear all lanes.

Refer to **Table 9 in Appendix C** for the location and type of documented deficiencies that can be mitigated with these proposed ATM strategies.

26. Conceptual Scope, Schedule, Cost Estimate and Procurement Options

Scope

The proposed ATM system would be located along the I-376 Parkway East Corridor and select intersecting roadways. The ATM system should be constructed within existing PennDOT right-of-way.

The next steps in the Parkway East ATM system development are listed below:

- Final Design – Innovative Technology Evaluation
  - This evaluation will explore existing and future technologies and industry best practices. Integrated corridor management systems, edge processing and cloud computing, automated detection, system analytics and machine learning capabilities, and connected vehicle-to-infrastructure implementation features will be explored.
- Asset Management Evaluation
  - Document existing ITS infrastructure and update ITS plans to current status.
- ATM System Plans, Specifications and Estimates (PS&E) Package
  - Detailed design of the ATM system and supporting civil infrastructure including pavement guiderail, overhead gantries, communications, electrical, and other roadside features will be included in the PS&E package.
- Construction
  - Utility coordination, material acquisition, underground work, overhead structure installation, signage and ITS device installation will take place during this phase of the project.
- Integration/Commissioning/Testing
  - Device testing, acceptance and integration testing will follow ATM system construction.
- Long term operations and maintenance
  - A device modernization/ life-cycle management plan to be developed.

- Consideration and estimation of future ITS maintenance costs need to be evaluated to ensure PennDOT can support the added cost and allow for efficient budgeting strategies.

High level proposed schedule and conceptual costs were compiled for the proposed ATM system. The schedule and cost estimate included below (**Table 10 shown in Appendix C)** and **(Figure 36).** The following items are identified at the conceptual level:

- New sign structures/gantries
- Half span sign structures
- Analysis of existing sign structures
- Right-of Way
- Design
- Construction Management and Construction Inspection
- ITS Devices (LUCS, DMS, CCTV)
- ITS Software and Integration
- Maintenance and Protection of Traffic
- Mobilization
- Construction Surveying

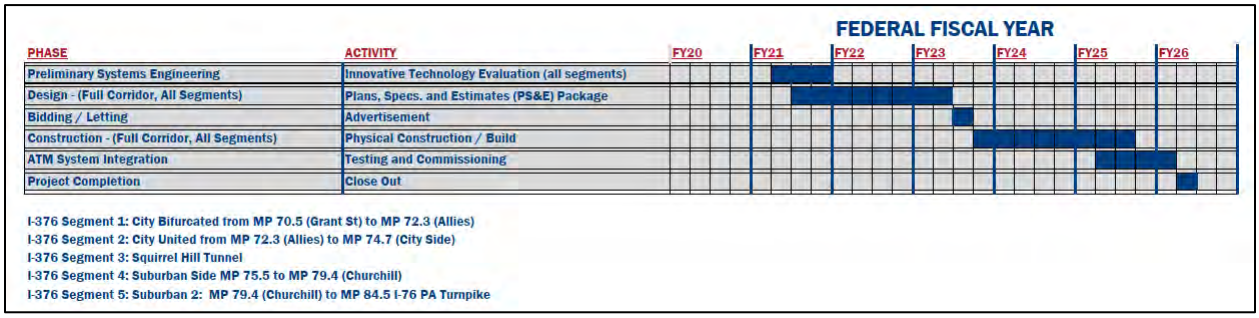


Figure 36: ATM System Schedule

Procurement strategies

Item and resource procurement options will be an important aspect to the success of the proposed ATM system project.

PennDOT and SPC have jointly applied for an Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) grant through the US Department of Transportation. ATCMTD grant funding will be matched by $11,600,000 in state funding to develop, deploy, and evaluate the Parkway East ATM project in Allegheny County, Pennsylvania. PennDOT has estimated the total project cost (Final Design and Construction) to be $23,200,000.

The 50% match has been committed as state transportation improvement funds and will be programmed in the SPC Transportation Improvement Program (TIP).

Letters of Commitment by PennDOT for the non-federal funding have been submitted and will become active upon the award of the ATCMTD grant.

27. Performance Measurements for System Validation

The measures referred to in this section are Measures of Effectiveness that validate the project and its effectiveness in meeting user needs, rather than Measures of Performance that verify that equipment meets requirements in testing.

In performing system validation, the operators must test and document the ATM system does exactly what it designed to do in a consistent and reproducible manner. The validation should focus on the macroscopic performance of the corridor and assess whether overall corridor-level operations and safety levels are being improved by ATM system implementation. In order to perform this validation, a series of steps must be undertaken: first, define what is being validated, then, determine the associated measures of effectiveness, what data needs to be collected and the method for analyzing the data. True value and effectiveness for the ATM system would need before and after analysis to provide historical trends, quantitative analysis and full trip performance.

Ultimately, a System Validation Plan would give additional details of this process and analysis, but is beyond the scope of this ConOps document. **Table 11 in Appendix C**, adapted from the I-66 Virginia Transportation Research Council Final Report VTRC 17-R5 (Chun, Fontaine, Ph.D., P.E., 2016), provides Measures of Effectiveness and suggested data sources for supporting data collection. It may be useful to collect before-implementation data before the system is constructed so as to ensure its availability.

28. Appendices

Appendix A - Bottleneck Locations This Appendix contains images of the interchanges and ramps that were determined to be bottlenecks from the previous study.

Appendix B - Conceptual Device Layout This appendix contains the proposed ATM device locations throughout the Parkway East.

Appendix C - List of Tables This appendix contains the tables referenced within this ConOps document.

Appendix D - Referenced Documents This appendix contains the tables referenced within this ConOps document.

Appendix E - Existing ITS Infrastructure This appendix contains existing ITS infrastructure.