MASTER PLAN

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MARYLAND DEPARTMENT OF TRANSPORTATION

STATE HIGHWAY ADMINISTRATION

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The 2020 TSMO Master Plan has been produced by the MDOT SHA Office of Transportation Mobility and Operations (OTMO) with oversight from the MDOT SHA TSMO Executive Committee.

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Message from the Administrator

The Maryland Department of Transportation State Highway Administration (MDOT SHA) strives to improve the lives of Maryland citizens and foster the economic vitality of the State by providing a safe, efficient and reliable highway system. The MDOT SHA team understands the direct impact that the movement of people and flow of goods has on our customers' ability to connect to life's opportunities. We face new challenges and shifting mobility trends each year, creating the need for progressive and cost-effective operations management, engineering, and context-sensitive design to manage our assets effectively and provide accessibility and mobility to our customers using all modes of transportation. This is where the Transportation Systems Management and Operations (TSMO) Program comes in –with a focus to effectively manage and operate existing facilities and systems and to maximize their full-service potential though Intelligent Transportation Systems (ITS). TSMO strategies leverage technology to optimize capacity that is limited by recurring and non-recurring congestion.

As MDOT SHA Administrator and former Chief Engineer for Operations, I am proud of the Coordinated Highway Action Response Team (CHART) Program's success in traffic-incident management and reducing delays on our roadway network. In order to deliver the best customer experience possible, we are working every day to keep Maryland moving forward by incorporating new technologies to propel our transportation network into the future. Led by Acting Deputy Administrator of Operations in Hanover and Director of the Office of Transportation Mobility and Operations (OTMO), Joey Sagal, the TSMO Program aims to shape our next generation of Mobility and Operations. The TSMO Master Plan provides a goal-oriented, performance-based and outcome-driven approach for transportation investments in Maryland.

The TSMO Master Plan lays the foundation and provides steps on how to plan for and deploy TSMO solutions and strategies in the day-to-day planning, design, construction, maintenance, and operations activities associated with Maryland's ITS. The TSMO Master Plan is a collaboration between the CHART, which provides monitoring and reporting of traffic conditions, emergency traffic patrol response, and active traffic management functions; the technical expertise of the Office of Traffic and Safety (OOTS), which is systematically upgrading traffic signals to adapt to changing traffic patterns and improve vehicular and pedestrian safety at our busiest intersections; and the local District Offices that are at the front lines of providing the customer experience to Maryland's drivers and meeting our local stakeholders' needs. Together, their many years of experience and unique areas of expertise will also help provide a cohesive approach to deploying projects and initiatives that will improve Maryland's roadways.

Our System of Systems approach will allow Maryland to continue to be a leader in advancing technological innovation through our TSMO Program. I look forward to seeing great results as we continue to deploy the latest TSMO strategies and solutions using this collaborative and cohesive approach.

Tim Smith

Tim Smith
Administrator

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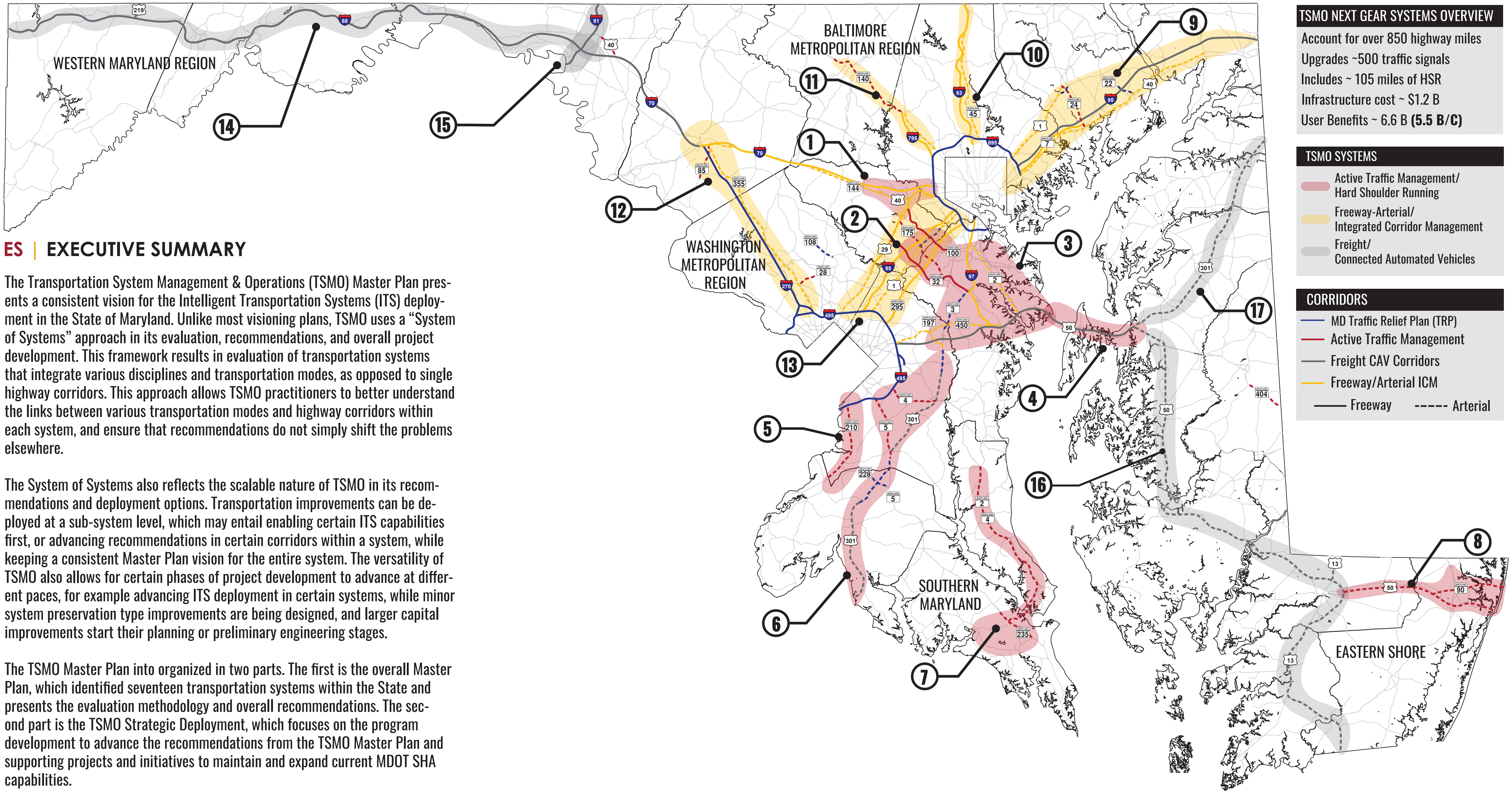
MARYLAND TRANSPORTATION SYSTEM MANAGEMENT & OPERATIONS SYSTEM



ES | EXECUTIVE SUMMARY

The Transportation System Management & Operations (TSMO) Master Plan presents a consistent vision for the Intelligent Transportation Systems (ITS) deployment in the State of Maryland. Unlike most visioning plans, TSMO uses a "System of Systems" approach in its evaluation, recommendations, and overall project development. This framework results in evaluation of transportation systems that integrate various disciplines and transportation modes, as opposed to single highway corridors. This approach allows TSMO practitioners to better understand the links between various transportation modes and highway corridors within each system, and ensure that recommendations do not simply shift the problems elsewhere.

The System of Systems also reflects the scalable nature of TSMO in its recommendations and deployment options. Transportation improvements can be deployed at a sub-system level, which may entail enabling certain ITS capabilities first, or advancing recommendations in certain corridors within a system, while keeping a consistent Master Plan vision for the entire system. The versatility of TSMO also allows for certain phases of project development to advance at different paces, for example advancing ITS deployment in certain systems, while minor system preservation type improvements are being designed, and larger capital improvements start their planning or preliminary engineering stages.

The TSMO Master Plan into organized in two parts. The first is the overall Master Plan, which identified seventeen transportation systems within the State and presents the evaluation methodology and overall recommendations. The second part is the TSMO Strategic Deployment, which focuses on the program development to advance the recommendations from the TSMO Master Plan and supporting projects and initiatives to maintain and expand current MDOT SHA capabilities.

Table of Contents

List of Figures

Acronyms

APN	Access Point Name
ATIS	Advanced Traveler Information Systems
AVL	Automatic Vehicle Location
BRT	Bus Rapid Transit
CCTV	Closed Circuit Television
CHART	Coordinated Highways Action Response Team
CVO	Commercial Vehicle Operations
DMS	Dynamic Message Sign
ETL	Express Toll Lanes
FHWA	Federal Highway Administration
FITM	Freeway Incident Traffic Management
GPS	Global Positioning System
HAR	Highway Advisory Radio
HAZMAT	Hazardous Materials
HIB	Hazard Identification Beacon
ITS	Intelligent Transportation System
LCS	Lane Control Signs
MDOT	Maryland Department of Transportation
MDOT SHA	MDOT State Highway Administration
MDTA	Maryland Transportation Authority
MTA	Maryland Transit Administration
OOTS	Office of Traffic and Safety
PTZ	Pan Tilt Zoom
RPU	Remote Processing Unit
RWIS	Road Weather Information System
SOC	Statewide Operations Center
TOC	Traffic Operations Center
TSS	Traffic Sensor Subsystem
VPN	Virtual Private Networks
VSL	Variable Speed Limit

1.0 MARYLAND STATEWIDE TSMO MASTER PLAN

1.1 | WHAT IS TSMO?

Transportation System Management and Operations (TSMO) is a framework used by transportation agencies to identify and develop projects which maximize the service potential of transportation systems. TSMO can be differentiated from other development strategies through its emphasis on targeted operational improvements that do not require traditional capacity improvements (*e.g.* additional lanes, interchanges, routes, etc.). TSMO initiatives achieve this high level of efficacy by utilizing information technology to create intelligent transportation systems (ITS).

The ITS infrastructure promoted by the TSMO framework is composed of three basic parts: ITS devices, telecommunications networks, and decision support systems (see Figure 1). ITS devices allow agencies to collect information about the performance of transportation networks and alter operational conditions. For example, sensors which detect traffic speed help transportation agencies understand how efficiently traffic is moving through an area. When congestion is occurring, traffic engineers would use the data to determine if ramp meters (a type of ITS device used to moderate the entry of vehicles onto an access-controlled roadway) should be activated.

In order for ITS devices to be used effectively, there must be a telecommunications network which can transmit both the data collected and the response messages. Traditionally, copper cables and radio transmissions were used to transmit and collect data. Fiber optic cables are becoming the golden standard to ensure digital messages can be conveyed quickly and reliably. With the improved performance and coverage of cellular networks, wireless data pathways are also being used.

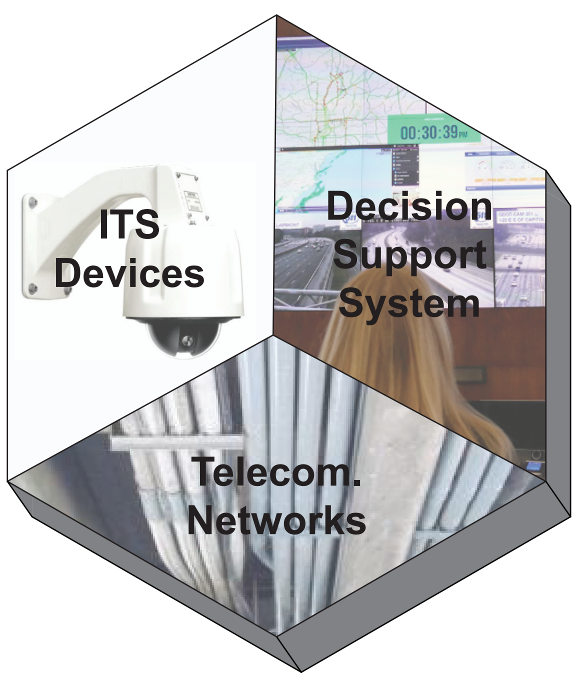


Figure 1. ITS INFRASTRUCTURE

At the center of the telecommunications network is the decision support system. The system is comprised of both physical assets and software systems which help agencies diagnose operational issues and design an appropriate response. The physical components of the decision support system include banks of displays, communication equipment (*e.g.* radios and telephones), and servers for hosting digital networks. The software components are programs designed to organize and analyze the incoming data so that traffic engineers can select the most appropriate response. The advancements in technology and increase in available real time data are creating a pathway for more automated systems that employ artificial intelligence to become part of future decision support systems.

The TSMO framework can also be distinguished from other development strategies by its heavy emphasis on integrating multiple scales of system analysis (*e.g.* local, corridor, and regional) and asset development (*e.g.* planning, design, construction, and maintenance). This emphasis is founded on the belief that transportation facilities function best when development focuses not just on individual facility characteristics (*e.g.* capacity) or agency actions (*e.g.* roadway widening), but also on broader systemic performance characteristics driven by the agency's core mission. Maryland Department of Transportation (MDOT) refers to this development strategy as the System of Systems approach. Figure 2 illustrates how the System of Systems approach informs the TSMO Framework.

By embracing these strategies, as well as changes in institutional practice, transportation agencies across the nation have been able to use TSMO frameworks to not only improve user experiences, but also maximize the return on public investment. Thanks to a history of embracing technological innovation, all three parts of ITS infrastructure already exist within Maryland and support MDOT's operations. Integrating the TSMO framework into MDOT's program will carry this tradition forward and assure that Maryland has the infrastructure it needs to support the economy of the 21st century.

1.2 | HOW DID THE TSMO PROGRAM BEGIN?

Although the emergence of TSMO as a formal Federal Highway Administration (FHWA) initiative is a relatively recent event, MDOT has been experimenting with many of the practices and techniques TSMO promotes for decades. Electronic tolling, traffic signal coordination, and traffic and incident management are all examples of long-standing MDOT programs that TSMO programs often pursue. Since the mid-1980's, MDOT State Highway Administration (MDOT SHA) has been using traffic operations centers and ITS devices to detect and respond to incidents along US 50 between Annapolis and Ocean City. The success of this program, known as "Reach the Beach", became the genesis of the Coordinated Highway Action Response Team (CHART).

At its core, transportation can be defined by a single service: moving people and goods from one place to another.

The advancement of transportation technology has provided a variety of ways to provide this core service. In response, most DOTs are organized into specialized service providers. While this strategy creates focus, it also makes it difficult to recognize and resolve challenges that affect multiple systems.

TSMO programs are designed to strengthen DOTs by identifying the operational linkages between modal and geograpghical networks. The result is a multi-scalar & multi-modal **System of Systems.**

Figure 2. TRANSPORTATION AS A SYSTEM OF SYSTEMS

CHART is the custodian and operator of MDOT's ITS network. Its core mission is to improve mobility and safety for the users of Maryland's highway through the application of ITS technology and inter-agency teamwork. The heart of CHART's program is the Statewide Operations Center (SOC). The SOC is a multi-disciplinary command and control center that processes traffic data collected by the state's four Traffic Operation Centers (TOC), Closed-Circuit Television (CCTV) system, and a large network of other field devices. Through these assets, CHART provides 24-hour traffic monitoring, disseminates traveler information, coordinates incident response activities, and guides active traffic management procedures throughout Maryland.

In 2014, MDOT SHA's ITS program entered a new phase with the receipt of a grant through FHWA's Strategic Highway Research Program 2 (SHRP2). The grant was an extension of a project designed to identify metrics DOTs could adopt to improve travel time reliability to address non-recurring sources of highway congestion (*e.g.* crashes, storms, and construction zones). Using these funds, MDOT conducted a series of workshops in 2014 and 2015 whose findings lead to the re-organization of MDOT's ITS activities and the preparation of the 2016 TSMO Strategic Plan. Based on its success developing and managing ITS networks, MDOT selected the Office of Transportation Mobility and Operations, which includes CHART, to be the office centrally responsible for overseeing the TSMO program and completing the Strategic Plan's recommendations. At present, the TSMO program is focused on improving highway operations. As the program matures, its scope will strengthen the links to mass transit, pedestrian facilities, and inter-modal connections.

MDOT's formal TSMO program began with the release of its TSMO Strategic Plan in August 2016. In this document, MDOT SHA translated the U.S. Department of Transportation's (USDOT) national TSMO framework into goals and strategies that fit Maryland's unique needs. Some of the Plan's principal recommendations include the development of performance metrics for TSMO projects, increasing the amount of operational information available to the traveling public, and the creation of specialized TSMO teams throughout MDOT SHA. In 2018, the Strategic Plan was updated to reflect changes in MDOT SHA's project development process and recent technological advancements. The recommendations presented in the 2018 Strategic Plan are organized around four thematic goals:

- Business Processes & Collaboration;
- Systems & Technology;
- Data, Analysis & Performance Management; and
- Customer Experience & Engagement.

Each goal is supported by objectives and strategies (see Figure 3). An objective is something MDOT SHA wants to achieve and strategies are actions that will help MDOT SHA achieve its objectives.

1.3 | WHY WAS THE TSMO MASTER PLAN CREATED AND WHAT IS ITS PURPOSE?

The purpose of any Master Plan, be it for a residential community or a transportation system, is to make future investments more effective by articulating priorities and goals. In the case of the TSMO Master Plan, MDOT's priority is to maximize the service potential of Maryland's transportation systems. Like most transportation plans, the goals are projects or initiatives which the agency believes are worthy of further development.

The creation of a TSMO Master Plan is one of the three objectives supporting the Business Process & Collaboration Goal (see Objective 1.2 in Figure 3). The primary purpose of the TSMO Master Plan is to present, describe, and promote a collection of TSMO systems (see Strategy 1.2b in Figure 3). A TSMO system is comprised of one or more roadways owned and/or operated by MDOT whose traffic conditions could be improved through a coordinated set of TSMO projects. The publication of this information will support MDOTs TSMO program by communicating performance metrics, illustrating the application of novel techniques, and serving as a starting point for further technical innovation.

The presentation and description of each TSMO system occurs on the fact sheets contained in Appendix A. Each fact sheet includes mapping of a system's location and informational graphics which describe existing traffic conditions. To ensure technical accuracy and programmatic compatibility, each of the TSMO systems was prepared with input from MDOT's disciplinary divisions (see Strategy 1.2a in Figure 3). The system fact sheets also identify the TSMO improvements which have the greatest potential to improve traffic conditions, the cost of completing the improvements, and the predicted user benefit. User benefit is the calculated economic value of the time and fuel that would have otherwise been lost due to congestion.

The predicted user benefit relative to the cost of completing the proposed improvements is one of the key criteria used to establish the business case for each of the TSMO projects (see Strategy 1.2c in Figure 3). When paired with the improvement type, this information also helps identify which of MDOT's programs and funding streams are best suited to refine the recommended improvements into projects (see Strategy 1.2d in Figure 3).

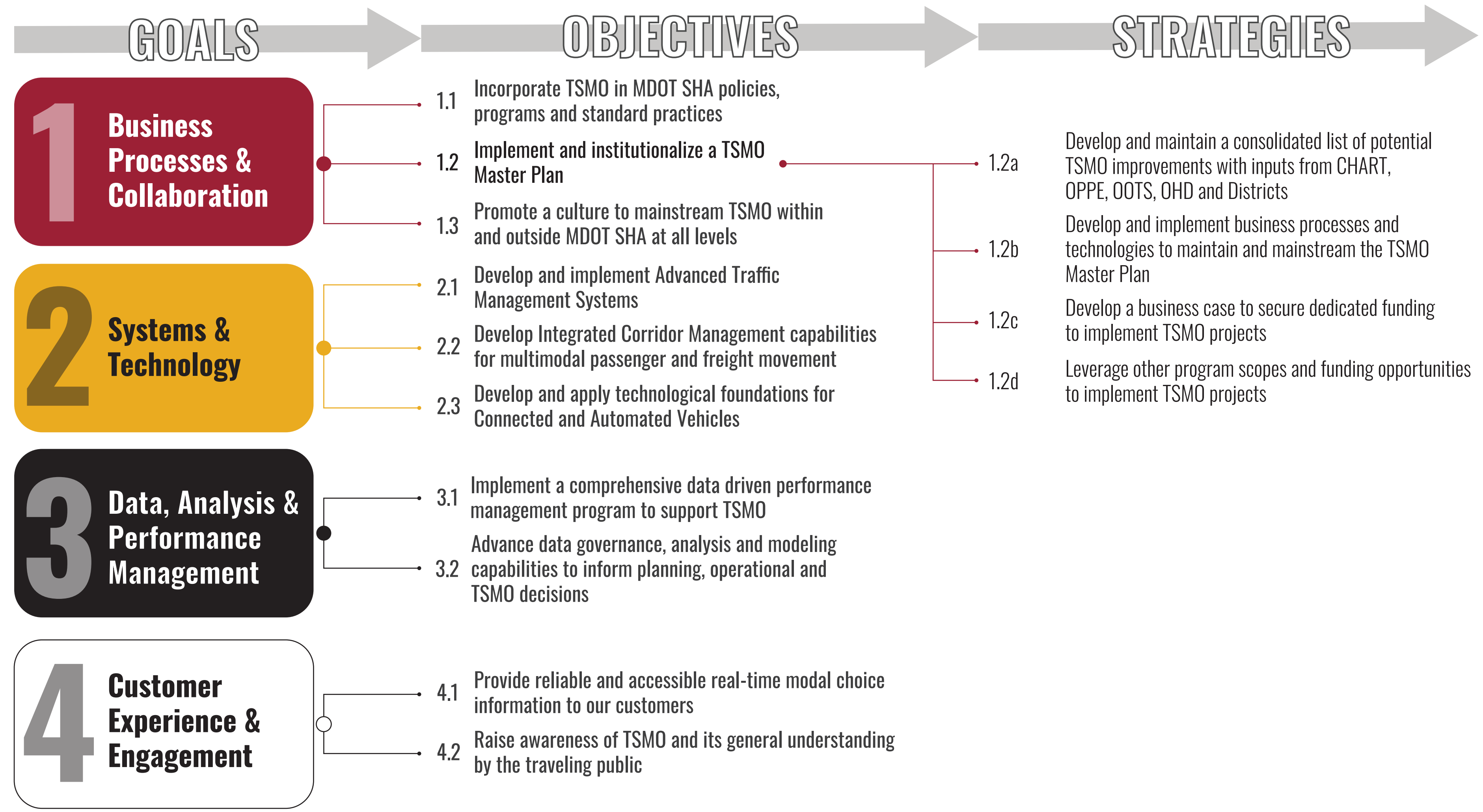


Figure 3 | STRATEGIC TSMO GOALS, OBJECTIVES & STRATEGIES

1.4 | WHAT INFORMATION IS USED TO DEVELOP THE TSMO MASTER PLAN'S RECOMMENDATIONS?

Since MDOT began conducting system performance analyses in the mid 1980's, many of the references needed by the TSMO program already exist. The four most crucial (see Figure 4) of these are:

- MDOT SHA Mobility Report;
- Strategic Highway Safety Plan;
- Maryland Strategic Goods Movement Plan; and
- Transportation Asset Management Plan (TAMP).

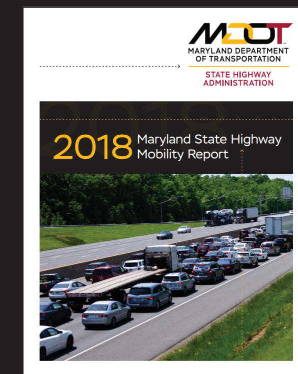
In addition to serving as valuable planning references, the subject matter of these reports helps to illustrate the types of operational issues related to MDOT's overall TSMO program. Outside of MDOT's own data collection systems, one of the largest sources of information for the TSMO program is the University of Maryland's Center for Advanced Transportation Technology Laboratory (CATT Lab). The CATT Lab's mission is to support efforts to improve the operations of transportation systems through research, education, and the implementation of advanced technologies. One of the CATT Lab's programs utilized by the TSMO program is the Regional Integrated Transportation Information System (RITIS). RITIS is an automated data sharing system that includes a wide range of performance statistics, including extensive records of traffic operations collected in real-time.

Successful development and execution of a TSMO program requires that transportation agencies not only gather detailed operational data, but also study the data in ways that will reveal the relationships between service failures. MDOT achieves this goal by organizing network analysis around four operational needs:

- Congestion;
- Reliability;
- Safety; and
- Freight.

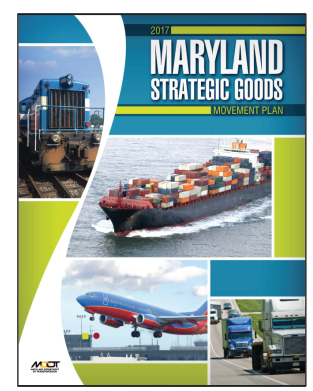
Congestion

Congestion is the operational condition that occurs when the number of vehicles using a roadway is large enough that they can no longer safely travel at the facility's design speed. In a 2004 report entitled *Traffic Congestion and Reliability: Linking Solutions to Problems*, FHWA identifies six causes of congestion:



The Annual MDOT SHA Mobility Report provides a detailed summary of the performance of the roadways operated by MDOT SHA. Some of the attributes documented in the Mobility Report include: the distribution of vehicle miles traveled by time and geographic and region; the level of congestion experienced on major corridors (*i.e.* Travel Time Index or TTI); the economic cost of congestion on major corridors; the reliability of major corridors (*i.e.* Planning Time Index or PTI); and the distribution and reliability of freight traffic across the state. These attributes are critical to the development of the TSMO program because they allow TSMO planners to identify where service failures exist and what might be causing them

The Strategic Highway Safety Plan is a guidance document designed to help MDOT reduce the number of fatalities and serious injuries that occur on Maryland's highways by 50% by 2030. The plan establishes performance targets for six emphasis areas: aggressive driving, distracted driving, impaired driving, highway infrastructure, and pedestrian and bicyclist safety. The Strategic Highway Safety Plan is an important resource for developing the TSMO program because it not only identifies areas where system upgrades are needed, but also describes relevant investment strategies.



The Maryland Strategic Good Movement Plan is focused on the movement of freight through the State. The plan provides operational summaries for the major modes of freight movement (*i.e.* highway, rail, inland waterways, and aviation) and cargo types (*i.e.* agricultural, mining, construction, energy, wholesale, and manufacturing). These summaries not only cover existing statistics, but also the strategies MDOT is using to improve the reliability of freight movement. Both sets of information can be use by planners to identify the networks that need improvement and set goals for the TSMO program.

The MDOT Transportation Asset Management Plan (TAMP) is a report which lists all the roads and bridges MDOT owns that are part of the National Highway System (NHS). In the 2018 TAMP, the statewide NHS inventory included approximately 9,037 lane miles of pavement and 1,932 bridges. The TAMP is a valuable resource for planning the MDOT's TSMO program. This information can help TSMO planners keep their records up to date and stage improvements to coincide with scheduled facility upgrades.

Figure 4 | PERFORMANCE BASED REFERENCES FOR TSMO

- **Physical Bottlenecks** are locations where traffic exceeds the maximum capacity capable of being handled by a given highway section. Capacity is determined by a number of factors: the number and width of lanes and shoulders; merge areas at interchanges; and roadway alignment (grades and curves).
- **Traffic Incidents** are events that disrupt the normal flow of traffic, usually by physical impedance in the travel lanes. Events such as vehicular crashes, breakdowns, and debris in travel lanes are the most common forms of incidents.
- **Work Zones** are construction activities on the roadway that result in physical changes to the highway environment. These changes may include a reduction in the number or width of travel lanes, lane "shifts," lane diversions, reduction, or elimination of shoulders, and even temporary roadway closures.
- **Weather** are environmental conditions that can lead to changes in driver behavior that affect traffic flow.
- **Poor Signal Timing** are intermittent disruption of traffic flow by traffic control devices such as railroad grade crossings and poorly timed signals that contribute to congestion and travel time variability.
- **Special Events** are a special case of demand fluctuations whereby traffic flow in the vicinity of the event will be radically different from "typical" patterns. Special events occasionally cause "surges" in traffic demand that overwhelm the system.

There are two types of congestion: recurring and non-recurring. Congestion related to physical bottlenecks and traffic control devices is referred to as recurring because it tends to occur day-after-day, often at the same time and in the same location. All other causes of congestion are referred to as non-recurring. More than half of the total causes of congestion are non-recurring (see Figure 5).

In general, new construction is viewed as an appropriate response to recurring congestion. However, in the current economic environment, raising highway construction budgets is unlikely. Moreover, new construction does not address non-recurring congestion. By identifying and mapping the cause of the congestion, TSMO planners can trace the source of service failures to address both recurring and non-recurring congestion.

Reliability

Transportation agencies use the term reliability to refer to the consistency of travel times over the course of a given period (*e.g.* weekday mornings from September to May). FHWA uses several different statistics to asses reliability, including:

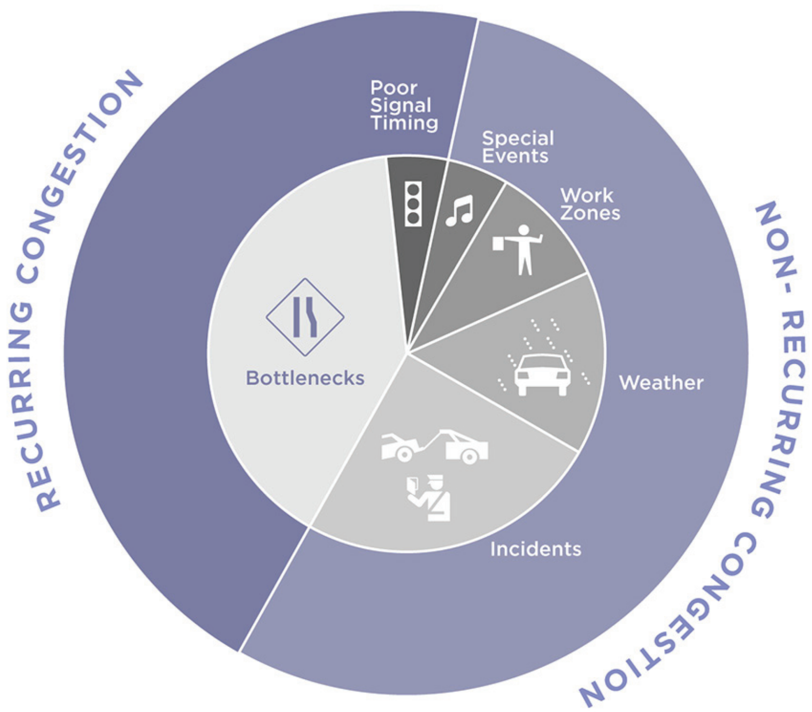


Figure 5. **FHWA Causes of Congestion**

- Free-flow travel time (*i.e.* the time needed to complete a trip without congestion);
- The 50th percentile travel time (*i.e.* the time needed to complete a trip because of typical, recurring congestion);
- The 95th percentile travel time (*i.e.* the time needed to complete a trip because of incidental, non-recurring congestion); and
- Buffer index (*i.e.* the extra time needed to travel because of recurring or non-recurring congestion).

MDOT SHA's TSMO program uses these statistics to calculate two key performance metrics: Travel Time Index (TTI) and Planning Time Index (PTI). Both metrics are ratios which describe the relationship between the travel time along a corridor under free flow conditions and travel time when congestion is causing delays. TTI is the ratio between these two conditions when the congestion is the result of recurring conditions, like the increase in traffic that occurs during the morning and evening commute. PTI is the ratio between these two conditions when the congestion is the result of recurring and non-recurring events. Extreme weather, crashes, and major league athletic events are good examples of incidents which generate non-recurring congestion. For both metrics, a large index value indicates a large disparity between how the corridor would ideally function and the user experience. By comparing PTI and TTI values, TSMO planners can assess the volatility of congestion and identify the relationships between contributing factors.

Safety

The preservation of public safety is the top performance criteria for every MDOT facility and initiative. The TSMO program embodies this mission by using the prevalence of crashes along a corridor as one of the principle means of identifying operational issues. By segregating crash records by type (*e.g.* rear-end, sideswipe, angle, etc.) and time of day, TSMO planners can highlight the areas where ITS measures (like the installation of smart signals) can not only protect the traveling public, but also reduce congestion caused by non-recurring events. Another important diagnostic metric is the number crashes per vehicle mile traveled. By adding this layer of context, TSMO planners can ensure that safety issues experienced on low-volume roadways aren't overlooked.

Freight Movement

Out of the four categories of performance criteria used by the TSMO program, the movement of freight is arguably the most dynamic. This distinction comes from the inherently inter-modal nature of freight movement. Although the highway system conveys most of the freight moving through the State, Maryland's diverse set of freight facilities means that operational issues that normally would be limited to a single facility type can branch out. Highway congestion on its own will affect the movement of heavy trucks through a region, but when it occurs near an important maritime facility, it can impact the movement of goods overseas.

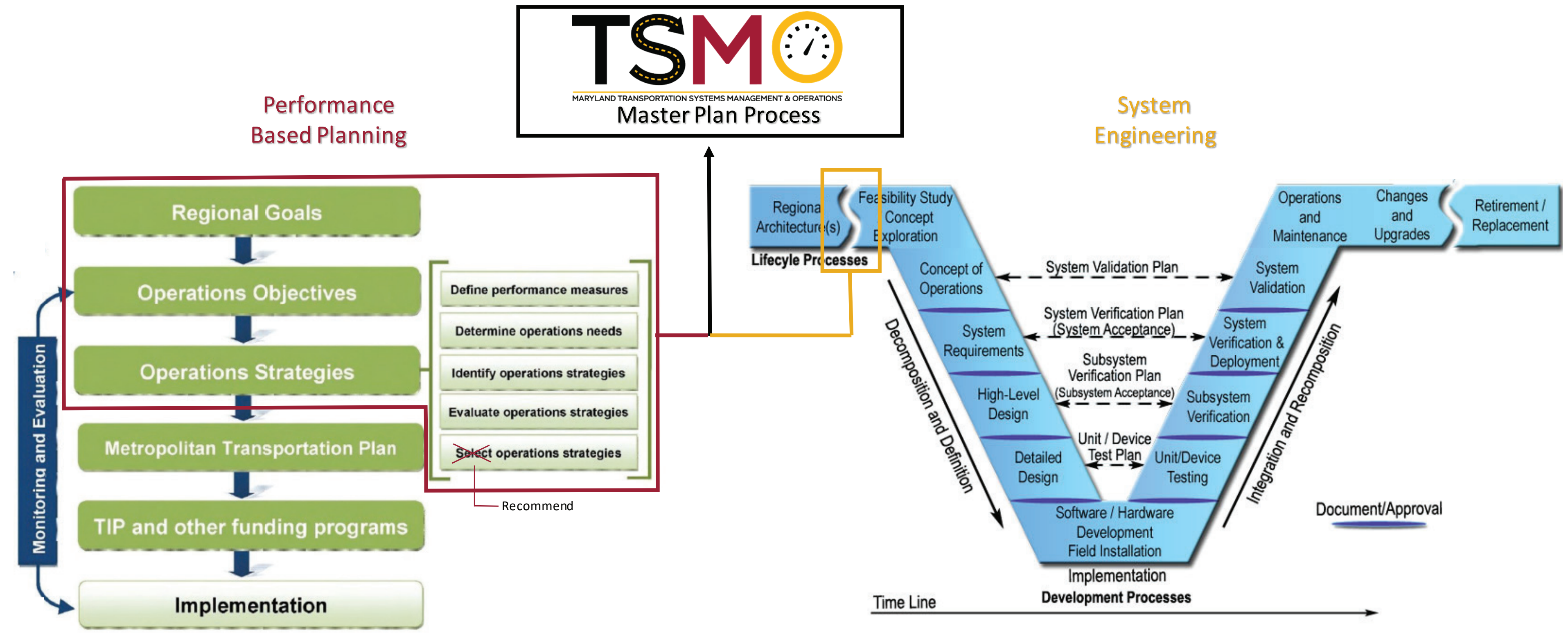
The TSMO program addresses the complex nature of freight traffic by using the Maryland Strategic Goods Movement Plan to identify the most critical freight facilities and highlight the key inter-modal connections. Another key criterion is the distribution of specialized freight facilities. Overnight truck parking and weigh stations are both good examples of facilities which don't directly influence the number of heavy trucks a highway can bear but have a strong influence on how safely and efficiently those trucks can complete their routes. Other important criteria used by TSMO planners include the occurrence of illegal truck parking and the economic losses generated because the movement of freight is delayed by congestion.

1.5 | HOW IS THE TSMO MASTER PLAN DIFFERENT FROM OTHER MDOT PLANNING EFFORTS?

What differentiates the TSMO Master Plan from other transportation planning efforts is the fluidity of its recommendations. Whereas traditional transportation plans describe future investments in very discrete terms (*e.g.* the construction of an interchange at a given intersection), the TSMO Master Plan describes a range of improvements that could be deployed to one or more related corridors. This flexibility is provided because the MDOT TSMO program is designed to be driven by performance-based metrics rather than a proscriptive vision of how the transportation network should look.

The TSMO Master Plan process (see Figure 6) is designed to fit between the Performance Based Planning and System Engineering (SE) processes. The data and analysis prepared for the Master Plan sets heavy emphasis on existing performance measures and operational needs at both the facility and network level based on broader understandings of regional goals. This process allows the TSMO Master Plan to serve as a link between documents expressing regional goals and the feasibility studies prepared in the SE process.

In addition to inviting potential solutions to compete for selection, the TSMO program's emphasis on performance-based metrics requires planners to consider the effects on the larger network as opposed to focusing on a single location. It also allows MDOT's design team to more easily respond to technological advancements. Unlike other elements of the transportation network, the capabilities of ITS assets are changing so rapidly that what appears to be cutting edge today may soon be outdated. In recognition of this, the TSMO Master Plan is presented as a living document that will be regularly updated. This process of revision will not only allow MDOT to respond to technology advancements, but also facilitate assessments of the TSMO program's performance and track progress towards the objectives expressed in the TSMO Strategic Plan.



Source: Adapted from Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations - A Desk Reference (FHWA, April 2010)
Adapted from System Engineering for Intelligent Transportation Systems - An Introduction to Transportation Professionals (FHWA, January 2007)

Figure 6. TSMO MASTER PLAN PROCESS

1.6 | HOW WERE THE TSMO MASTER PLAN'S RECOMMENDATIONS PREPARED?

The TSMO evaluation process culminates in recommended TSMO strategies (e.g. signal upgrades for congestion, camera deployment for incident response, transit signal priority for buses, hard shoulder running for capacity, etc.) and a proposed course of action to deliver the recommendations. The TSMO Master Plan's recommendations were prepared through a three-step process (see Figure 7). These three steps are:

Step 1: Identification of Statewide Priorities

The preparation of the TSMO Master Plan's recommendations begins with reviewing reference documents (from *Section 1.4*) and extracting data which describes TSMO key performance metrics (*i.e.* congestion, reliability, safety, and freight movement). Using these datasets, MDOT creates thematic maps which highlight areas where operation conditions could be improved. Corridors within these networks are then reviewed by teams of subject matter experts (*e.g.* regional planners, operational specialists, asset managers, roadway designers, district traffic, etc.) to add context to the gathered data and identify other regional or local needs and priorities. This first step helps identify the

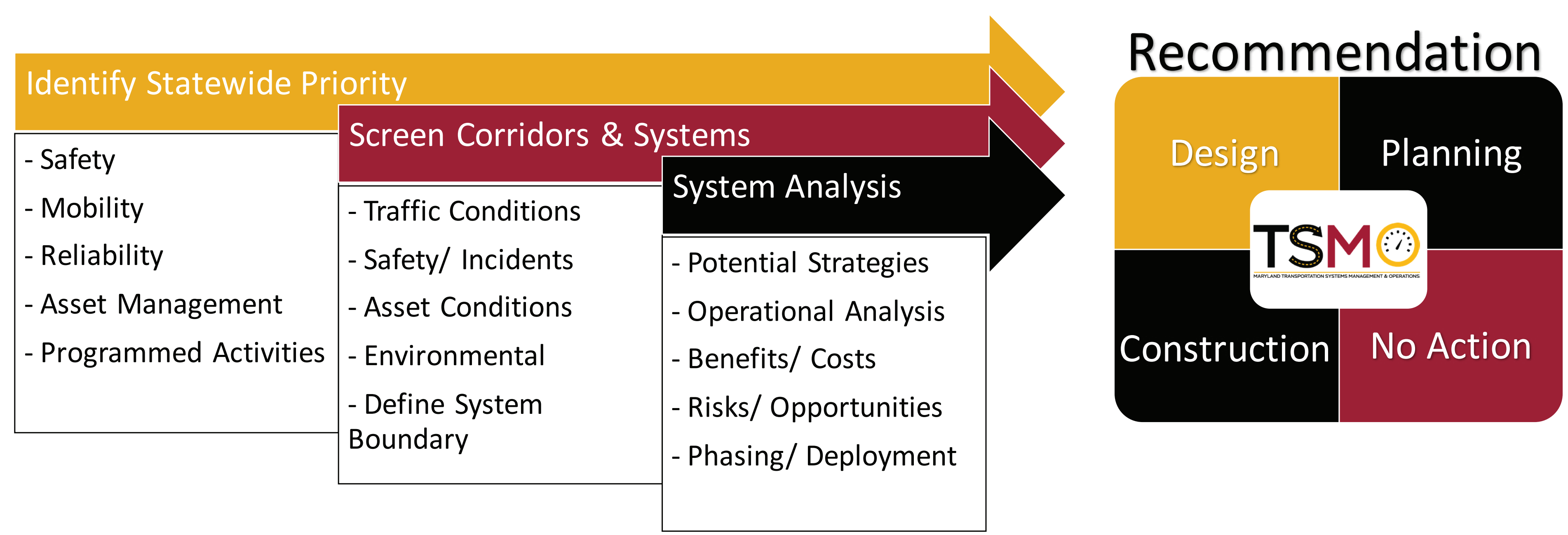


Figure 7. TSMO EVALUATION PROCESS

gaps in the State's transportation network and presents corridors and systems to be considered for screening.

Step 2: Screen Corridors and Develop TSMO Systems

The screening process begins with expanding the description of each corridor to include the condition of major assets, the presence of sensitive environmental resources, transit and multi-modal considerations, and unique operational characteristics. Assessments of asset condition help planners determine if TSMO upgrades could be integrated into upcoming maintenance efforts. Mapping of sensitive environmental resources helps TSMO planners identify constraints and mitigation requirements associated with potential construction activities.

Evaluation of this data, sometimes accompanied by operational studies, help identify TSMO strategies tailored to fit the unique operational needs of the corridor. By combining the results of these processes, TSMO planners can select those corridors which fit the TSMO program best and assemble them into systems to be managed in a more coordinated fashion. These TSMO systems are comprised of multiple corridors (freeways and arterials) that share a common boundary and traffic operations, where operations of one corridor directly influence the other. These systems also take seasonal routes into consideration to support local tourism and multi-modal connections and systems that impact operations.

Step 3: Perform System Analysis

TSMO system analysis begins by focusing on a few general strategies to help communicate a vision based on transportation needs and existing technologies. This approach is used because MDOT's catalog of TSMO strategies is constantly increasing, and overly discrete recommendations are likely to hinder innovation and decrease the programs efficacy. Each strategy is evaluated from a system-wide perspective to ensure that improved operations along certain corridors do not shift the problem elsewhere and to focus on recommendations based on the end-to-end trip experience and user benefit. Multiple strategies are recommended for each TSMO system to address different needs within targeted locations in the transportation network.

Strategies that were evaluated but not recommended due to physical and/or operational constraints are documented in the individual corridor sheets used during screening for future reference. Recommended strategies are included in the TSMO System fact sheets included in Appendix A. The planning level costs and user benefits (see Figure 8) provide an order of magnitude of the potential infrastructure needs and return on investment to assist fiscal decision makers in prioritizing funding opportunities.

The three-step process results in the following:

- Corridor Needs (*e.g.* congestion, reliability, safety, freight)
- TSMO Systems (*e.g.* grouping of corridors and other transportation modes that influence each others' operations)
- Recommendations (*e.g.* TSMO strategies organized by systems)

TSMO Recommendation

MDOT's catalog of TSMO improvements covers a broad range of disciplinary specializations and construction requirements. As a result, the same development process is not ideal for all of the recommendations presented in the TSMO Master Plan. The last phase of the Master Planning process reacts to this diversity by identifying appropriate development processes and lead divisions. TSMO improvements involving the construction of hard running shoulders could require the renovation of ancillary highway systems (*e.g.* drainage systems) and are best handled by MDOT's principal design offices and innovative contracting teams. Smaller scale system preservation projects or spot improvements may be led by the MDOT's district offices. Implementation of smart traffic signals or ITS devices may be designed and led directly by MDOT's asset managers. Lastly, TSMO systems with high environmental risk would be best studied by MDOT's planning offices.

These recommendations do not prescribe specific improvements and locations, and will change as project development progresses. The TSMO Master Plan provides a framework to advance these recommendations as part of scalable systems and sub-systems based on identified operational needs rather than specific treatments. Strategies identified in the Master Plan will be re-evaluated in planning, design and as part of the SE process where they may be modified, discarded, and new strategies may be added to the sub-systems based on updated information, refined analyses, and potentially new technologies and TSMO strategies.

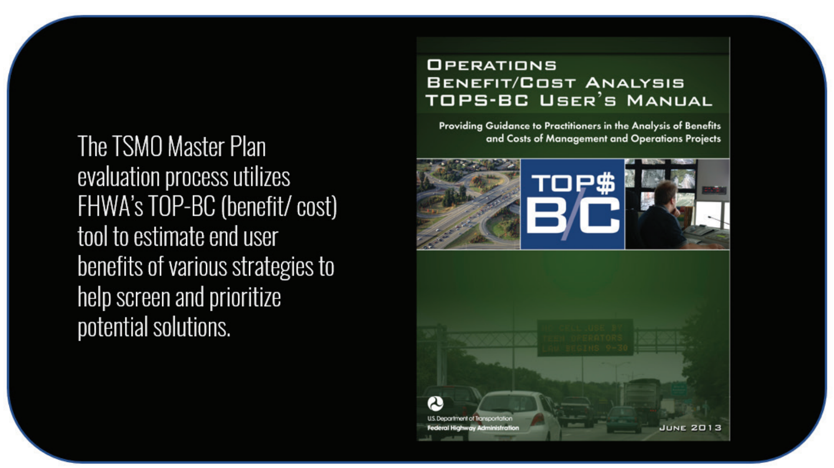
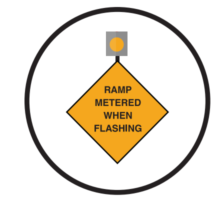


Figure 8. **TSMO END USER BENEFIT METHODOLOGY**

TSMO STRATEGIES OVERVIEW

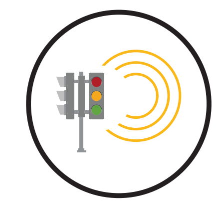
Traveler Information
Provides information to motorists on travel conditions and alternative travel routes

Ramp Metering / Junction Control



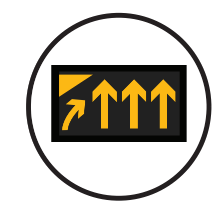
Adjusting lane assignments and vehicle flow entering highways to reduce conflicts and resulting accidents

Smart Traffic Signals / Connected & Automated Vehicles



Utilizing technology to adjust signal timing to meet current conditions and for vehicles to communicate with each other and the connected infrastructure

Hard Shoulder Running



Utilizing the roadway shoulder as a travel lane during peak travel periods to alleviate congestion

Managed Lanes

Managing the use of travel lanes in relation to travel conditions

Integrated Corridor Management

Interconnected system capable of cross-network travel management

Figure 9. **SAMPLE TSMO STRATEGIES**

1.7 | WHAT'S IN THE TSMO MASTER PLAN?

The TSMO Master Plan presents a vision of a Statewide Multi-Scalar System of Systems (see Figure 10). Each system is composed of one or more recommended project, grouped into sub-systems. The term multi-scalar reflects the nature of TSMO projects that not all recommended improvements must be delivered at once. Smaller sub-systems may be deployed enabling certain TSMO strategies and still strive for a larger vision for the TSMO System. For example, traffic cameras and detectors may be deployed initially to increase situational awareness on freeways and arterials improving overall incident response times. Subsequent sub-systems leverage the initial deployment to provide traveler information signs to communicate traffic conditions to drivers or to expand online services to provide information before they initiate their travels. Later deployments may include ramp meters or queue warnings that utilize the cameras, detectors, and message signs deployed in previous sub-systems.

The plan presents seventeen TSMO Systems that make up Maryland's most significant corridors and presents analyses and recommendations for TSMO treatments within each sub-system (see Figure 12). The plan also includes fact sheets in Appendix A summarizing the traffic operations, identified TSMO strategies, costs, user benefits, and current efforts for every TSMO System. Sub-systems are categorized in three tiers (see Figure 10) that reflect priorities and ease of deployment as described next:

- Tier 1 sub-systems are higher priority with lower construction costs and impacts that are likely to advance be deployed within one to three years.
- Tier 2 sub-systems leverage infrastructure and technologies deployed from Tier 1 projects and involve more complex construction and technologies and are planned to be advanced within three to five years.
- Tier 3 sub-systems require civil improvements (i.e. roadway widening/ reconstruction, improvement to structures such as bridges, stormwater management, and other ancillary components) and additional Federal and State approvals and will require over five years to plan, design, and deploy.

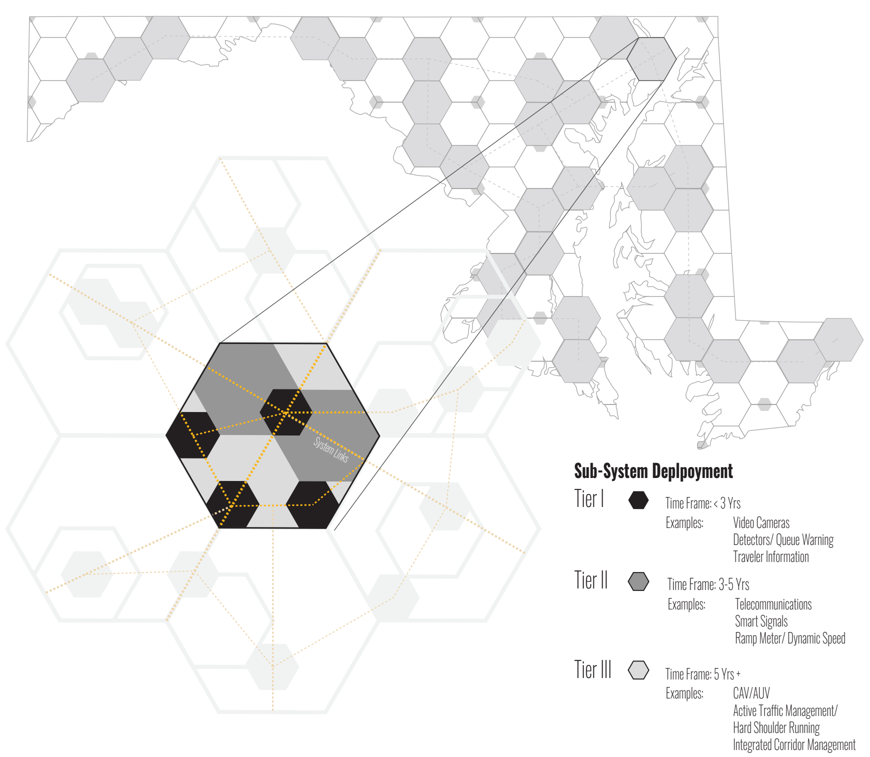


Figure 10. TSMO MULTI-SCALAR SYSTEM OF SYSTEMS

1.8 | WHAT HAPPENS NEXT?

After the Master Plan: Linking Planning and Design

After the planning process is complete, teams of subject matter experts are formed to scrutinize the Master Plan Systems' recommendations and develop a formal Concept of Operations (ConOps). These teams include a wide range of perspectives, including: ITS specialists, traffic engineers, planners, asset managers, emergency responders, local partner agencies, and academic researchers. These teams use the information collected during the screening process to explore project implementation, operational performance, and revisit the cost-benefit evaluations. Together, these reassessments provide the information needed to select, modify, or add TSMO strategies. The ConOps teams then create a menu of smaller projects by grouping proposed TSMO strategies based on their operational characteristics. This multi-scalar system approach provides flexibility in funding and delivering sub-system improvement (e.g. breakout projects) consistent with the Master Plan, as depicted in Figure 11.

Tracking

The next part of the Master Plan, the TSMO Strategic Deployment, tracks and prioritizes the recommendations from the Statewide System of Systems. The Master Plan will be regularly updated to reflect changes in technology, land use, and changes in the transportation network within the TSMO systems; to track the evolution of the its recommendations into transportation improvement projects; and to update the statewide vision as sub-systems are deployed. Since the initial TSMO Strategic Plan, MDOT SHA has advanced various activities that support the TSMO Master Plan. These are:

- I-270 ICM (System 12)
- I-695 TSMO Design Build
- I-270/ I-495 Managed Lanes Study
- I-95 Active Traffic Management Study (System 2)
- System 1 Concept of Operations
- Baltimore-Washington Concept of Operations (System 13)
- US 1 Smart Traffic Signal Corridor (Systems 2&13)

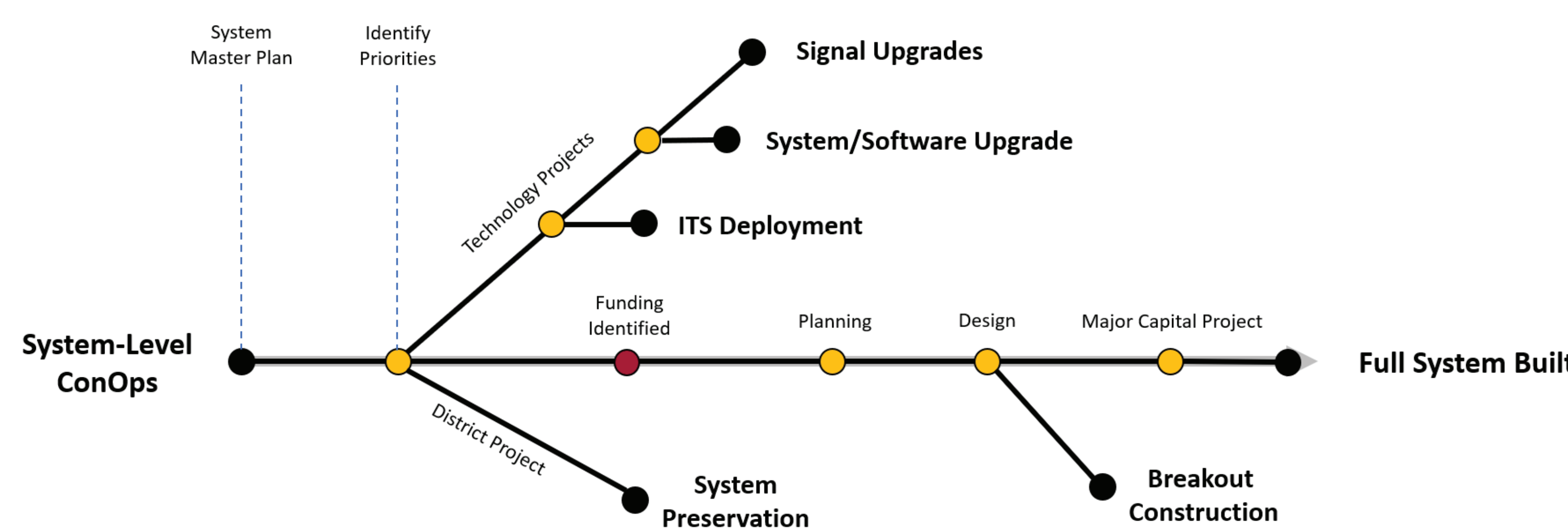
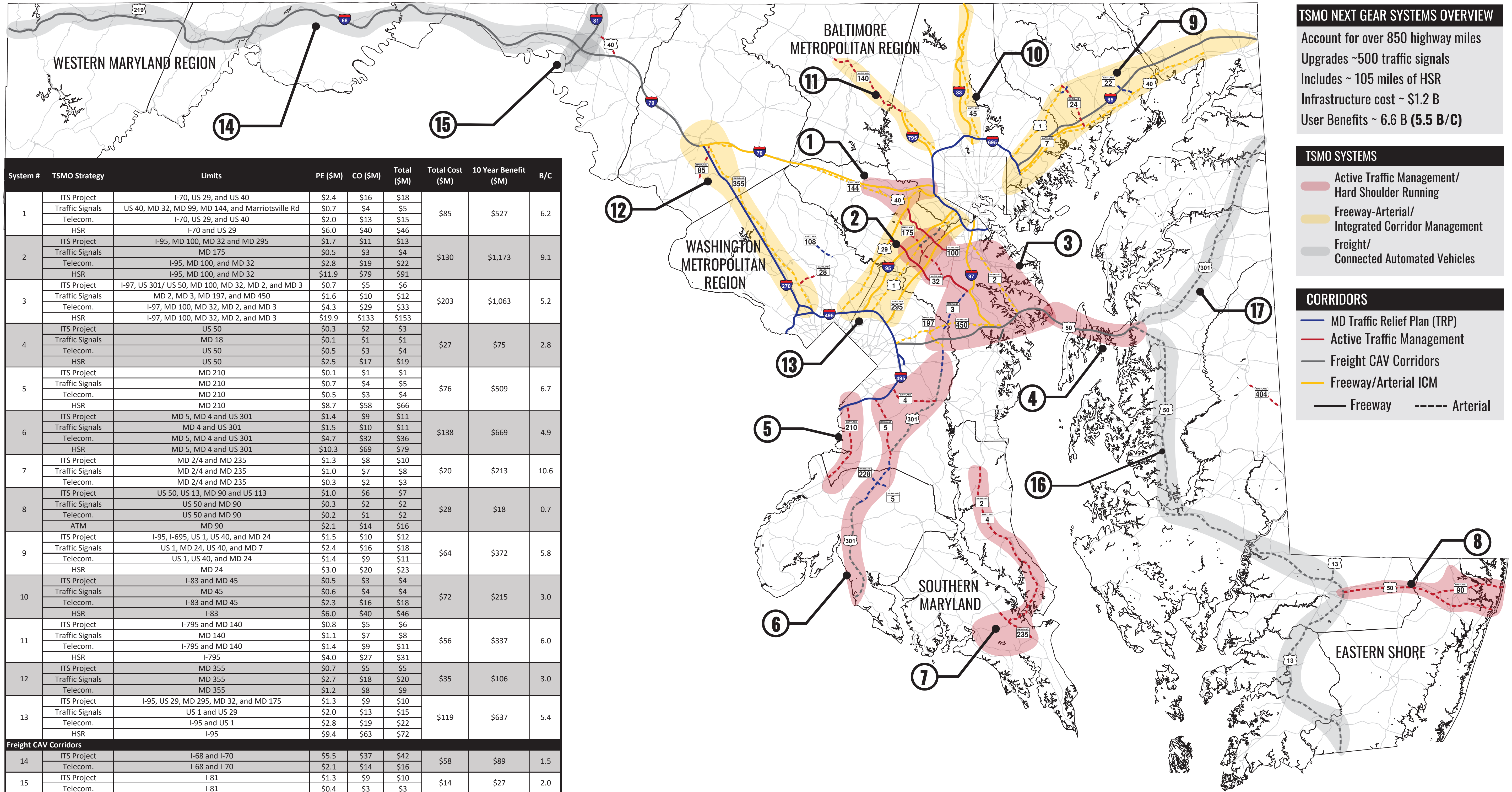


Figure 11. TSMO NEXT STEPS



TSMO NEXT GEAR SYSTEMS OVERVIEW

Account for over 850 highway miles
Upgrades ~500 traffic signals
Includes ~ 105 miles of HSR
Infrastructure cost ~ $1.2 B
User Benefits ~ 6.6 B **(5.5 B/C)**

System #	TSMO Strategy	Limits	PE ($M)	CO ($M)	Total ($M)	Total Cost ($M)	10 Year Benefit ($M)	B/C
1	ITS Project	I-70, US 29, and US 40	$2.4	$16	$18	$85	$527	6.2
	Traffic Signals	US 40, MD 32, MD 99, MD 144, and Marriotsville Rd	$0.7	$4	$5			
	Telecom.	I-70, US 29, and US 40	$2.0	$13	$15			
	HSR	I-70 and US 29	$6.0	$40	$46			
2	ITS Project	I-95, MD 100, MD 32 and MD 295	$1.7	$11	$13	$130	$1,173	9.1
	Traffic Signals	MD 175	$0.5	$3	$4			
	Telecom.	I-95, MD 100, and MD 32	$2.8	$19	$22			
	HSR	I-95, MD 100, and MD 32	$11.9	$79	$91			
3	ITS Project	I-97, US 301/ US 50, MD 100, MD 32, MD 2, and MD 3	$0.7	$5	$6	$203	$1,063	5.2
	Traffic Signals	MD 2, MD 3, MD 197, and MD 450	$1.6	$10	$12			
	Telecom.	I-97, MD 100, MD 32, MD 2, and MD 3	$4.3	$29	$33			
	HSR	I-97, MD 100, MD 32, MD 2, and MD 3	$19.9	$133	$153			
4	ITS Project	US 50	$0.3	$2	$3	$27	$75	2.8
	Traffic Signals	MD 18	$0.1	$1	$1			
	Telecom.	US 50	$0.5	$3	$4			
	HSR	US 50	$2.5	$17	$19			
5	ITS Project	MD 210	$0.1	$1	$1	$76	$509	6.7
	Traffic Signals	MD 210	$0.7	$4	$5			
	Telecom.	MD 210	$0.5	$3	$4			
	HSR	MD 210	$8.7	$58	$66			
6	ITS Project	MD 5, MD 4 and US 301	$1.4	$9	$11	$138	$669	4.9
	Traffic Signals	MD 4 and US 301	$1.5	$10	$11			
	Telecom.	MD 5, MD 4 and US 301	$4.7	$32	$36			
	HSR	MD 5, MD 4 and US 301	$10.3	$69	$79			
7	ITS Project	MD 2/4 and MD 235	$1.3	$8	$10	$20	$213	10.6
	Traffic Signals	MD 2/4 and MD 235	$1.0	$7	$8			
	Telecom.	MD 2/4 and MD 235	$0.3	$2	$3			
8	ITS Project	US 50, US 13, MD 90 and US 113	$1.0	$6	$7	$28	$18	0.7
	Traffic Signals	US 50 and MD 90	$0.3	$2	$2			
	Telecom.	US 50 and MD 90	$0.2	$1	$2			
	ATM	MD 90	$2.1	$14	$16			
9	ITS Project	I-95, I-695, US 1, US 40, and MD 24	$1.5	$10	$12	$64	$372	5.8
	Traffic Signals	US 1, MD 24, US 40, and MD 7	$2.4	$16	$18			
	Telecom.	US 1, US 40, and MD 24	$1.4	$9	$11			
	HSR	MD 24	$3.0	$20	$23			
10	ITS Project	I-83 and MD 45	$0.5	$3	$4	$72	$215	3.0
	Traffic Signals	MD 45	$0.6	$4	$4			
	Telecom.	I-83 and MD 45	$2.3	$16	$18			
	HSR	I-83	$6.0	$40	$46			
11	ITS Project	I-795 and MD 140	$0.8	$5	$6	$56	$337	6.0
	Traffic Signals	MD 140	$1.1	$7	$8			
	Telecom.	I-795 and MD 140	$1.4	$9	$11			
	HSR	I-795	$4.0	$27	$31			
12	ITS Project	MD 355	$0.7	$5	$5	$35	$106	3.0
	Traffic Signals	MD 355	$2.7	$18	$20			
	Telecom.	MD 355	$1.2	$8	$9			
13	ITS Project	I-95, US 29, MD 295, MD 32, and MD 175	$1.3	$9	$10	$119	$637	5.4
	Traffic Signals	US 1 and US 29	$2.0	$13	$15			
	Telecom.	I-95 and US 1	$2.8	$19	$22			
	HSR	I-95	$9.4	$63	$72			
Freight CAV Corridors								
14	ITS Project	I-68 and I-70	$5.5	$37	$42	$58	$89	1.5
	Telecom.	I-68 and I-70	$2.1	$14	$16			
15	ITS Project	I-81	$1.3	$9	$10	$14	$27	2.0
	Telecom.	I-81	$0.4	$3	$3			
16	ITS Project	US 50 and US 13	$2.8	$19	$21	$52	$618	11.9
	Traffic Signals	US 50 and US 13	$0.7	$5	$5			
	Telecom.	US 50 and US 13	$3.3	$22	$25			
17	ITS Project	US 301	$1.5	$10	$11	$40	$18	0.5
	Traffic Signals	US 301	$0.8	$6	$6			
	Telecom.	US 301	$2.9	$19	$22			

Figure 12. TSMO SYSTEMS SUMMARY

2.0 TSMO STRATEGIC DEPLOYMENT

2.1 | WHAT IS A STRATEGIC DEPLOYMENT PLAN?

The growth of MDOT's TSMO program will require CHART to take new roles and capabilities beyond the conventional incident management and highway operations (see Figure 13) . These new responsibilities will require CHART to employ collection of ITS solutions. The Strategic Deployment Plan identifies the long-range costs to sustain current CHART operations, and to expand its capabilities to support MDOT's TSMO Strategic and Master Plans.

The Strategic Deployment Plan achieves these goals by identifying: the operational needs and goals for CHART, planning opportunities for MDOT, and key performance measures. As a companion and extension of the TSMO Master Plan, the Strategic Deployment Plan also acts as a catalyst for stakeholder communication and collaboration. These activities will, in turn, help articulate a consistent statewide vision and deployment priorities. For example, the Strategic Deployment Plan can be used to identify projects which should be added to future MDOT's CTP and CHART's programming process.

In addition to describing how CHART can adapt to support the TSMO Master Plan, the Strategic Deployment Plan also presents actions associated with MDOT's broader TSMO program. These include personnel training and equipment, upgrades and replacement of existing assets including buildings, software and system costs, telecommunication connections, and other ITS deployments outside the geographic boundaries of the TSMO Systems identified in the Master Plan. The Strategic Deployment Plan also accounts for the operations and maintenance costs as well as recurring costs associated with ITS deployment based on a life-cycle planning cost.

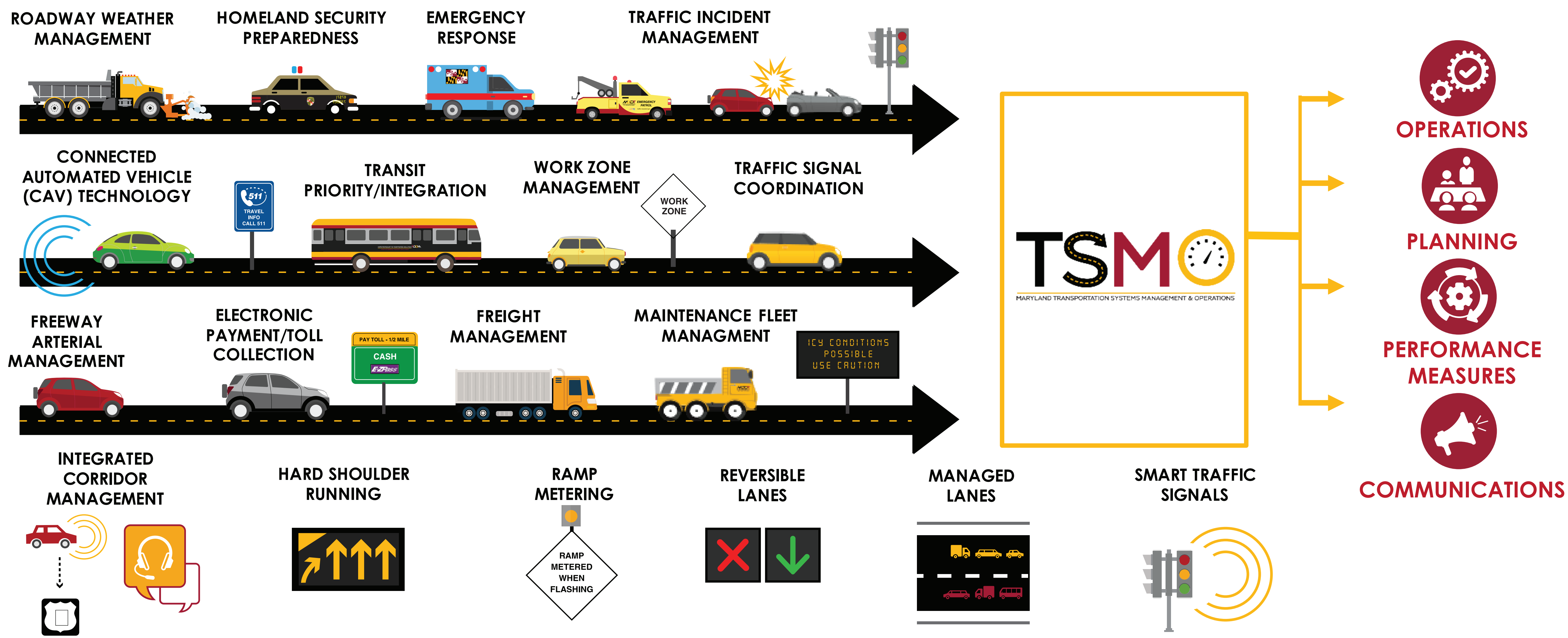


Figure 13. CHART's EXPANDED ROLE AND CAPABILITIES

The Strategic Deployment Plan provides a means for:

- Identifying new projects to be added to future MDOT CTPs and initiate CHART's project planning and programming process;
- Portraying the possibilities of future program operations to all stakeholders and decision-makers;
- Providing a consolidated CHART vision for future deployments and operations consistent with the TSMO Master Plan.

ITS projects and ancillary support projects and initiatives are presented as a "menu" of options for periodic deployment with associated operations and maintenance costs that span a planning time line of twenty years. The intended effect of these projects is to improve safety, mobility, reliability, increase traveler situation awareness, and develop the future capabilities identified in the TSMO Master Plan. The projects are categorized into six major planning areas (see Figure 14):

1. Traffic and Roadway Monitoring
2. Traffic Incident Management
3. Multi-Modal Traveler Information
4. Active Traffic Management
5. Systems Integration and Communication
6. Emergency Operations

These planning areas, also referred to as CHART's Core Elements, were modified to include the expanded TSMO roles and capabilities. The integration of TSMO expands Core Element 3 to include "Multi-Modal" traveler information to encompass connection and coordination with other transportation modes; Core Element 4 to include "Active" traffic management to account for active traffic management capabilities; and Core Element 5 to include "Systems Integration" to highlight the importance of the decision support software and system integration required to deliver the TSMO Master Plan. The Core Elements are further described below:

Traffic and Roadway Monitoring

Actions within this element are designed to improve highway safety and efficiency by augmenting CHART's ability to rapidly respond to hazardous highway conditions through enhanced traffic and roadway monitoring, including the use of new technology and additional device deployment. The amount of probe data available for traffic monitoring continues to increase, expanding the opportunities to utilize crowd source data and big data applications.

Traffic Incident Management

Actions within this element are designed to quickly and efficiently restore normal traffic flow after an incident by enhancing CHART's incident management program through training of personnel, technology solutions, and teamwork both internally and with other agencies.

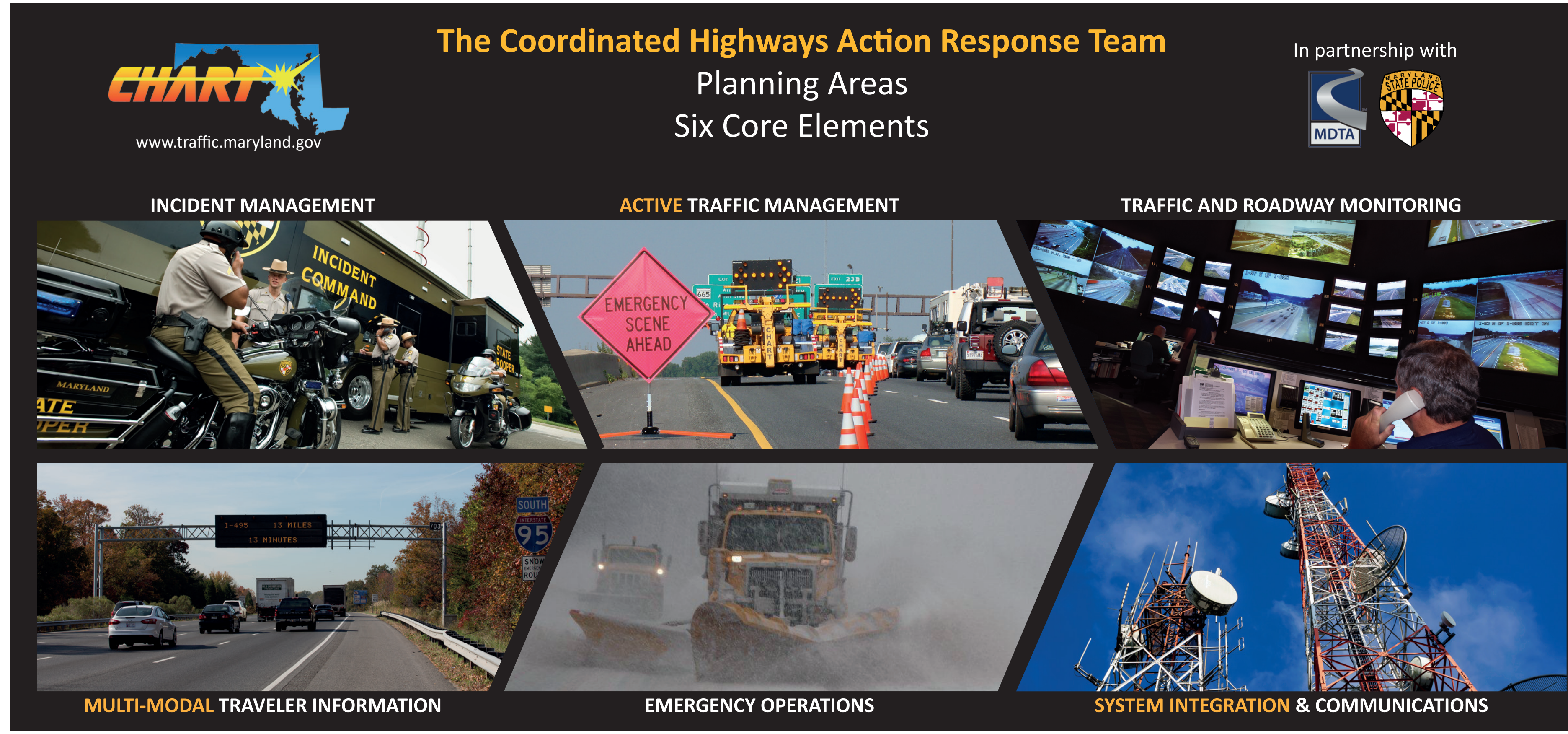


Figure 14. CHART's PLANNING AREAS (CORE ELEMENTS)

Multi-Modal Traveler Information

Actions within this element are designed to provide timely and reliable mobility information to the traveling public both prior to travel and en route using roadside devices, electronic media, and public-private partnerships with information providers.

Active Traffic Management

Actions within this element are designed to reduce congestion on highways by employing traffic management strategies to control vehicular movements, increase highway efficiency, and encourage travelers to choose alternative modes of travel. Integrated Corridor Management leverages real-time data and analysis and decision support systems to optimize vehicular operations.

Systems Integration and Communications

Actions within this element are designed to expand the CHART Advanced Transportation Management System (ATMS; the operating system) and network to support inter-agency and inter-modal coordination, connectivity and sharing of transportation management information. The volume of big data continues to increase requiring the overall system to be nimble to big data fusion from multiple sources, interoperability and compatibility of data and capabilities, edge computing coordination with centralized decision support systems, and planning for future CAV data needs.

Emergency Operations

Actions within this element are designed to establish a secure, resilient, and safe transportation system by deploying emergency response equipment and establishing coordinated preparedness and response plans for large-scale natural and man-made disasters, including adverse weather responsive management operations, terrorist activities and evacuations.

2.2 | HOW IS THE STRATEGIC DEPLOYMENT PLAN DEVELOPED?

The development of the Strategic Deployment Plan began with a review of the recommendation of TSMO Master Plan applicable to CHART's responsibilities. The selected recommendations were then used to initiate three planning exercises:

- Begin the ITS Project Development Process;
- Develop the Scope of Work; and to
- Initiate ITS Project Programming Process to advance projects.

ITS Project Development Process

This is a cyclical process and follows a high-level SE process (see Figure 15). This process is overseen and directed by the CHART Board of Directors and the TSMO Executive Committee, and begins with identifying ITS Project Needs, which is directly informed by the findings and recommendations from the TSMO Master Plan. The process continues with the following steps:

- Planning/Stakeholder Input: Gathers stakeholder inputs to explore project concepts and feasibility through feasibility studies and ConOps documents;
- Design: Uses the ConOps to develop requirements and detailed design;
- Construction: Implements all pieces of the project such as installation of field devices and development of software and hardware;
- Acceptance Testing: Tests and validates individual components of the system for functionality according to requirements;
- Network Integration: Integrates the system into the CHART network for operations to begin;
- Operations and Maintenance: Operates the system as part of daily operations and subsequently performs routine and emergency maintenance throughout the life of the system.

Scope of Work

The Scope of Work is defined founded on the information collected from the ITS Project Need and the Planning/ Stakeholder Input step. There are three primary considerations in developing scopes of projects in this plan: deployment priority, deployment constraint, and state of technology. (See Figure 16)

Deployment priorities: Statewide systems, sub-systems, and corridor priorities are identified in the TSMO Master Plan, which identifies preliminary needs, strategies, costs, risks, and user benefits. The Strategic Deployment Plan categorizes the ITS and supporting infrastructure from the TSMO Master Plan and provides a deployment sequence to achieve desired operational capabilities.

Figure 15. ITS PROJECT DEVELOPMENT PROCESS

Deployment Constraints: Construction costs, project risks, and regulatory requirements are identified in the TSMO Master Plan. The Strategic Plan elaborates further details on the preliminary findings, evaluating whether adequate funding is available, implementation schedules for phasing, capacity of current network and software.

Technologies: Due to the nature of this plan, several ITS technologies that facilitate transportation solutions were considered. These technologies include those that are seemingly feasible due to the existing and planned capability of the CHART system or the current operating priorities within the program. Therefore, the Plan provides a depiction of the fully feasible operating potential of CHART because it details existing ITS technologies that can be utilized by CHART considering institutional and resource constraints. The Plan also provides an outlook on technological advancement possibilities in the future.

ITS Project Programming Process

Once projects are prioritized and the scope of work has been developed, the ITS projects must obtain funding to advance into design and subsequent phases of the ITS Project Development Process. This process is depicted in Figure 17 and described below:

A) TSMO Master Plan: ITS deployment projects must be included in the Statewide TSMO Master Plan to ensure a consistent vision for future deployment and operations. The Master Plan provides information regarding the needs, such as traffic, incidents, crashes, asset conditions, environmental constraints, and summaries of past studies and planning initiatives.

B) Other Inputs: stakeholder input is integral to the development of the TSMO Master Plan, but there are times that priorities arise outside of the time frame when the TSMO Master Plan is developed and updated. Projects outside of the TSMO Master Plan must move to step C for project exploration and identification.

C) Project Exploration and Identification: gathering information from the previously defined planning documents and initiatives to determine the project needs, such as traffic, incidents, crashes, asset condition overview, and environmental resources. Projects in the TSMO Master Plan already have this information, therefore this step is only required for unexpected projects that arise from step B. Information developed for unexpected projects are included in the

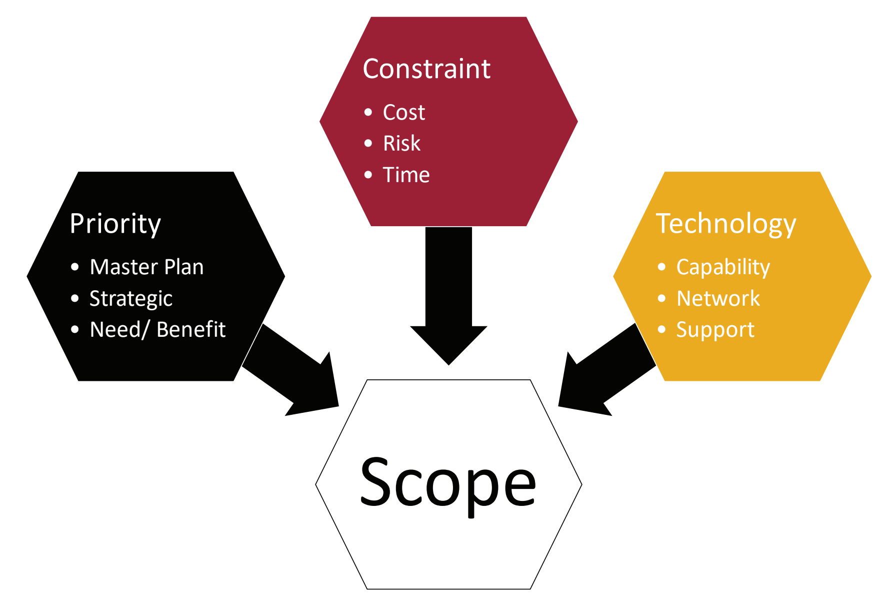


Figure 16. SCOPE CONSIDERATIONS FOR ITS PROJECTS

TSMO Master Plan to ensure consistency with other Statewide initiatives and recommendations.

D High-Level Project Summary: develop to include the project in the MDOT Consolidated Transportation Program (CTP) to begin the programming process. For most projects, the information required is identified in the TSMO Master Plan and include:

- a Project Title
- b Preliminary cost estimate
- c Rough scope definition
- d Projected implementation schedule
- e High-level benefits and needs addressed

E Projects for MDOT CTP: develop detailed listings and descriptions of capital projects that are proposed for construction, development and evaluation during the next six years. CHART updates its projects and budgets every year for submittal to the MDOT CTP.

F Detailed Project Descriptions and ITS Architectures / Systems Engineering (SE) Analysis: required to be carried out prior to a project going through the Preliminary Engineering Phase (if applicable), and eventually entered into the Federal and MDOT Project Setup Phase. Detailed project description expands on the high-level summary and typically includes:

- a Brief project description and/or background
- b Refined cost estimate
- c Detailed scope (e.g., system functionality, location, number of devices, etc.)
- d Project tasks and/or milestones
- e Project schedule
- f Refined high-level benefits and needs addressed
- g Project funding source

The project-level ITS architecture and SE compliance documentation is carried out to fulfill the FHWA rule on ITS Architecture and Standards, which implements section 5206(e) of the Transportation Equity Act for the 21st Century (TEA-21). This final rule/policy requires that ITS projects funded by the Highway Trust Fund conform to the National ITS Architecture. Part of this process includes a project-level architecture, as well as a SE analysis.

G Preliminary Engineering (if needed): define all details about the deployment prior to beginning the final project design. Not all CHART projects require preliminary engineering services such as projects that are solely equipment procurement.

H Federal & MDOT Project Setup: project is documented in the Federal and/or MDOT project tracking systems, which records budget, payments, scheduling, etc. The USDOT/FHWA project setup utilizes project information from (1) Project-level ITS architecture and (2) Systems Engineering analysis documents. The MDOT project setup utilizes project information from (1) Detailed project descriptions and (2) Preliminary engineering services.

I Design Request: follows the Federal and MDOT Project Setup and is the last phase within the CHART Project Planning and Programming Process. Once the project is setup in the USDOT/FHWA and/or MDOT project system, it can then move forward with design and deployment.

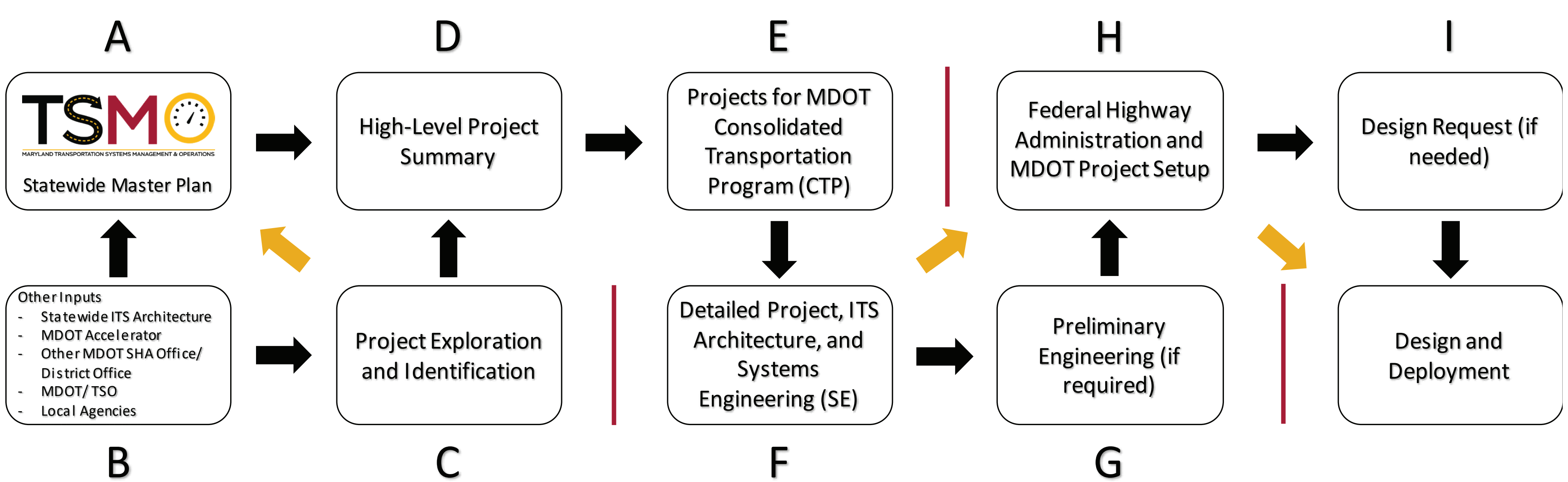


Figure 17. ITS PROJECT PROGRAMMING PROCESS

2.3 | WHAT IS INCLUDED IN THE COSTS?

Projects are presented as profiles (see Appendix B) that provide a practicable understanding of what CHART needs to build, develop, integrate, and initiate to achieve the plan's objectives. The projects and capital costs focus on the following categories:

- Field and Infrastructure Deployment – includes activities such as device site selection, site preparation, construction of supporting infrastructure, device purchase, installation, etc.
- Integration and Communications – includes activities such as provisioning the required communications to each device site, procuring the necessary networking/system components, configuring and installing the networking/system equipment, test/ validate, etc.
- Software Development - includes the modification and module development for the central CHART system software, development of device drivers and communications protocol modules for new technology device that must be integrated into the central CHART system software.

The notion behind this is to facilitate identification of projects by the appropriate parties to obtain input for planning and programming to advance the project.

Cost Estimates

Cost estimates were developed for the ITS projects outside the TSMO Master Plan's Systems, initiatives required to support CHART's growing responsibilities, and ancillary efforts. Construction costs were developed using MDOT SHA's Construction Cost Manual and other historically available data. These are intended to provide a "ballpark" funding estimate required for CHART to build on its existing operations. All estimated costs are in current dollars and are for planning purposes only.

Software Development Considerations

CHART is MDOT SHA's statewide customized ATMS supporting freeway incident and mobility management functions. As statewide operations evolve to support various TSMO strategies across all roadway networks the need to expand the CHART system capabilities will need to be evaluated. CHART was developed as a custom software platform since at the time of its inception, no suitable solution existed that met MDOT SHA's operational needs. As additional functional capabilities are planned, a Systems Architecture/ SE analysis will help determine the most effective roadmap moving forward. There are essentially three different methods for expanding the functionality of the CHART system capability: custom developed, commercial off-the-shelf (COTS), and semi-custom developed. These approaches may be mixed and matched by project specific opportunity or capability feature enhancement. The trade-offs between the different methods include deployment time, overall cost, traffic needs, reliability/ accuracy, compatibility of future deployments, and ownership risk. General considerations are reflected in Figure 19.

Operations and Maintenance

A successful ITS program requires a strong commitment to efficiently operating and maintaining field devices, system components, communications network, and software. For the purposes of this Plan, operations and maintenance (O&M) costs have been determined as an estimated percentage of capital costs. O&M cost estimates for Field and Infrastructure Deployments, Integration and Communications, and Software Development are 15%, 15%, and 4.6% of capital costs respectively.

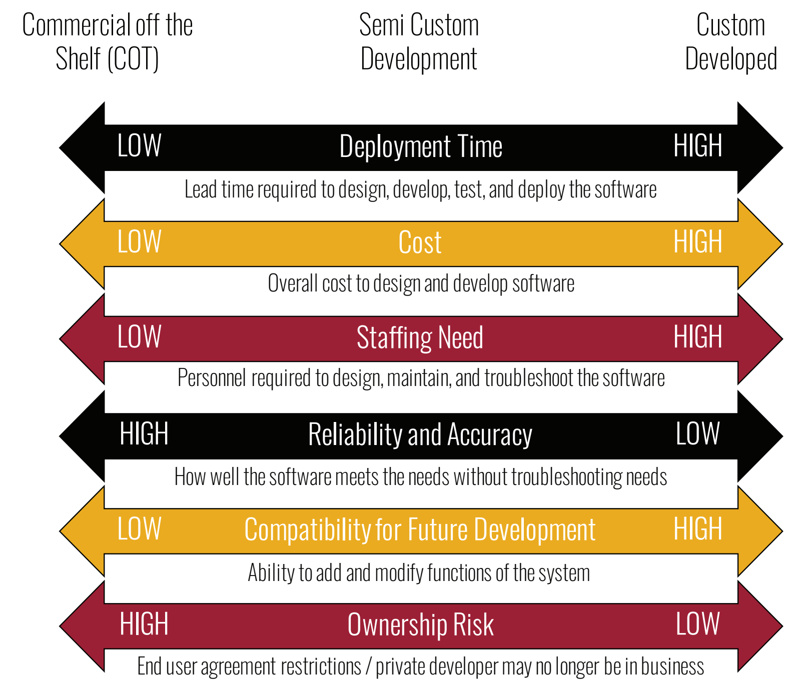


Figure 19. SOFTWARE DEVELOPMENT CONSIDERATIONS

The O&M for Field and Infrastructure, and Integration and Communication projects account for the following associated costs:

Management staff hours – full-time labor to manage day-to-day program activities/initiatives, contracts, in-house planning and technical studies, operational/maintenance staff, public outreach, training, coordination with other agencies, and general program decision-making.

Operational staff hours – full/part-time and on-call labor to control, configure, provide security, administer, and troubleshoot systems/software/communications electronics and hardware; undergo training; provide patrolling and incident management services along highways; perform other administrative program/office functions.

Maintenance staff hours – full/part-time and on-call MDOT SHA labor or contracted labor to troubleshoot, repair, run diagnostics on, and generally perform upkeep on CHART field devices and system components.

Operational expenses – costs related to day-to-day running of facilities and systems, including building use costs, monthly phone and power, and leased communication lines.

Maintenance expenses/equipment – costs to supply spare parts, vehicles, equipment, and tools needed to repair CHART field devices and systems components

O&M costs for Software Development projects are defined as a percentage of the original development to provide intermittent "fixes" to initial software. This estimate does not include true software "enhancements", which would require significant programming to add software functionality, and are thus considered a separate standalone project.

Based on information collected throughout the ITS arena, a system O&M cost of 15% of CHART's capital expenditures is considered appropriate. While

Figure 18. SAMPLE COSTS INCLUDED IN THE PLAN

this figure could be on the high side, it enables decision-makers to know with greater certainty that the O&M estimates are not under-represented, as is often the case. A 4.6% software cost estimate is based on documented software support estimates for initial implementation adjustments (*FHWA ITS Joint Program Office – The Road to Successful ITS Software Acquisition, Volume II)*.

The plan assumes deployment of the devices in phases based on past experience and current deployment capabilities. O&M costs are accounted for a 20 year life cycle timespan and are averaged throughout the phases a project. These deployment costs and phases are intended to assist capital programing purposes and require traffic and system engineering studies to advance in project development.

2.4 | WHAT IS IN THE 2020 PLAN?

The 2020 Strategic Deployment Plan includes over 200 projects or initiatives, with a total estimated cost for planning/ preliminary engineering and construction of approximately $1.2 billion. The Strategic Deployment Plan includes improvements proposed by the TSMO Master Plan organized by TSMO System, and broken down by sub-systems organized by corridors or proposed TSMO strategy. As mentioned before, the plan also includes costs for supporting projects and initiatives for CHART's operations. The costs included in the plan are associated with CHART's Core Elements, as shown in Figure 20.

Structure of the Strategic Deployment Plan

The projects are organized into four major groups:

- TSMO Master Plan Systems and Sub-Systems
- Areawide ITS Deployment (outside TSMO Master Plan System boundaries)
- Personnel, Equipment, and Infrastructure
- Software Development and Systems Integration

TSMO Master Plan Systems and Sub-Systems

This groups contains the projects which constitute the seventeen systems recommended in the TSMO Master Plan (see Appendix A). Sus-systems are organized based on four types of strategy being recommended:

1. ITS Deployment: primarily in the form of video cameras, traffic detectors, roadside units for CAV, virtual weigh stations, weather stations, dynamic message signs for traveler information, etc. These strategies focus on enhancing highway monitoring and traffic data collection, improving traveler information (including en route and for multi-modal connections), and improving incident response time by expanding situational awareness at traffic operations centers.

2. Traffic Signals: upgrade and integrate existing traffic signals to enable freeway/ arterial congestion management and active traffic management along the arterials. Upgrades also include video cameras for safety and incident detection, roadside units to CAV, and transit signal priorities for select arterials with existing or planned transit operations.

3. Telecommunications: identifies fiber optics, cellular, and radio communication needs to support the TSMO Master Plan. Recommendations in this plan leverage the findings from the Statewide Telecommunications Plan, currently under development.

4. Active Traffic Management: include combination of ITS and roadway civil improvements to enable active traffic strategies such as hard shoulder running or ramp metering. The deployment time frame for these projects are longer term than the previous categories because they require more Federal and State approvals as they involve roadway construction/ reconstruction.

Areawide ITS Deployment

This group contains projects which deploy ITS assets beyond the geographic boundaries of the seventeen TSMO Systems (see Appendix B). Projects in this category are just as important as the TSMO systems, but are simply not geographically connected. Examples in this category include replacement of existing devices, safety warnings at rural crossings, ITS warnings for railroad crossings, weather stations at specific bridges, or deployment of mobile devices for incident response, inclement weather, or for construction sites.

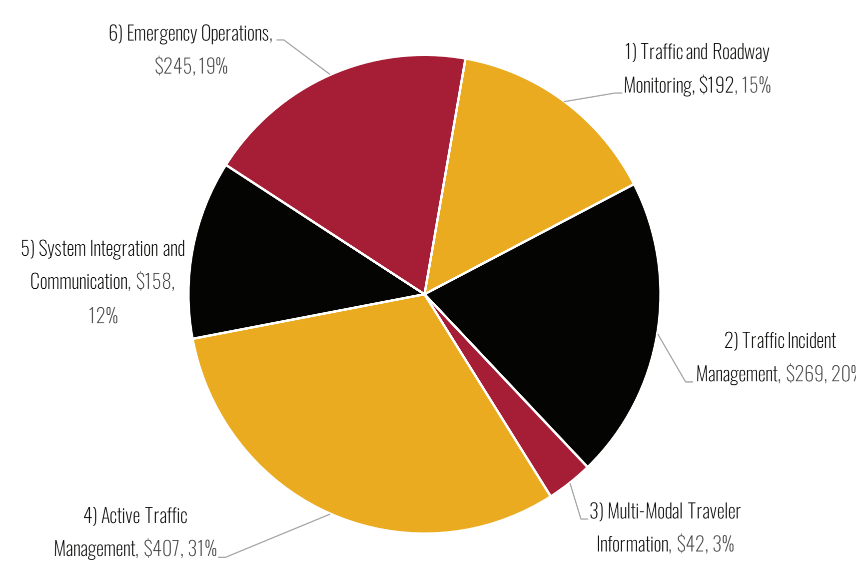


Figure 20. **CHART's PLANNING AREAS (CORE ELEMENTS)**

Personnel, Equipment, and Infrastructure

Projects in this group focus on the personnel, equipment, and infrastructure required by CHART to maintain current operations support the TSMO Master Plan recommendations (see Appendix B). These include training and hiring of new personnel; maintaining, upgrading, and expanding the fleet of emergency response vehicles; providing field equipment for incident response and emergency operations; and upgrading existing SOC and TOCs.

Software Development and Systems Integration

The existing ATMS employed by CHART requires new software and system integration (see Appendix B) to enable freeway/ arterial coordination, integrated corridor management and active traffic management strategies recommended in the TSMO Master Plan.

2.5 | WHAT IS IN THE APPENDIX?

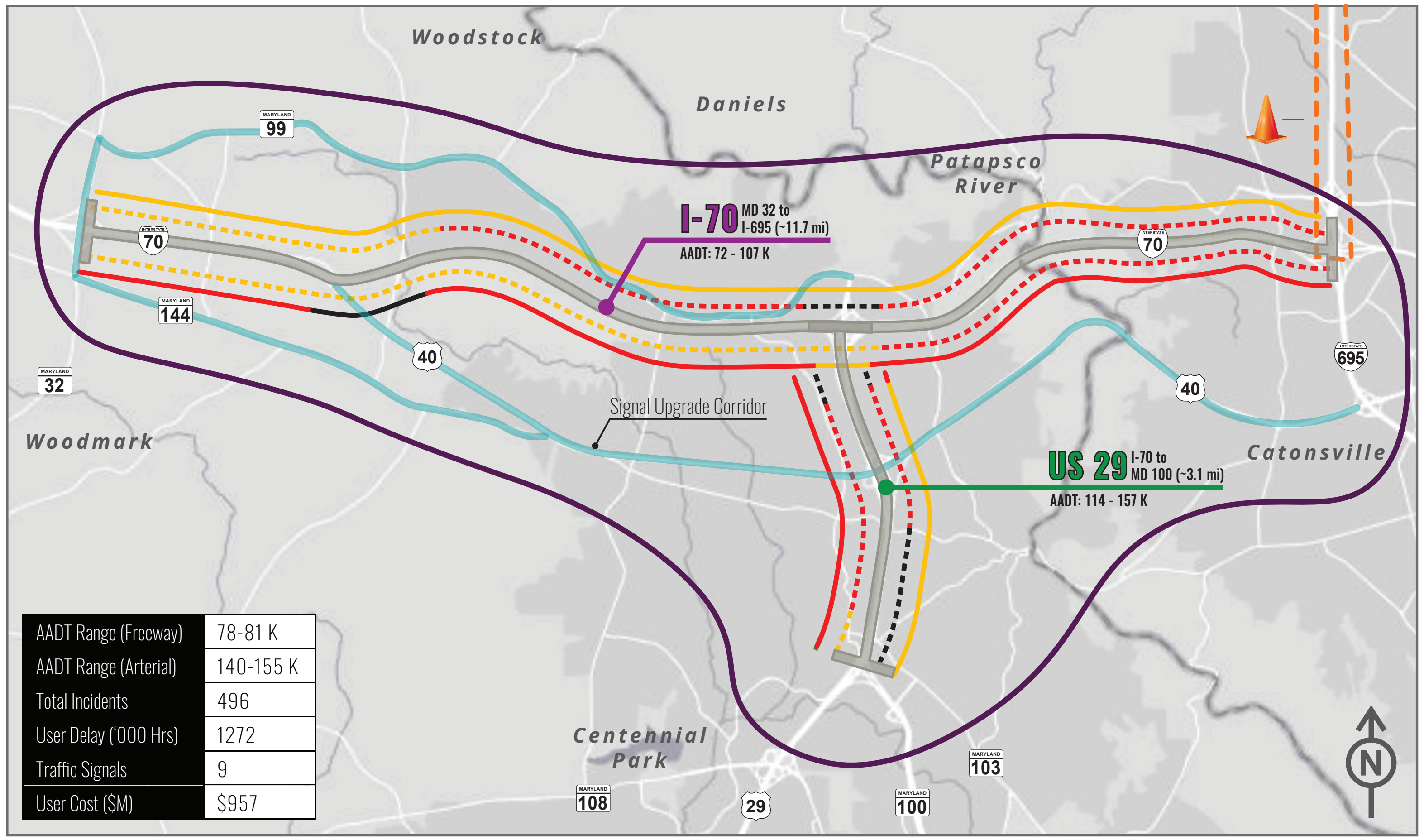
Appendix A presents the fact sheets for the TSMO Master Plan Systems. This includes three fact sheets per system summarizing: overall system needs in terms of congestion and safety; recommended shorter-term ITS related projects; and recommended longer-term improvements requiring roadway civil work.

Appendix B presents areawide ITS projects, personnel/ equipment/ infrastructure projects and initiatives, and software and system integration projects.

Both appendices present planning-level cost estimates for planning and programming purposes. Projects costs and scope will be refined as funding becomes available and TSMO Projects advance in project development.

APPENDIX A - TSMO SYSTEM FACT SHEETS

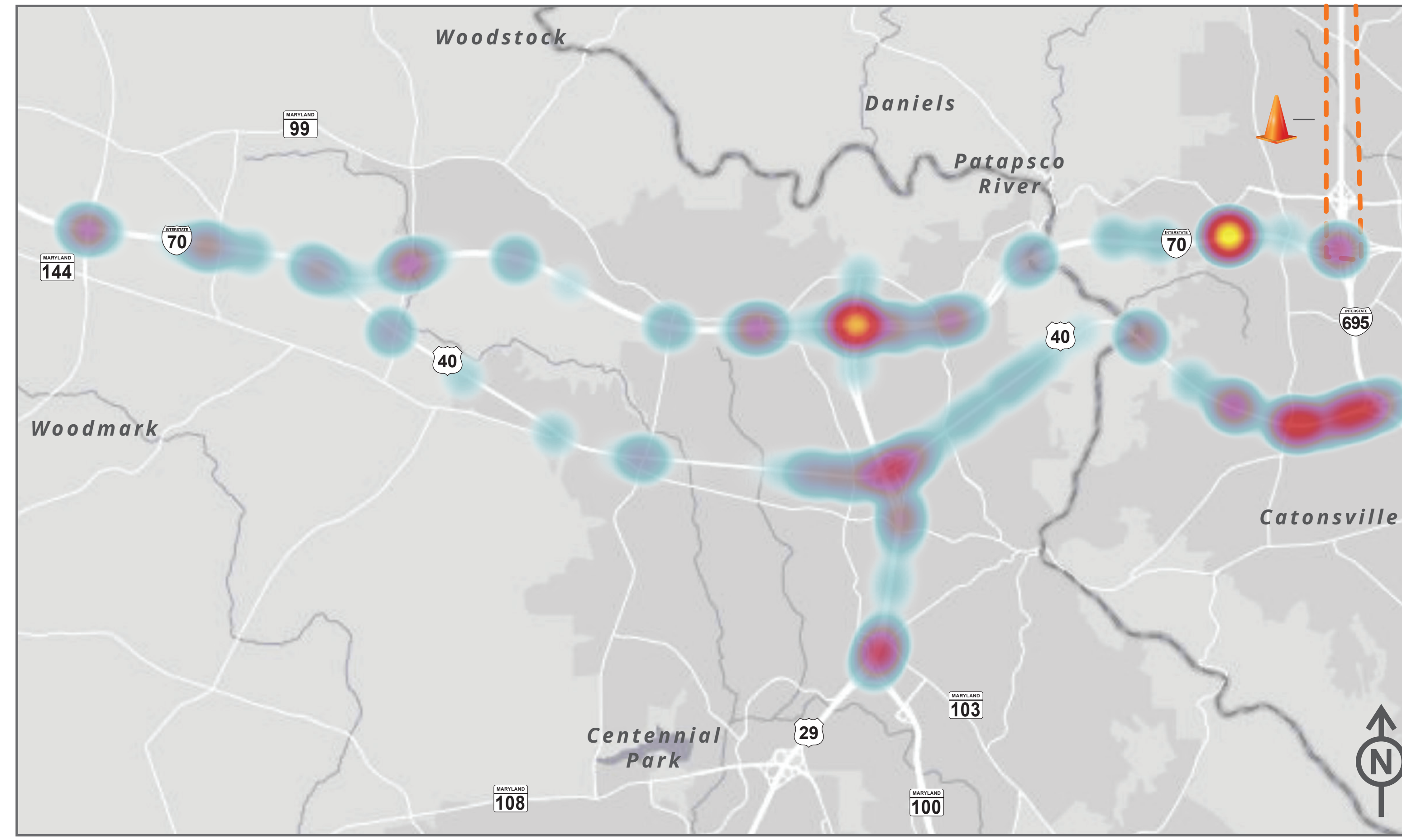
TSMO SYSTEM # 1



AADT Range (Freeway)	78-81 K
AADT Range (Arterial)	140-155 K
Total Incidents	496
User Delay ('000 Hrs)	1272
Traffic Signals	9
User Cost ($M)	$957

UNCONGESTED (TTI < 1.15) MODERATE CONGESTION (1.15 < TTI < 1.3) HEAVY CONGESTION (1.3 < TTI < 2.0) SEVERE CONGESTION (TTI > 2.0)
AM TTI PM TTI

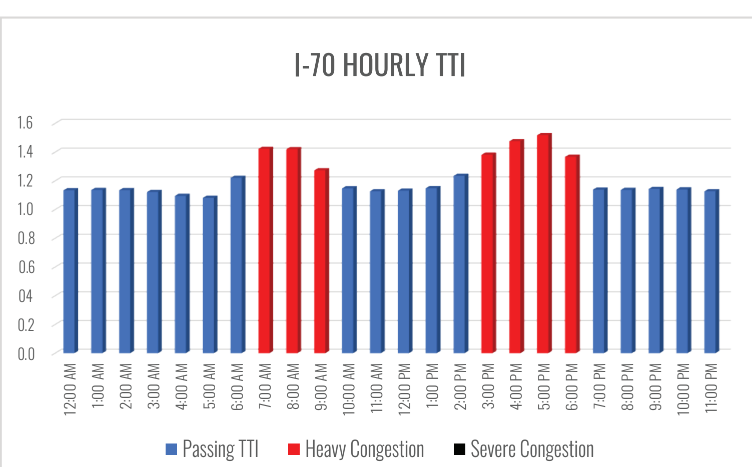
CRASH DENSITY

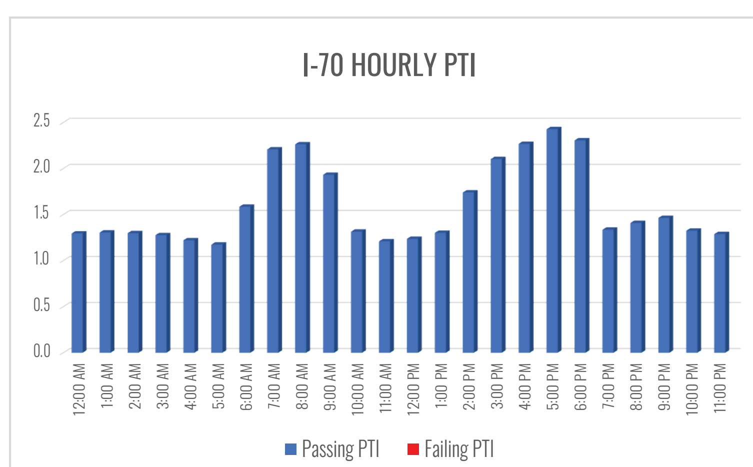


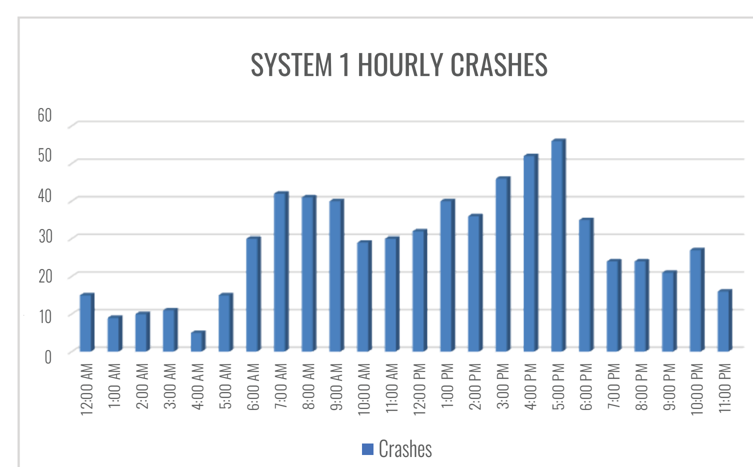
Crash Density: Sparse Dense

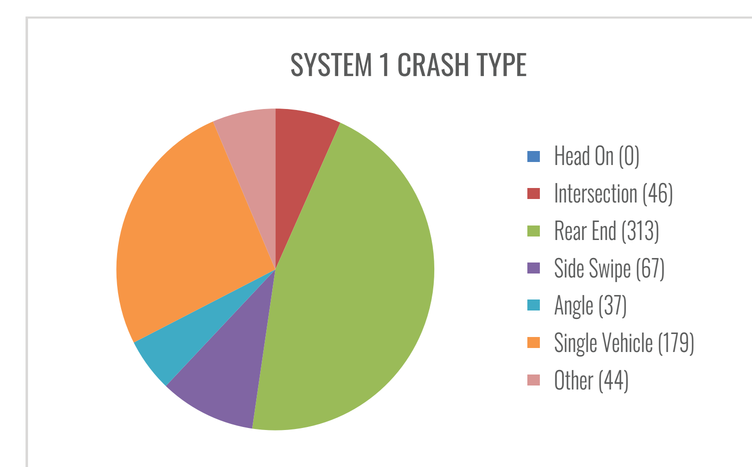
BACKGROUND: TSMO System # 1 improves operations for major traffic movements along I-70 and US 29 heading to/from Baltimore, Columbia, and Fort Meade. The system has major bottlenecks around I-70/US 29 and I-70/Marriottsville Road during both peak periods. I-70 is designated as a Maryland Freight Route and is part of the National Freight Network. US 40 and US 29 have been identified as potential transit corridors.

SAFETY OVERVIEW: The highest concentrations of crashes are along I-70 around the US 29 interchange and approaching the I-695 interchange. Crash data shows that the highest number of crashes occur during the AM or PM peak and the most common crash type is rear ends. In 2018, there were 686 crashes reported within TSMO System # 1, with three fatalities and 230 injuries.

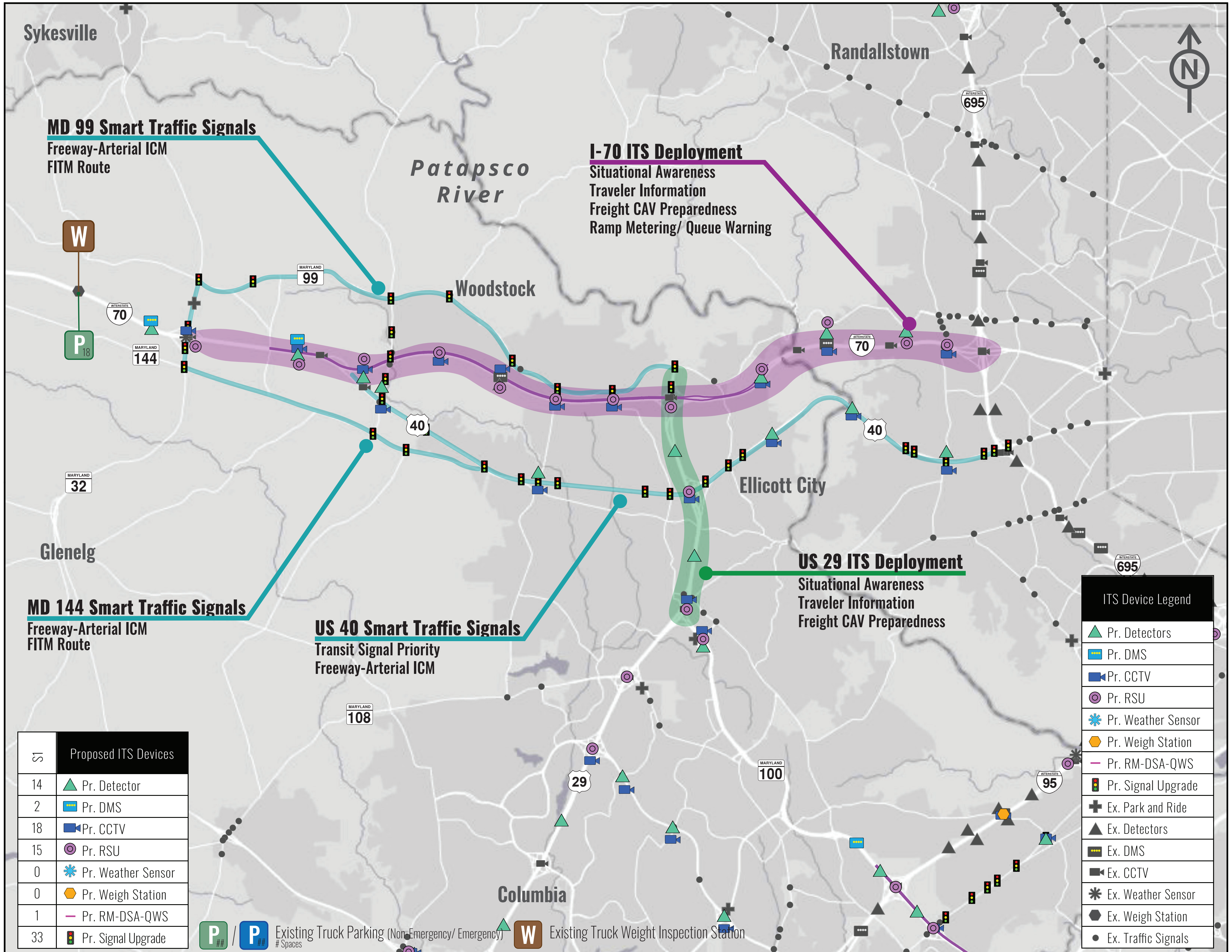








TSMO SYSTEM # 1: ITS OVERVIEW



COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$2	<$1	$2	$6
Construction	$16	$4	$13	$40
Total	$18	$5	$15	$46
Annual recurring costs: $311.6 K		Annual O & M costs: $4.7 M		

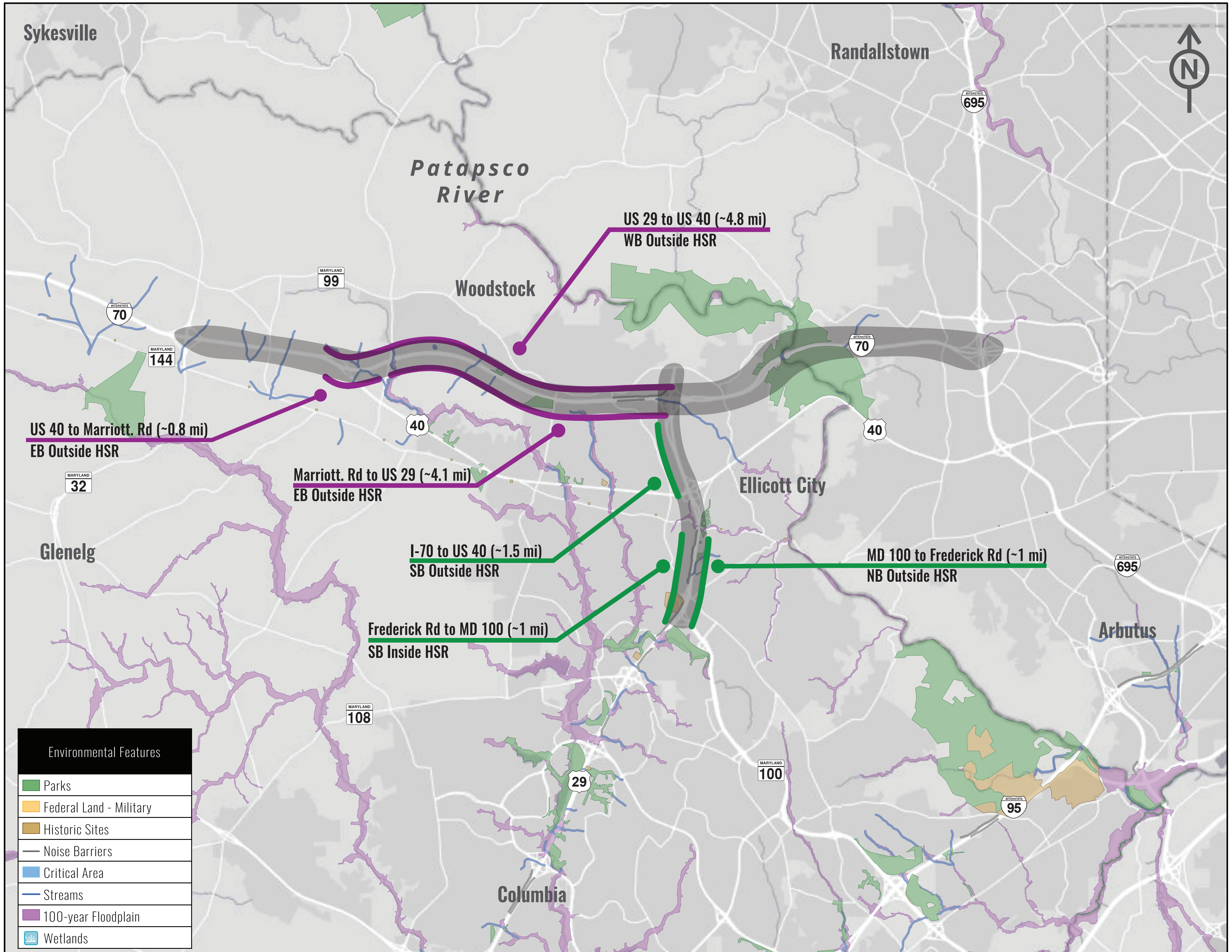
SUB-SYSTEM DEPLOYMENT:

System 1.1.1 (B/C: 12) Tier 1	I-70 ITS Deployment Deployment of CCTV, DMS, traffic detectors, and RSU along I-70 between MD 32 and I-695.	PE: $0.6 M CO: $4.0 M Recurring Cost: $51.6 K Annual O&M: $0.6 M
System 1.1.2 (B/C: 49) Tier 2	US 29 ITS Deployment Deployment of CCTV, traffic detectors, and RSU along US 29 between I-70 and MD 100.	PE: $0.1 M CO: $0.9 M Recurring Cost: $14.8 K Annual O&M: $0.1 M
System 1.1.3 (B/C: 96) Tier 2	US 40 ITS Deployment Deployment of CCTV and traffic detectors along US 40 between I-70 and I-695.	PE: $0.1 M CO: $0.8 M Recurring Cost: $18.6 K Annual O&M: $0.1 M
System 1.1.4 (B/C: 5) Tier 1	I-70 Ramp Meter/ Queue Warning System Deploy detectors, cameras, and DMS along I-70 between MD 32 and US 29 to implement queue warming/ dynamic speed advisory systems and ramp metering.	PE: $1.5 M CO: $10.3 M Recurring Cost: $106.2 K Annual O&M: $1.5 M
System 1.2.1 (B/C: 7) Tier 1	US 40 Traffic Signal Upgrade Upgrade existing traffic signals along US 40 between I-70 and I-695 to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled and have TSP.	PE: $0.4 M CO: $2.7 M Recurring Cost: $12.2 K Annual O&M: $0.4 M
System 1.2.2 (B/C: 4) Tier 1	MD 32 Traffic Signal Upgrade Upgrade existing traffic signals along MD 32 between MD 144 and MD 99 to be equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled.	PE: <$0.1 M CO: $0.2 M Recurring Cost: $1.4 K Annual O&M: <$0.1 M
System 1.2.3 (B/C: 11) Tier 2	MD 99 Traffic Signal Upgrade Upgrade existing traffic signals along MD 99 between MD 32 and US 29 to be equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled.	PE: $0.1 M CO: $0.9 M Recurring Cost: $5.8 K Annual O&M: $0.1 M
System 1.2.4 (B/C: 1) Tier 2	MD 144 Traffic Signal Upgrade Upgrade existing traffic signals along MD 144 between MD 32 and US 40 to be equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled.	PE: $0.1 M CO: $0.4 M Recurring Cost: $2.2 K Annual O&M: $0.1 M
System 1.2.5 (B/C: <1) Tier 3	Marriottsville Traffic Signal Upgrade Upgrade existing traffic signals along Marriotsville Road between MD 144 and MD 99 to be equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled.	PE: <$0.1 M CO: $0.3 M Recurring Cost: $2.2 K Annual O&M: <$0.1 M
System 1.3.1 Tier 1	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $2.0 M CO: $13.4 M Annual O&M: $0.6 M

PROGRESS STATUS:

- Concept of Operations (completed Winter 2019)
- Preliminary Engineering (to begin Spring 2020)
- US 40 Event Signal Timing Plan (under development)

TSMO SYSTEM # 1: ROADWAY OVERVIEW



HARD SHOULDER RUNNING: I-70 US 29

COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$2	<$1	$2	$6
Construction	$16	$4	$13	$40
Total	$18	$5	$15	$46
Annual recurring costs: $311.6 K		Annual O & M costs: $4.7 M		

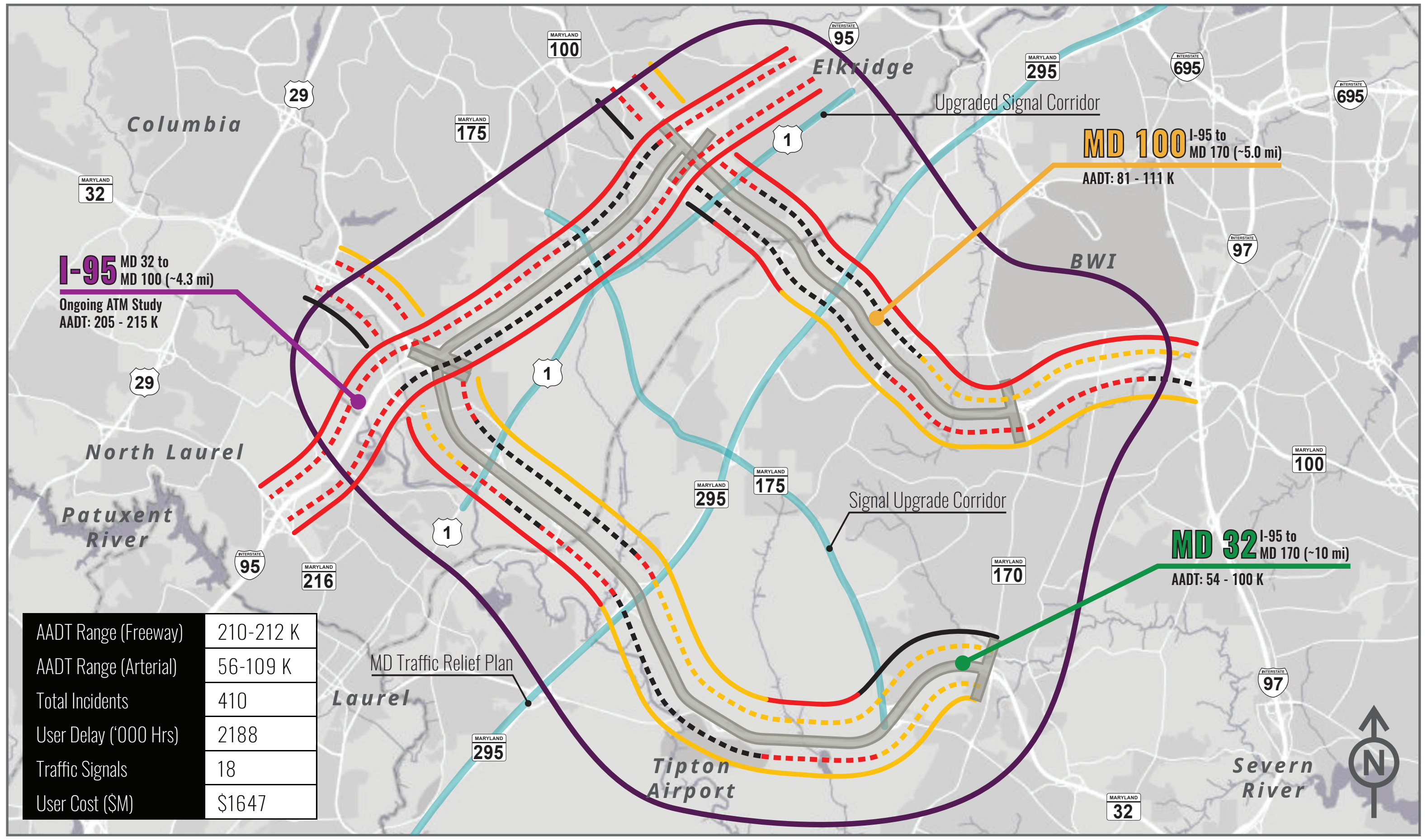
SUB-SYSTEM DEPLOYMENT:

System 1.4.1 (B/C: 6) Tier 2	I-70 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along I-70 at key locations.	PE: $0.8 M CO: $5.5 M Recurring Cost: $74.4 K Annual O&M: $0.8 M
System 1.4.2 (B/C: 6) Tier 2	I-70 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along I-70 at key locations.	PE: $3.4 M CO: $22.7 M
System 1.4.3 (B/C: 8) Tier 3	US 29 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along US 29 at key locations.	PE: $0.2 M CO: $1.6 M Recurring Cost: $22.3 K Annual O&M: $0.2 M
System 1.4.4 (B/C: 8) Tier 3	US 29 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along US 29 at key locations.	PE: $1.5 M CO: $10.3 M

PROGRESS STATUS:

- I-70 Project Planning Study (On Hold)
- I-70/ I-695 Triple Bridges Projects (Advertised)

TSMO SYSTEM # 2

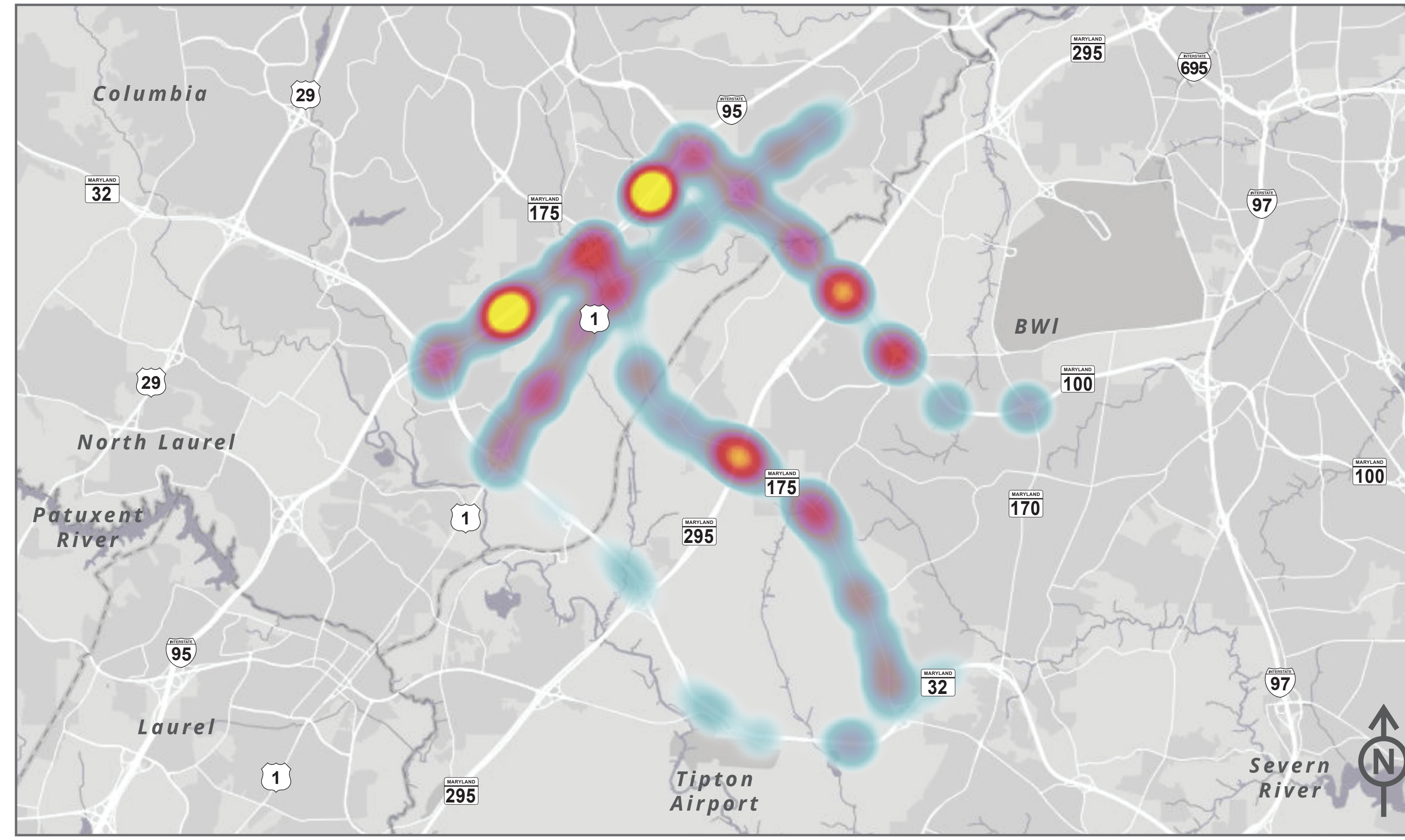


AADT Range (Freeway)	210-212 K
AADT Range (Arterial)	56-109 K
Total Incidents	410
User Delay ('000 Hrs)	2188
Traffic Signals	18
User Cost ($M)	$1647

UNCONGESTED (TTI < 1.15) MODERATE CONGESTION (1.15 < TTI < 1.3) HEAVY CONGESTION (1.3 < TTI < 2.0) SEVERE CONGESTION (TTI > 2.0)

AM TTI PM TTI

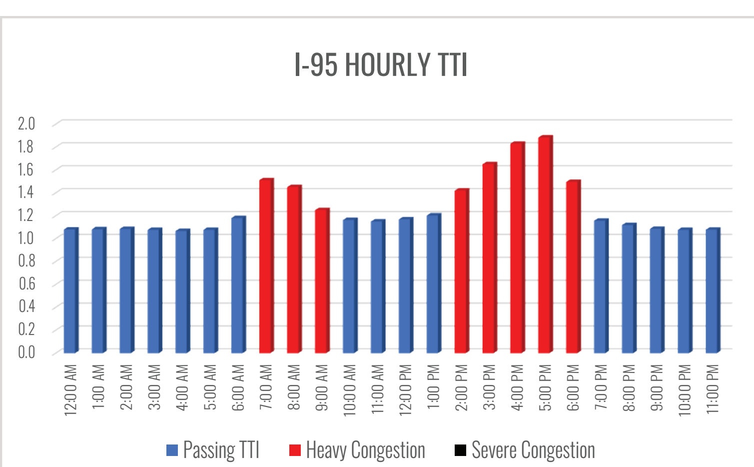
CRASH DENSITY

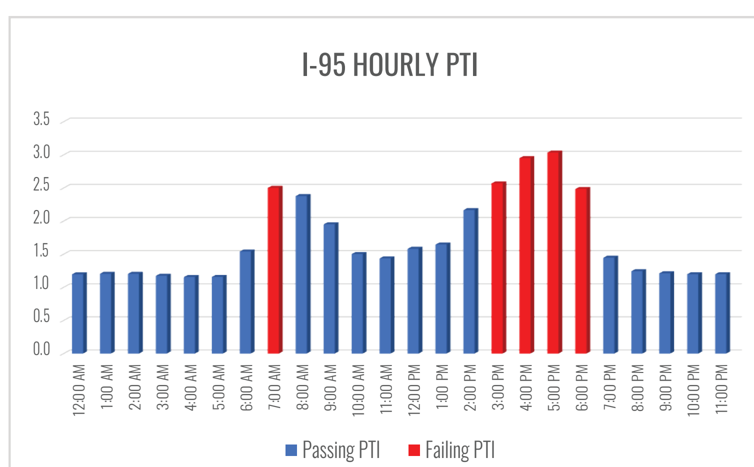


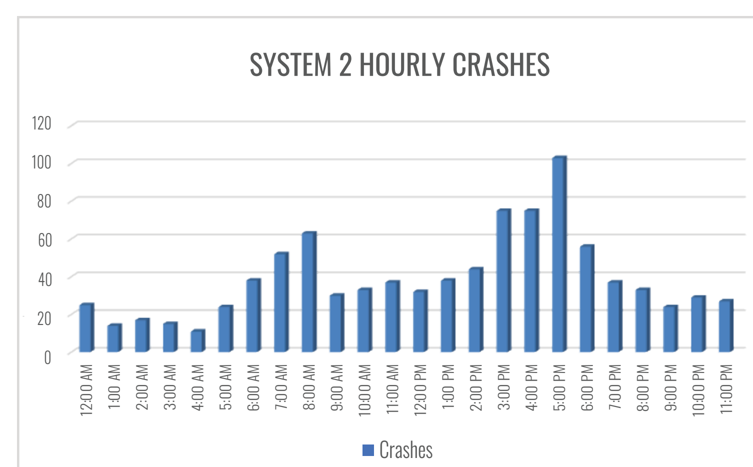
Crash Density: Sparse Dense

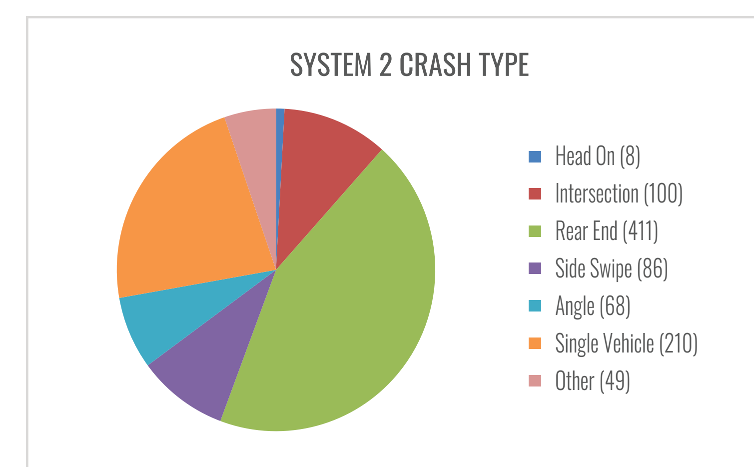
BACKGROUND: TSMO System # 2 improves operations along I-95, MD 100, and MD 32 that provide access to BWI, Anne Arundel Mall, and Fort Meade. I-95, MD 32, and MD 100 are part of the National Highway Freight Network. MD 175 and MD 100 are critical urban freight corridors. MD 175, US 1, MD 32, and MD 100 have been identified as potential transit corridors.

SAFETY OVERVIEW: The highest concentrations of crashes are along I-95 just north and south of MD 175. MD 175 and MD 100 also have high concentrations of crashes around MD 295. Crash data shows that the highest number of crashes occur during the AM or PM peak and the most common crash type is rear ends. In 2018, there were 932 crashes reported within TSMO System # 2, with three fatalities and 322 injuries.

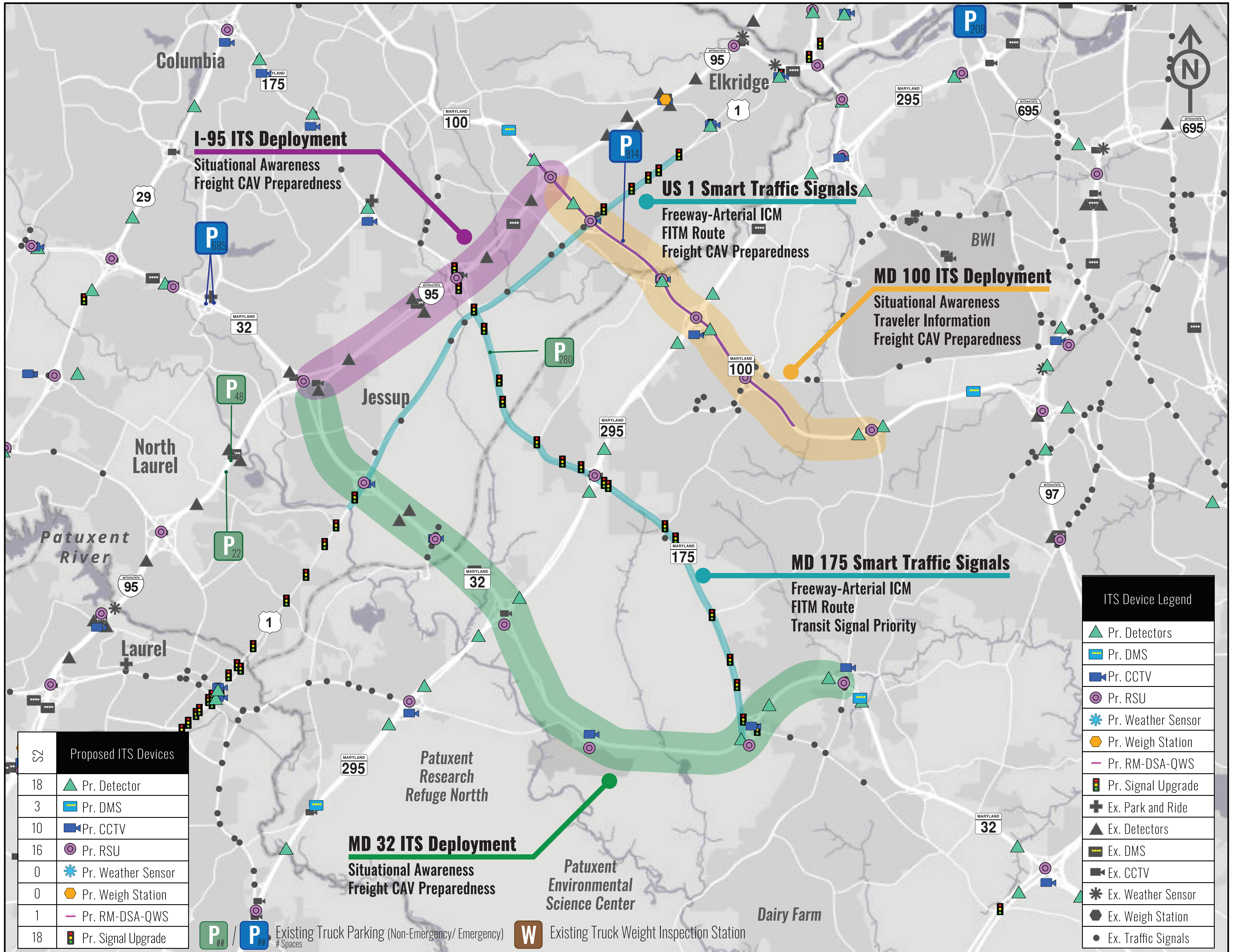








TSMO SYSTEM # 2: ITS OVERVIEW



COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$2	<$1	$3	$12
Construction	$11	$3	$19	$79
Total	$13	$4	$22	$91
Annual recurring costs: $364.4 K		Annual O&M costs: $5.5 M		

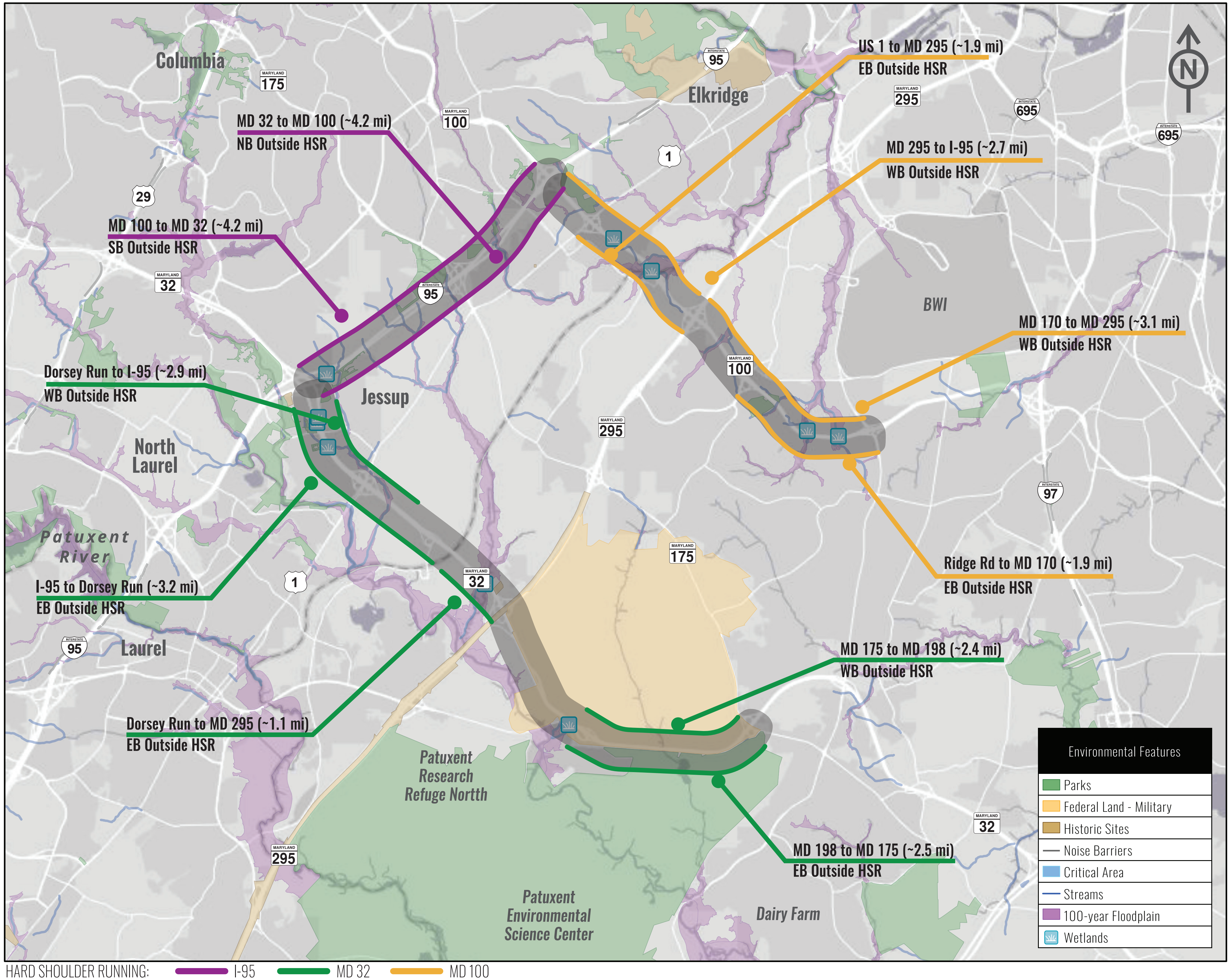
SUB-SYSTEM DEPLOYMENT:

System 2.1.1 (B/C: 270) Tier 1	I-95 ITS Deployment Deployment of RSUs along I-95 between MD 32 and MD 100.	PE: <$0.1 M CO: $0.2 M Recurring Cost: $2.2 K Annual O&M: <$0.1 M
System 2.1.2 (B/C: 20) Tier 1	MD 100 ITS Deployment Deployment of VMS signs, CCTV, traffic detectors, and RSU along MD 100 between I-95 and MD 170.	PE: $0.3 M CO: $1.7 M Recurring Cost: $19.2 K Annual O&M: $0.3 M
System 2.1.3 (B/C: 28) Tier 1	MD 32 ITS Deployment Deployment of VMS signs, CCTV, traffic detectors, and RSU along MD 32 between I-95 and MD 170.	PE: $0.3 M CO: $1.8 M Recurring Cost: $22.2 K Annual O&M: $0.3 M
System 2.1.4 (B/C: 22) Tier 1	MD 295 ITS Deployment Deployment of VMS signs, CCTV, traffic detectors, and RSU along MD 295 between MD 32 and MD 100.	PE: $0.2 M CO: $1.3 M Recurring Cost: $12.4 K Annual O&M: $0.2 M
System 2.1.5 Tier 1	US 1 Signals/ ITS Deployment Upgrade of signals along US 1 between I-195 and MD 32 along with ITS/ CAV equipment	Advertised
System 2.1.6 (B/C: 5) Tier 1	MD 100 Queue Warning System Deploy detectors, cameras, and DMS to implement queue warning system along MD 100 between I-95 and MD 295	PE: $1.0 M CO: $6.4 M Recurring Cost: $61.2 K Annual O&M: $1.0 M
System 2.2.1 (B/C: 3) Tier 1	MD 175 Traffic Signal Upgrade Upgrade existing traffic signals along MD 175 between I-95 and MD 32 to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled and have TSP.	PE: $0.5 M CO: $3.3 M Recurring Cost: $13.0 K Annual O&M: $0.5 M
System 2.3.1 Tier 2	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $2.8 M CO: $18.9 M Annual O&M: $0.9 M

PROGRESS STATUS:

- Baltimore-Washington Concept of Operations (completed)
- I-95 Active Traffic Management (in Design)
- US 1 Smart Traffic Signals (in Development)

TSMO SYSTEM # 2: ROADWAY OVERVIEW



COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$2	<$1	$3	$12
Construction	$11	$3	$19	$79
Total	$13	$4	$22	$91
Annual recurring costs: $364.4 K		Annual O&M costs: $5.5 M		

SUB-SYSTEM DEPLOYMENT:

System 2.4.1 (B/C: 6) Tier 2	I-95 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along I-95 at key locations.	PE: $0.6 M CO: $4.1 M Recurring Cost: $59.5 K Annual O&M: $0.6 M
System 2.4.2 (B/C: 6) Tier 2	I-95 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along I-95 at key locations.	PE: $3.1 M CO: $20.6 M
System 2.4.3 (B/C: 10) Tier 3	MD 100 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along MD 100 at key locations.	PE: $0.7 M CO: $4.6 M Recurring Cost: $67.0 K Annual O&M: $0.7 M
System 2.4.4 (B/C: 10) Tier 3	MD 100 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along MD 100 at key locations.	PE: $3.3 M CO: $22.2 M
System 2.4.5 (B/C: 23) Tier 3	MD 32 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along MD 32 at key locations.	PE: $1.1 M CO: $7.4 M Recurring Cost: $107.9 K Annual O&M: $1.1 M
System 2.4.6 (B/C: 23) Tier 3	MD 32 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along MD 32 at key locations.	PE: $3.0 M CO: $20.3 M

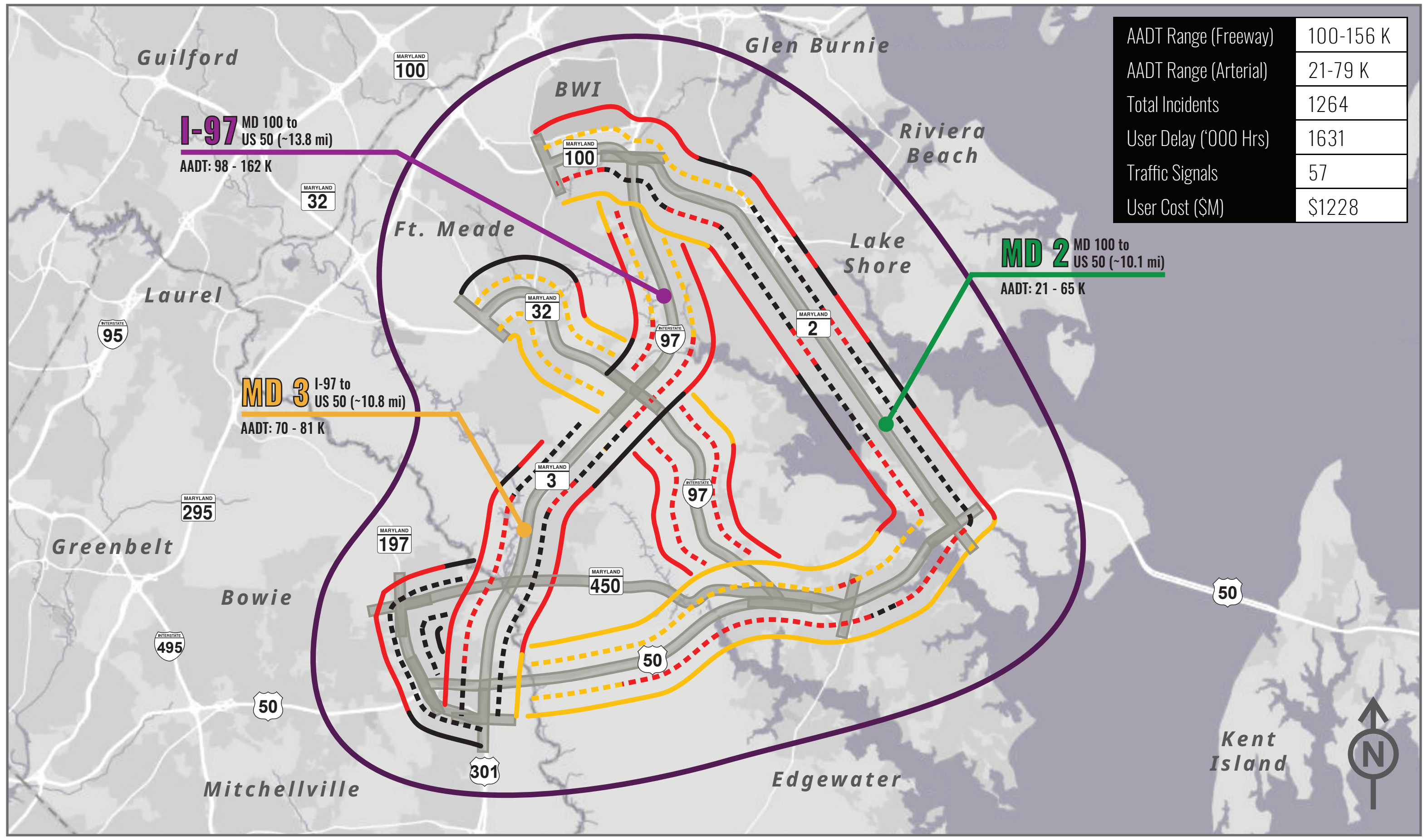
PROGRESS STATUS:

- Baltimore-Washington Concept of Operations (completed)
- I-95 Active Traffic Management (in Design)
- US 1 Smart Traffic Signals (in Development)

TSMO MASTER PLAN

INTERSTATE 97 | MARYLAND 2 | MARYLAND 450 | MARYLAND 3 | 50

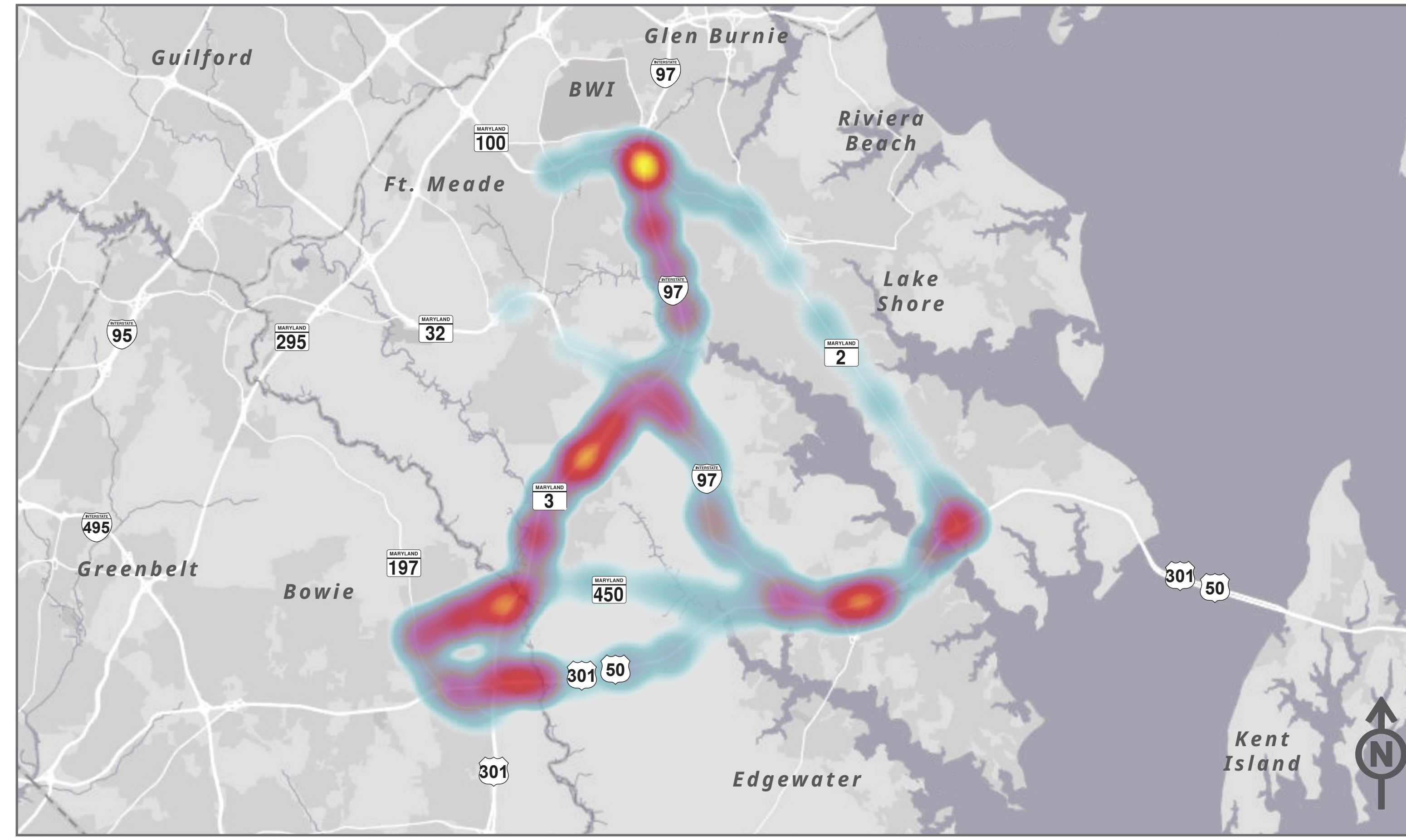
TSMO SYSTEM # 3



UNCONGESTED (TTI < 1.15) MODERATE CONGESTION (1.15 < TTI < 1.3) HEAVY CONGESTION (1.3 < TTI < 2.0) SEVERE CONGESTION (TTI > 2.0)

AM TTI PM TTI

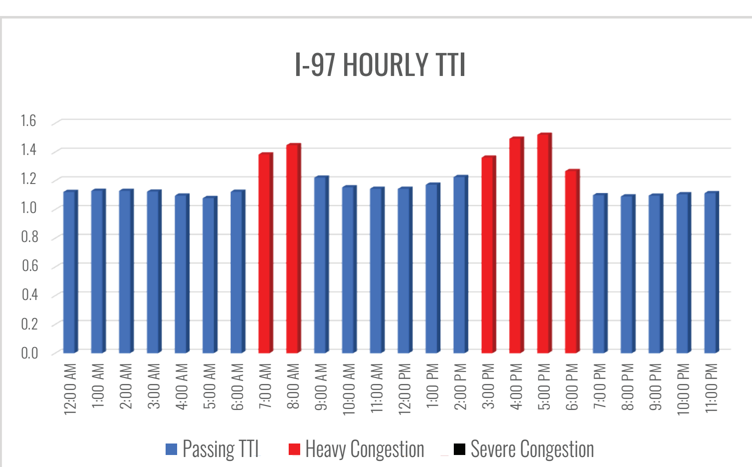
CRASH DENSITY

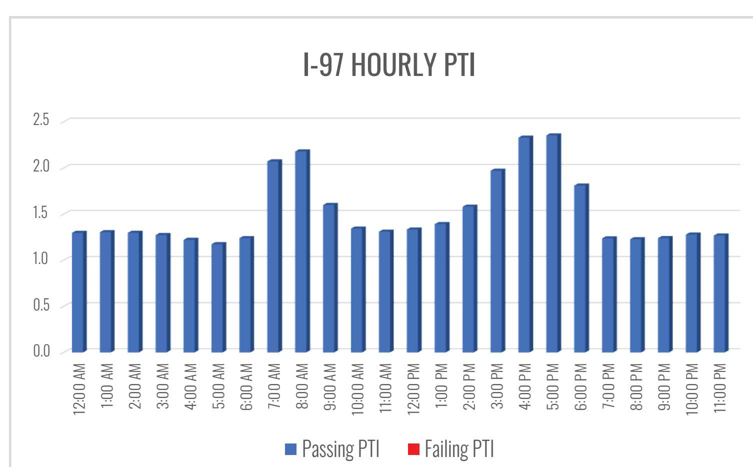


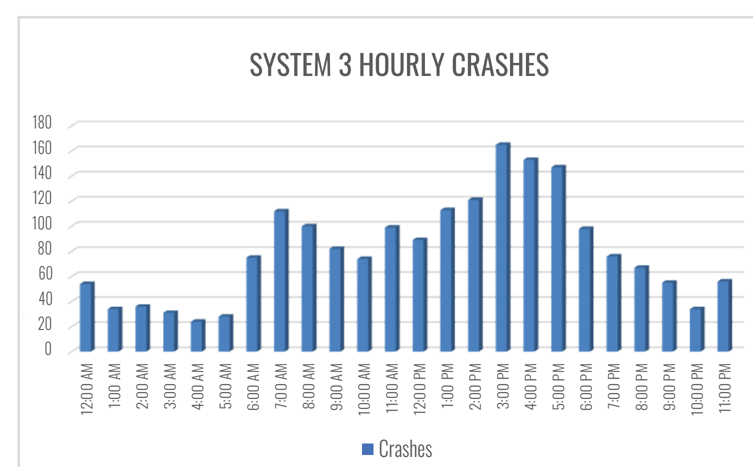
Crash Density: Sparse Dense

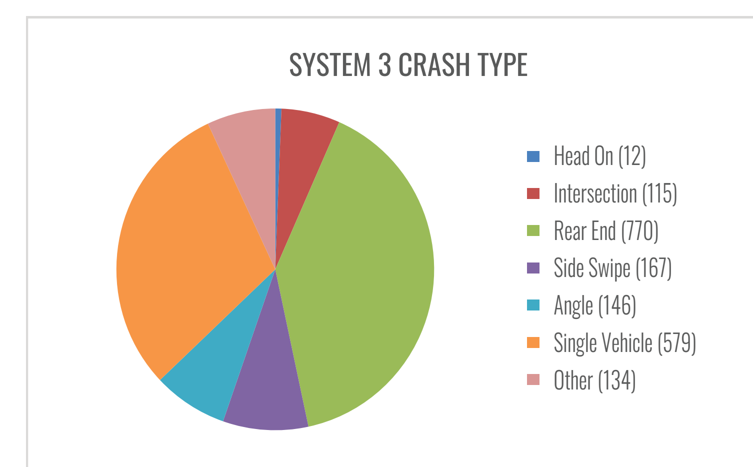
BACKGROUND: TSMO System # 3 improves operations around Fort Meade and BWI and connects the region to Washington DC and the Eastern Shore via US 50. The System connects to US 301 providing alternative north-south route to MD 295. I-97, US 50, and MD 3 are designated as Maryland Freight Routes; I-97 and US 50 are also part of the National Highway Freight Network. MD 2, MD 3, and US 50 have been identified as potential transit corridors.

SAFETY OVERVIEW: The highest concentrations of crashes are along MD 3 and MD 450. There are also high concentrations of crashes along I-97 around MD 100 and along US 50/ US 301 between MD 2 and I-97 and at the MD 3 interchange. Crash data shows that the highest number of crashes occur during the AM or PM peak and the most common crash type is rear ends. In 2018, there were 1923 crashes reported within TSMO System # 3, with 18 fatalities and 785 injuries.

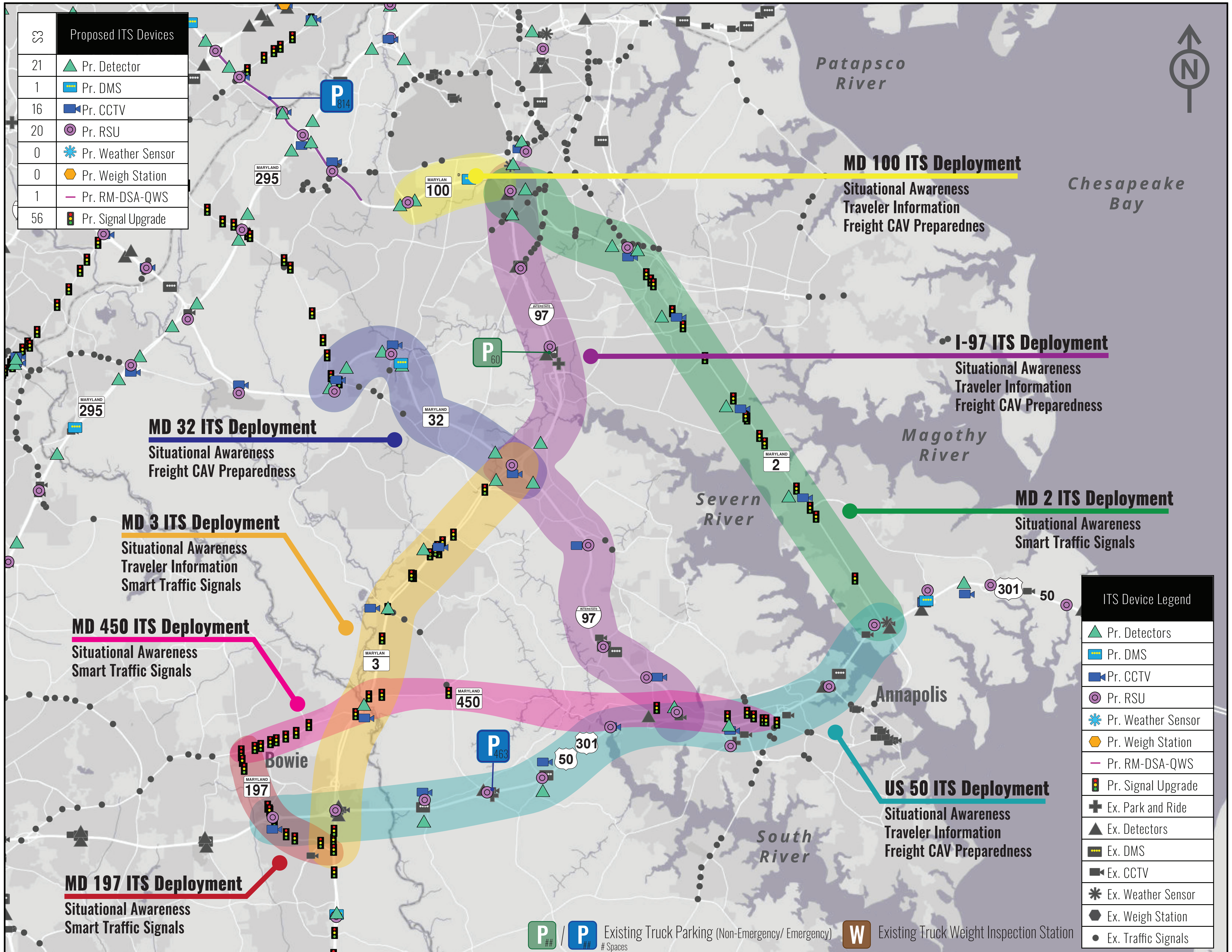








TSMO SYSTEM # 3: ITS OVERVIEW



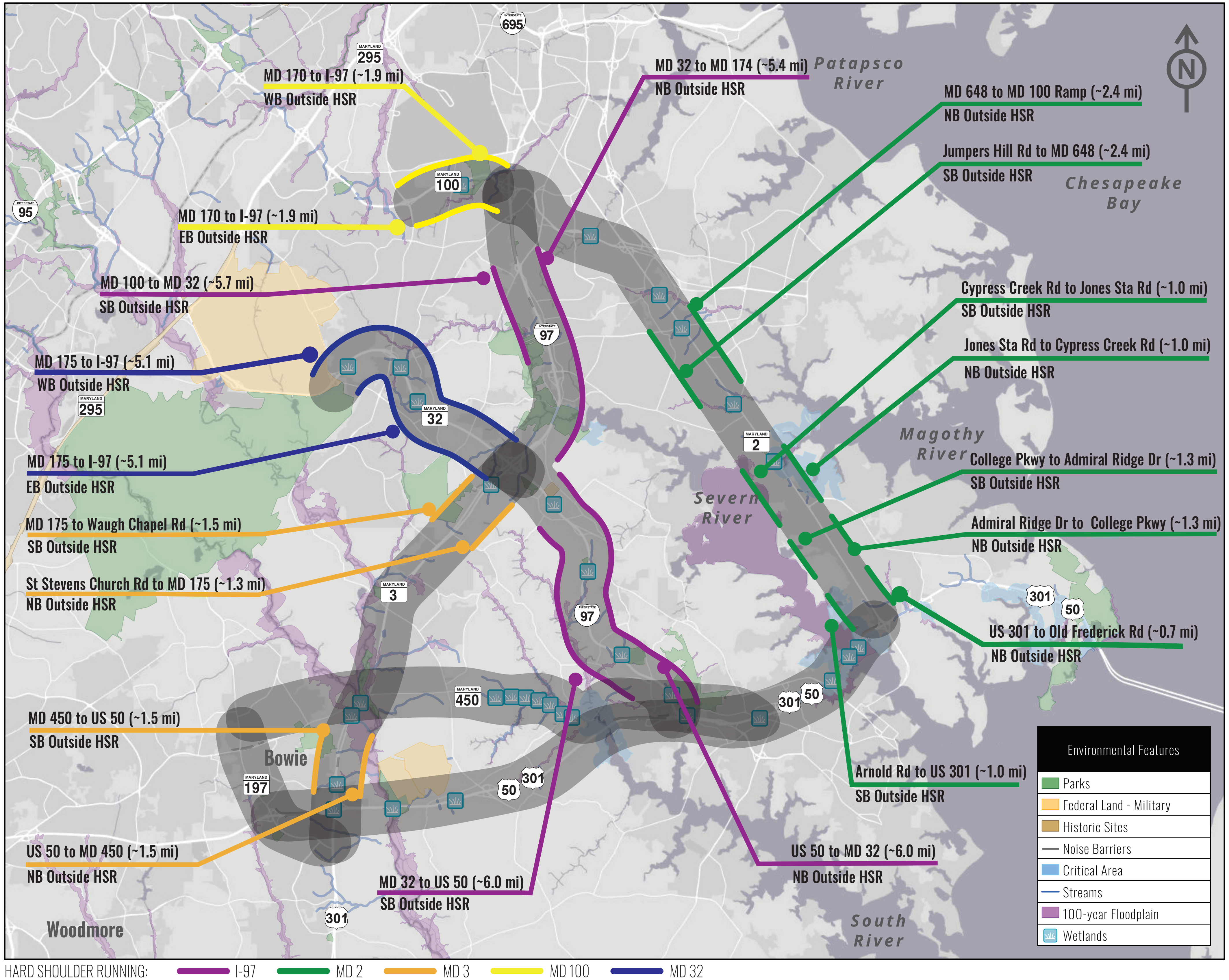
COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	$2	$4	$20
Construction	$5	$10	$29	$133
Total	$6	$12	$33	$153
Annual recurring costs: $484.6 K		Annual O&M costs: $7.4 M		

SUB-SYSTEM DEPLOYMENT:

System 3.1.1 (B/C: 32) Tier 1	I-97 ITS Deployment Deployment of CCTV, traffic detectors, and RSU along I-97 between MD 100 and US 50.	PE: $0.2 M CO: $1.3 M Recurring Cost: $20.5 K Annual O&M: $0.2 M
System 3.1.2 (B/C: 46) Tier 1	US 50/ US 301 ITS Deployment Deployment of CCTV, traffic detectors, VMS signs, and RSU along US 50/ US 301 between MD 3 and MD 2.	PE: $0.2 M CO: $1.2 M Recurring Cost: $19.9 K Annual O&M: $0.2 M
System 3.1.3 (B/C: 12) Tier 1	MD 100 ITS Deployment Deployment of traffic detectors and VMS signs along MD 100 between MD 170 and I-97.	PE: $0.2 M CO: $1.0 M Recurring Cost: $6.6 K Annual O&M: $0.2 M
System 3.1.4 (B/C: 32) Tier 1	MD 32 ITS Deployment Deployment traffic detectors along MD 32 between MD 170 and I-97.	PE: <$0.1 M CO: $0.2 M Recurring Cost: $4.4 K Annual O&M: <$0.1 M
System 3.1.5 (B/C: 75) Tier 1	MD 2 ITS Deployment Deployment of CCTV, traffic detectors, and RSU along MD 2 between MD 100 and US 50/ US 301.	PE: $0.1 M CO: $0.5 M Recurring Cost: $11.2 K Annual O&M: $0.1 M
System 3.1.6 (B/C: 79) Tier 1	MD 3 ITS Deployment Deployment of VMS signs, CCTV, traffic detectors, and RSU along MD 3 between I-97 and US 50/ US 301.	PE: $0.1 M CO: $0.6 M Recurring Cost: $11.9 K Annual O&M: $0.1 M
System 3.2.1 (B/C: 4) Tier 2	MD 2 Traffic Signal Upgrade Upgrade existing traffic signals along MD 2 between MD 100 and US 50/ US 301.	PE: $0.5 M CO: $3.1 M Recurring Cost: $10.8 K Annual O&M: $0.5 M
System 3.2.2 (B/C: 4) Tier 2	MD 3 Traffic Signal Upgrade Upgrade existing traffic signals along MD 3 between I-97 and US 50/ US 301.	PE: $0.4 M CO: $2.5 M Recurring Cost: $10.8 K Annual O&M: $0.4 M
System 3.2.3 (B/C: 9) Tier 2	MD 450 Traffic Signal Upgrade Upgrade existing traffic signals along MD 450 between US 50/ US 301 and MD 197.	PE: $0.4 M CO: $2.4 M Recurring Cost: $12.2 K Annual O&M: $0.4 M
System 3.2.4 (B/C: 8) Tier 2	MD 197 Traffic Signal Upgrade Upgrade existing traffic signals along MD 197 between MD 450 and US 301.	PE: $0.4 M CO: $2.4 M Recurring Cost: $7.9 K Annual O&M: $0.4 M
System 3.3.1 Tier 2	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $4.3 M CO: $28.9 M Annual O&M: $1.3 M

TSMO SYSTEM # 3: ROADWAY OVERVIEW



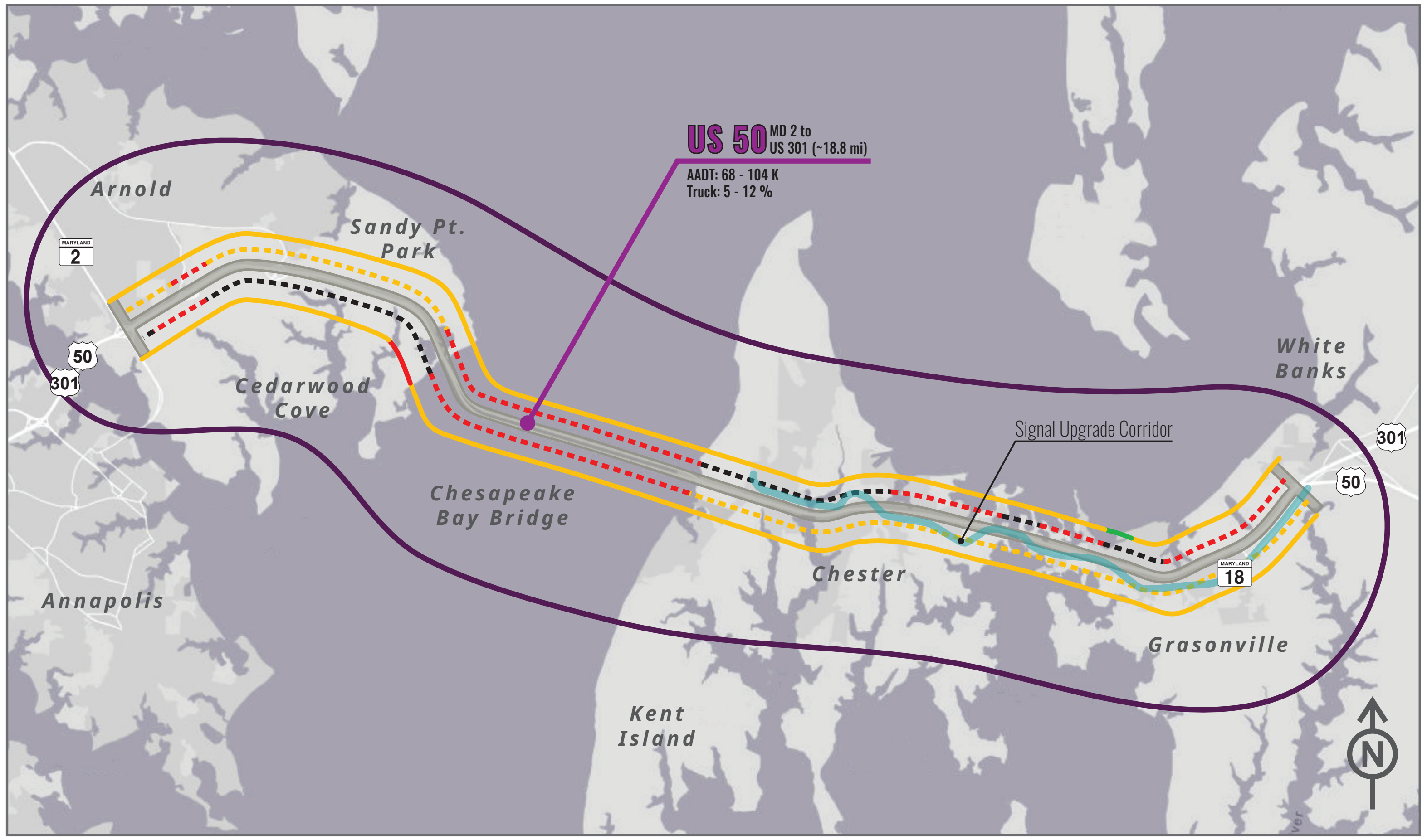
COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	$2	$4	$20
Construction	$5	$10	$29	$133
Total	$6	$12	$33	$153
Annual recurring costs: $484.6 K		Annual O&M costs: $7.4 M		

SUB-SYSTEM DEPLOYMENT:

System 3.4.1 (B/C: 8) Tier 3	I-97 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along I-97 at key locations.	PE: $1.4 M CO: $9.6 M Recurring Cost: $141.4 K Annual O&M: $1.4 M
System 3.4.2 (B/C: 8) Tier 3	I-97 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along I-97 at key locations.	PE: $6.5 M CO: $43.2 M
System 3.4.3 (B/C: 5) Tier 3	MD 2 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along MD 2 at key locations.	PE: $0.8 M CO: $5.6 M Recurring Cost: $81.8 K Annual O&M: $0.8 M
System 3.4.4 (B/C: 5) Tier 3	MD 2 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along MD 2 at key locations.	PE: $3.8 M CO: $25.4 M
System 3.4.5 (B/C: 11) Tier 3	MD 3 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along MD 3 at key locations.	PE: $0.4 M CO: $2.9 M Recurring Cost: $44.6 K Annual O&M: $0.4 M
System 3.4.6 (B/C: 11) Tier 3	MD 3 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along MD 3 at key locations.	PE: $2.0 M CO: $13.3 M
System 3.4.7 (B/C: <1) Tier 3	MD 32 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along MD 32 at key locations.	PE: $0.7 M CO: $4.8 M Recurring Cost: $70.7 K Annual O&M: $0.7 M
System 3.4.8 (B/C: <1) Tier 3	MD 32 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along MD 32 at key locations.	PE: $2.5 M CO: $16.8 M
System 3.4.9 (B/C: 4) Tier 3	MD 100 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along MD 100 at key locations.	PE: $0.3 M CO: $2.0 M Recurring Cost: $29.8 K Annual O&M: $0.3 M
System 3.4.10 (B/C: 4) Tier 3	MD 100 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along MD 100 at key locations.	PE: $1.3 M CO: $8.8 M

TSMO SYSTEM # 4



UNCONGESTED (**TTI < 1.15**) MODERATE CONGESTION (**1.15 < TTI < 1.3**) HEAVY CONGESTION (**1.3 < TTI < 2.0**) SEVERE CONGESTION (**TTI > 2.0**)

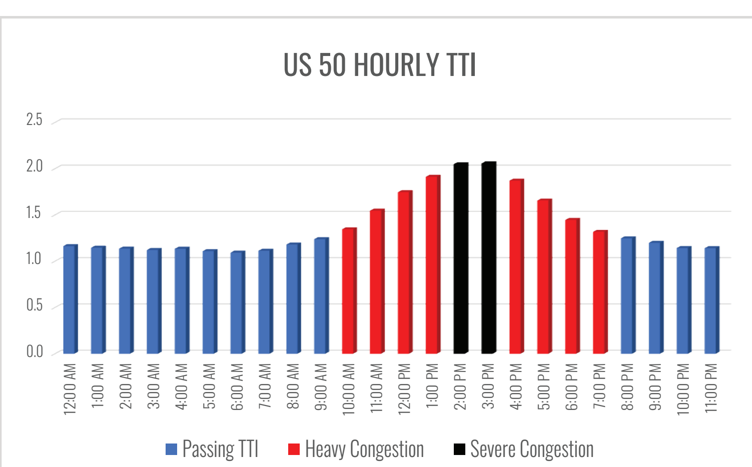
AM SUMMER TTI PM SUMMER TTI

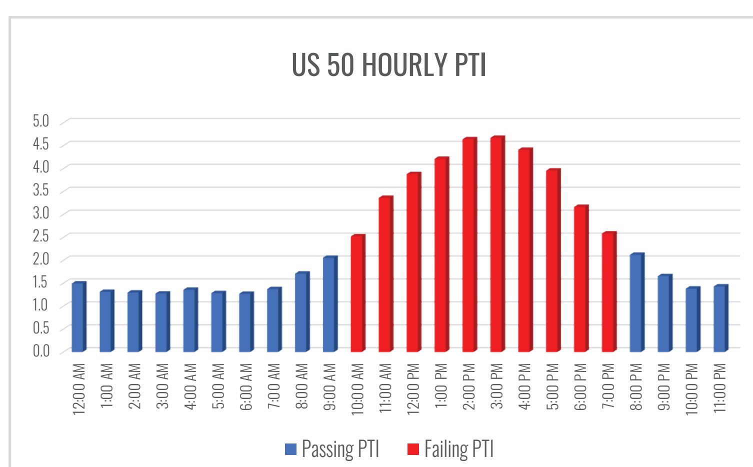
CRASH DENSITY

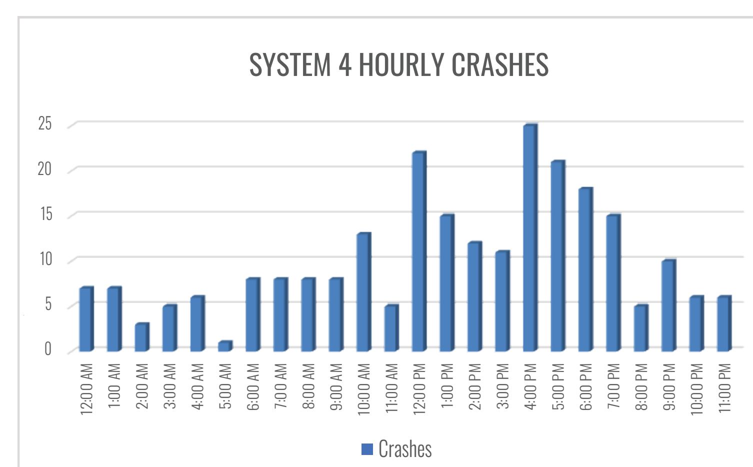
Crash Density: Sparse Dense

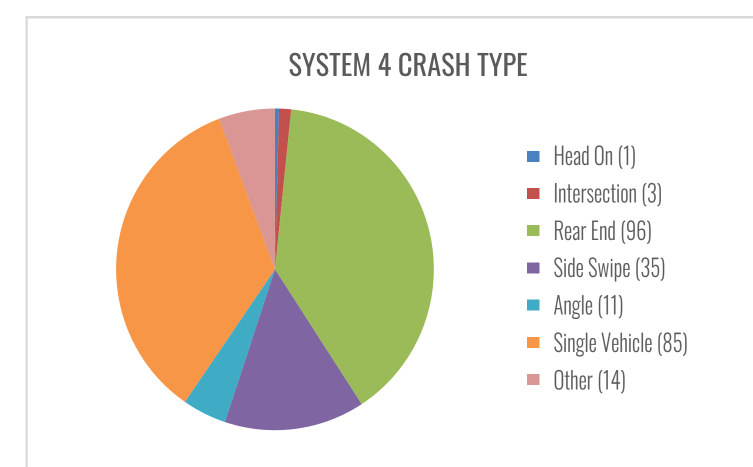
BACKGROUND: TSMO system # 4 improves operations along US 50 and parallel local roads approaching the Bay Bridge Crossing. The rush to cross the Bay Bridge during the Summer begins around 10 AM and extends through 7 PM, during which ~45,000 vehicles attempt to cross. When crashes occur ~25% of traffic attempts to bypass congestion by diverting to MD 18. US 50 is also designated Maryland Freight Route and is part of the National Highway Freight Network.

SAFETY OVERVIEW: The highest concentrations of crashes are along US 50/ US 301 around MD 2 and on the east side of the Bay Bridge. Crash data shows that the highest number of crashes occur in the afternoon and the most common crash type is rear ends. In 2018, there were 245 crashes reported within TSMO System # 4, with zero fatalities and 92 injuries.





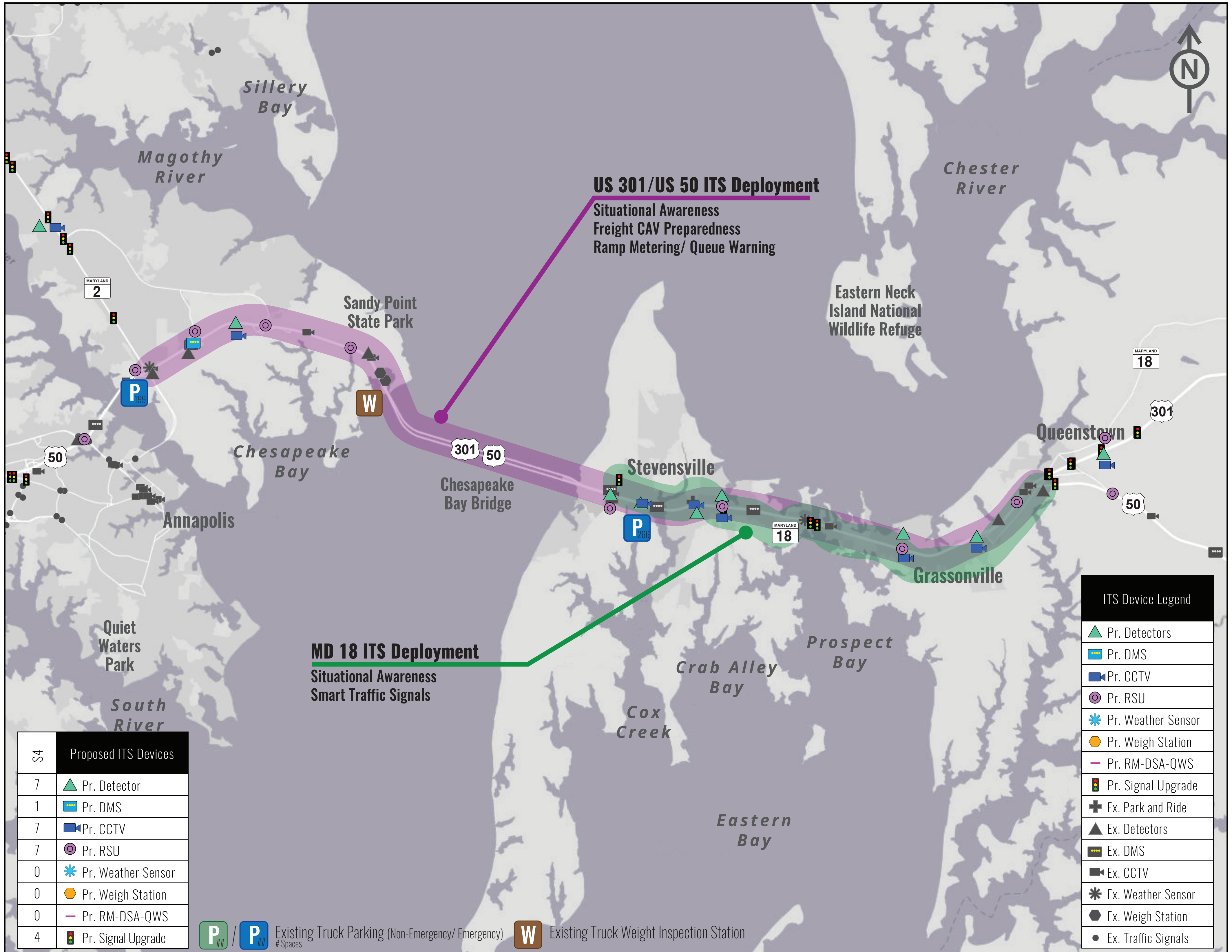




TSMO MASTER PLAN

301 50

TSMO SYSTEM # 4: ITS OVERVIEW



COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	<$1	<$1	$1	$3
Construction	$2	$1	$3	$17
Total	$3	$1	$4	$19
Annual recurring costs: $86.8 K		Annual O&M costs: $1.2 M		

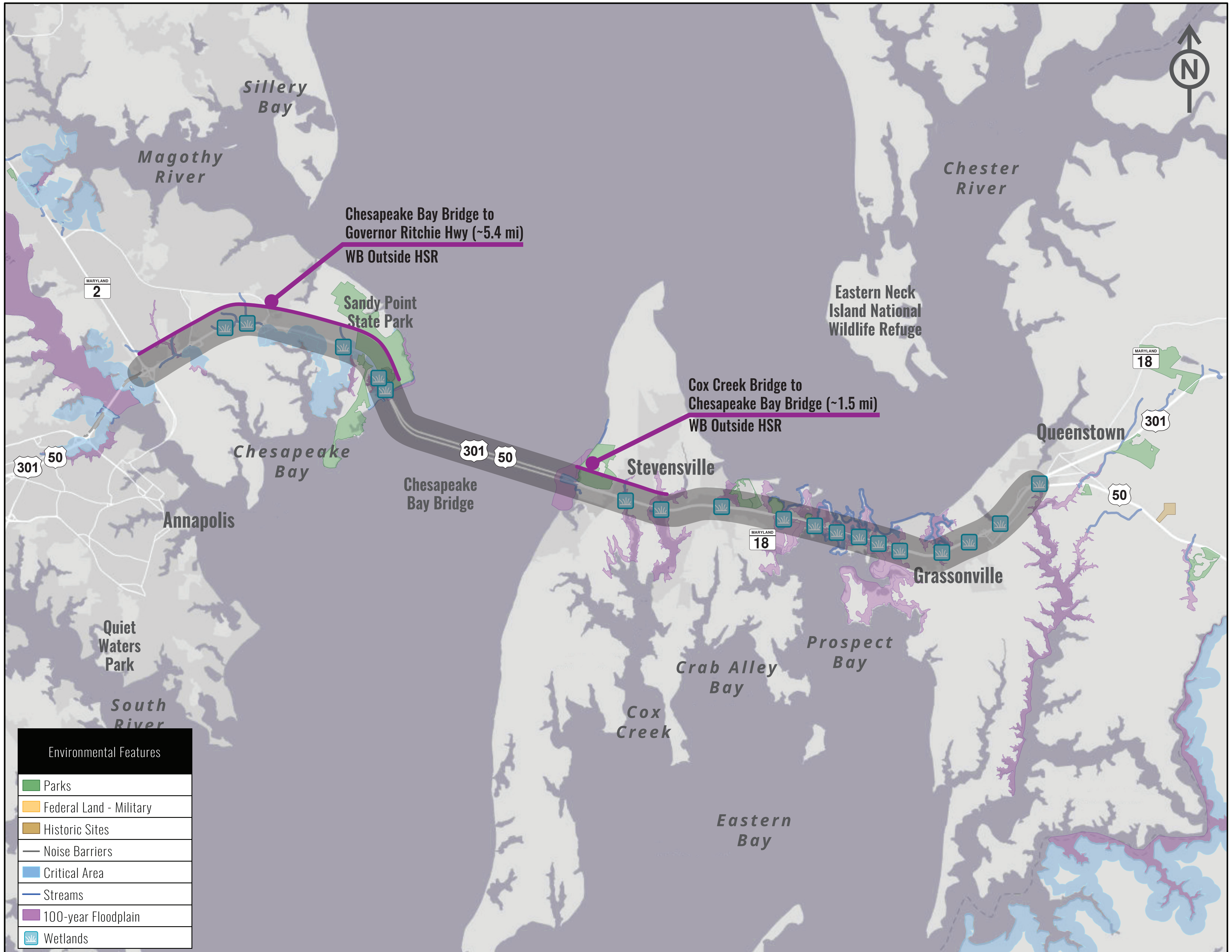
SUB-SYSTEM DEPLOYMENT:

System 4.1.1 (B/C: 13) Tier 1	US 50/ US 301 ITS Deployment Deployment of CCTV, traffic detectors, and RSU along US 50/ US 301 between MD 2 and US 50/ US 301 split.	PE: $0.3 M CO: $2.2M Recurring Cost: $31.8 K Annual O&M: $0.3 M
System 4.2.1 (B/C: <1) Tier 2	MD 8 Traffic Signal Upgrade Upgrade existing traffic signals along MD 8 between MD 8 and US 50 to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, and ATMS enabled.	PE: $0.1 M CO: $1.0 M Recurring Cost: $2.9 K Annual O&M: $0.1 M
System 4.3.1 Tier 2	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $0.5 M CO: $3.5 M Annual O&M: $0.2 M

PROGRESS STATUS:

- Detailed traffic operations analysis (completed)
- All Electronic Tolling (planned)
- Bay Bridge Crossing Study (underway)

TSMO SYSTEM # 4: ROADWAY OVERVIEW



HARD SHOULDER RUNNING: US 50/ US 301

COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	<$1	<$1	$1	$3
Construction	$2	$1	$3	$17
Total	$3	$1	$4	$19
Annual recurring costs: $86.8 K		Annual O&M costs: $1.2 M		

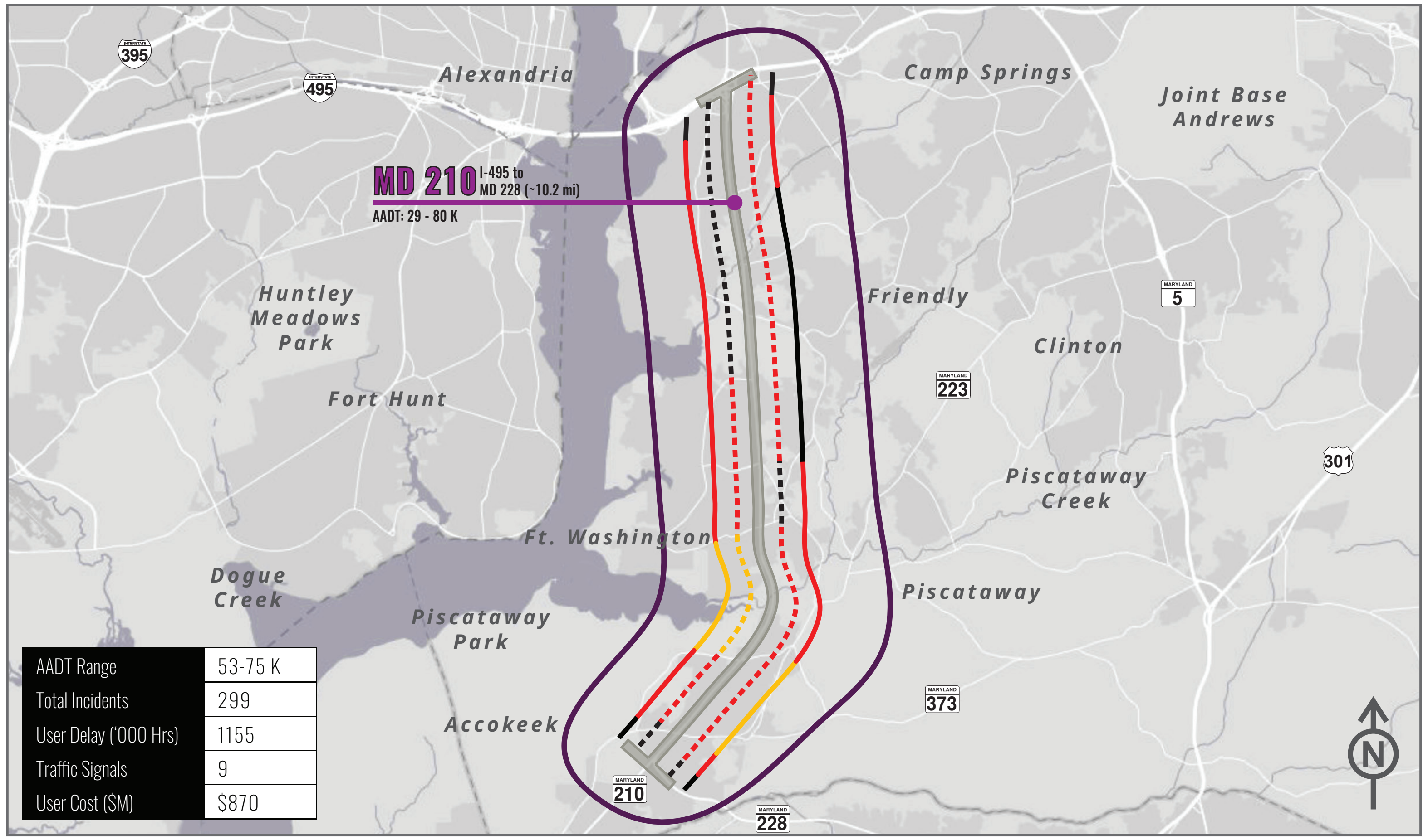
SUB-SYSTEM DEPLOYMENT:

System 4.4.1 (B/C: 3) Tier 3	US 50/ US 301 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along US 50/ US 301 at key locations.	PE: $0.5 M CO: $3.5 M Recurring Cost: $52.1 K Annual O&M: $0.5 M
System 4.4.2 (B/C: 3) Tier 3	US 50/ US 301 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along US 50/ US 301 at key locations.	PE: $2.0 M CO: $13.3 M

PROGRESS STATUS:

- Detailed traffic operations analysis (completed)
- All Electronic Tolling (planned)
- Bay Bridge Crossing Study (underway)

TSMO SYSTEM # 5

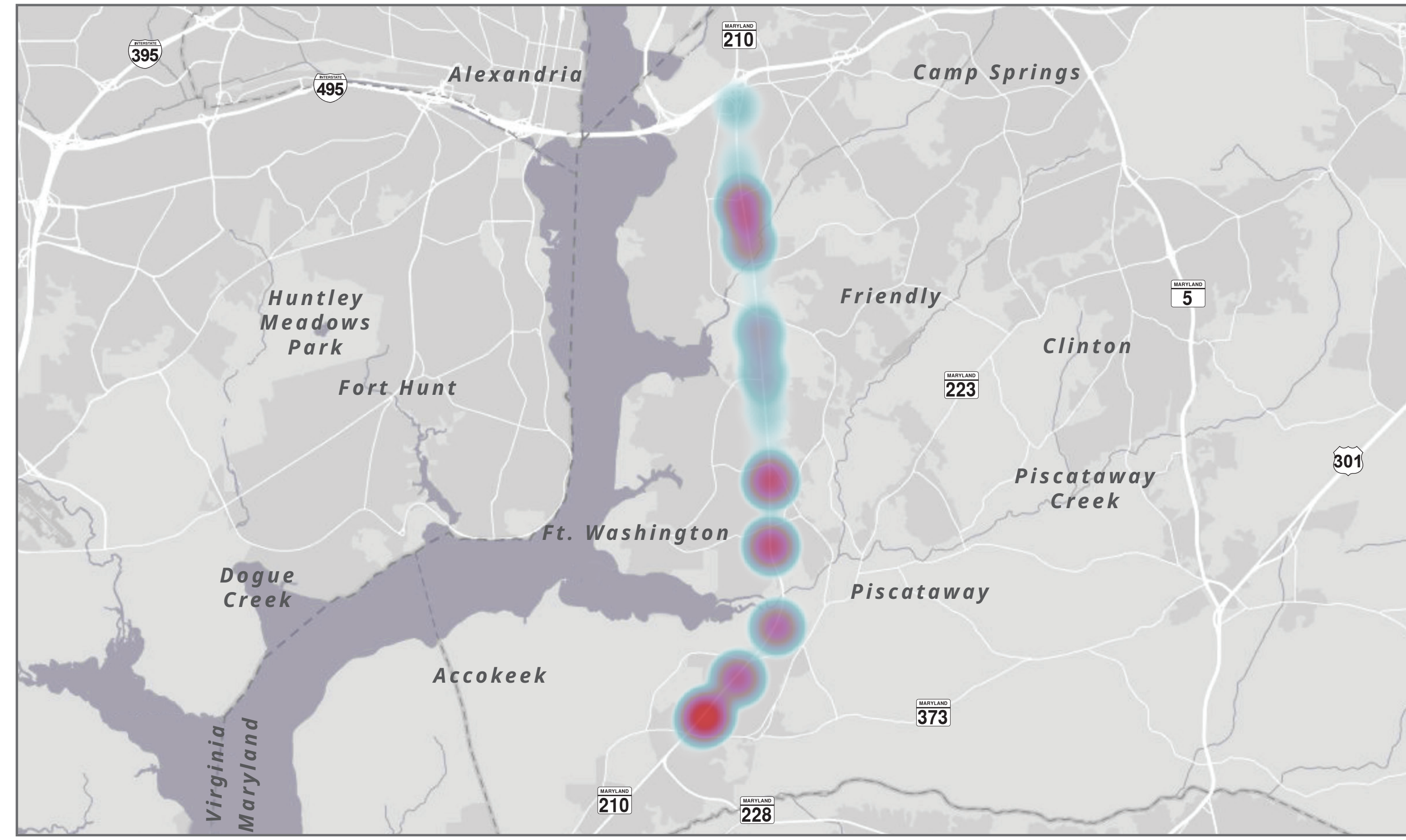


AADT Range	53-75 K
Total Incidents	299
User Delay ('000 Hrs)	1155
Traffic Signals	9
User Cost ($M)	$870

UNCONGESTED (**TTI < 1.15**) MODERATE CONGESTION (**1.15 < TTI < 1.3**) HEAVY CONGESTION (**1.3 < TTI < 2.0**) SEVERE CONGESTION (**TTI > 2.0**)

AM TTI PM TTI

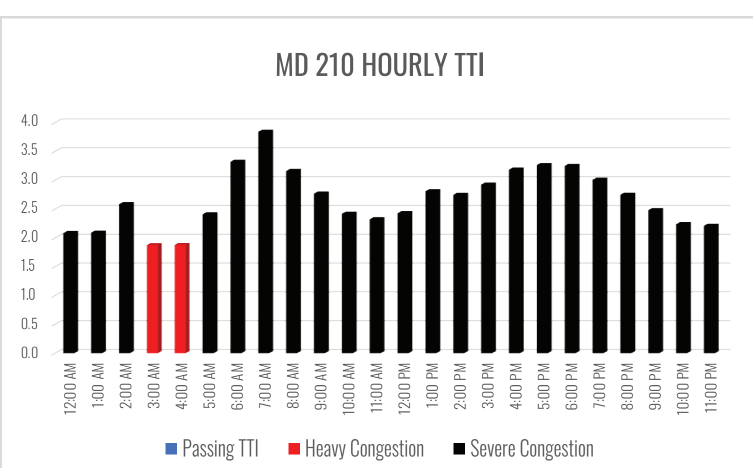
CRASH DENSITY

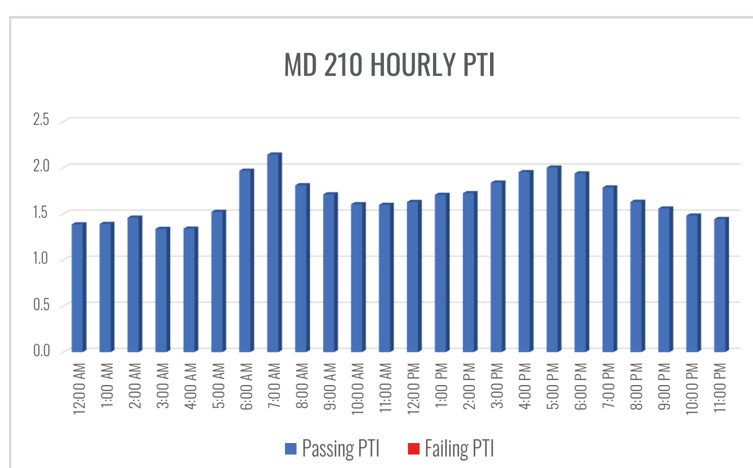


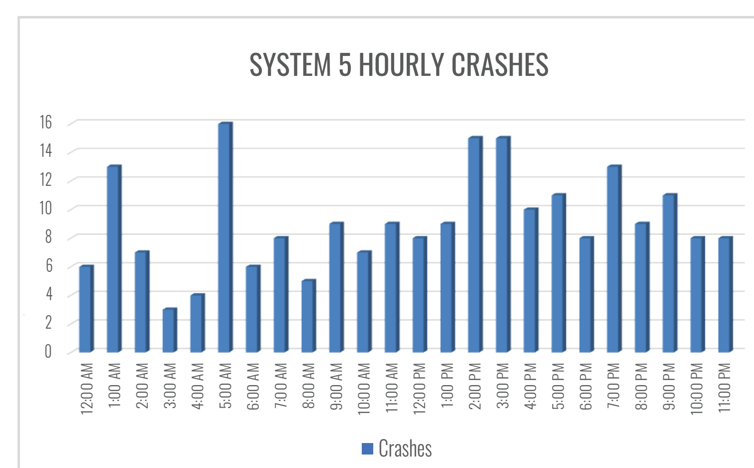
Crash Density: Sparse Dense

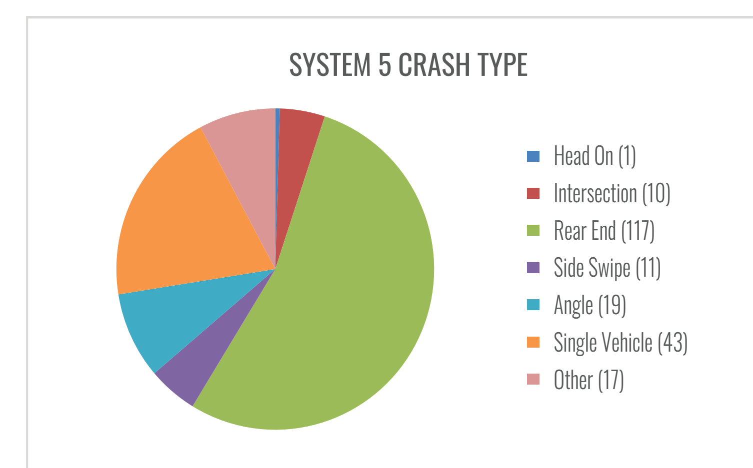
BACKGROUND: TSMO System # 5 improves operations along MD 210 and surrounding local transportation network. MD 210 is a commuter route, with heavy congestion in the AM towards Washington DC and the reverse in the PM. The system is compatible with PG County's proposed hard shoulder running and with the Selected Alternative from the NEPA study and the ongoing Kerby Hill interchange project.

SAFETY OVERVIEW: MD 210 suffers from higher than average crash rates related to speeding and aggressive driving. The highest concentrations of crashes are along MD 210 between MD 373 and MD 228. Crash data shows that the highest number of crashes occur outside the regular peak periods and the most common crash type is rear ends. In 2018, there were 218 crashes reported within TSMO System # 5, with zero fatalities and 106 injuries.

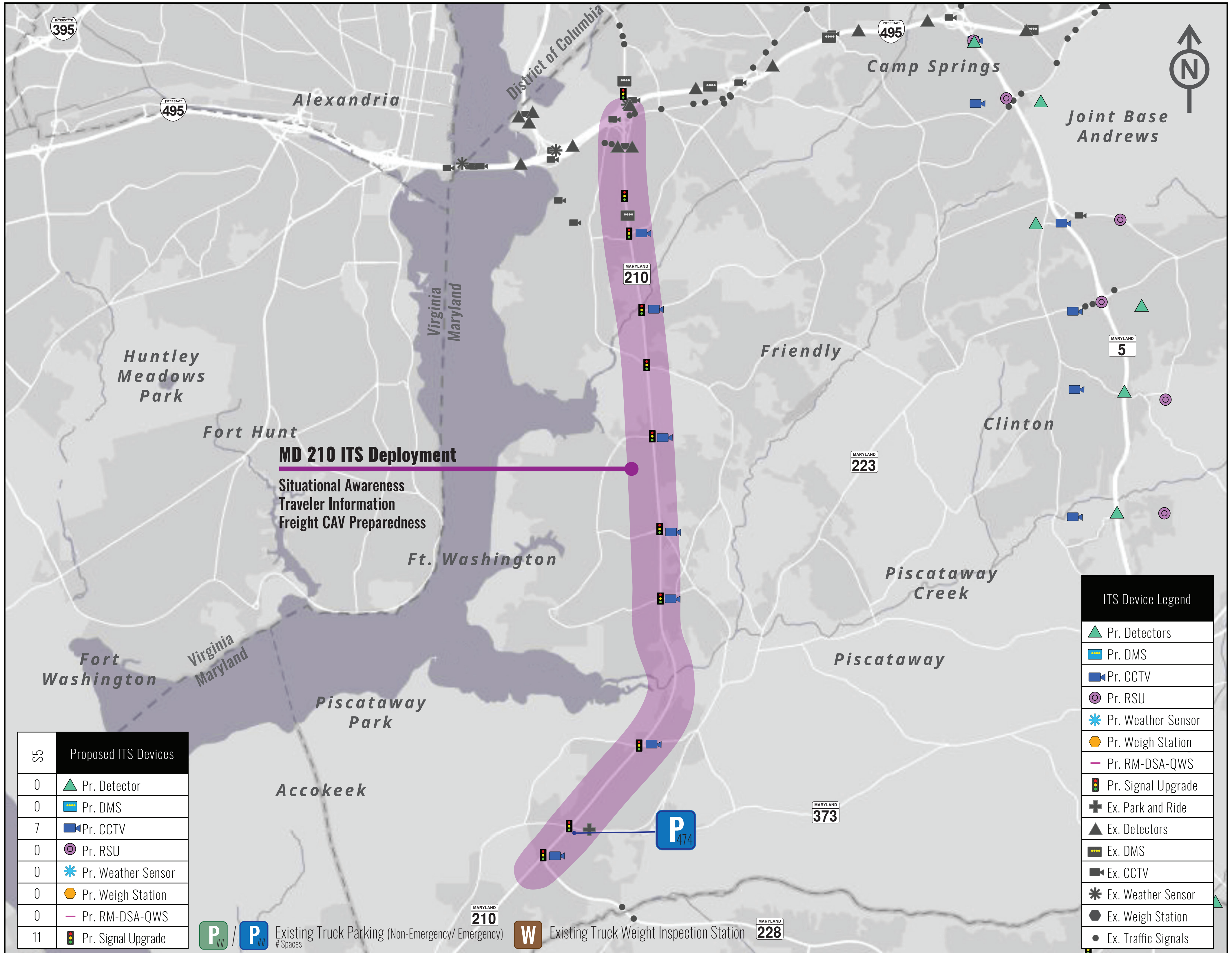








TSMO SYSTEM # 5: ITS OVERVIEW



COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	<$1	$1	$1	$9
Construction	$1	$4	$3	$58
Total	$1	$5	$4	$66
Annual recurring costs: $133.1 K		Annual O&M costs: $2.0 M		

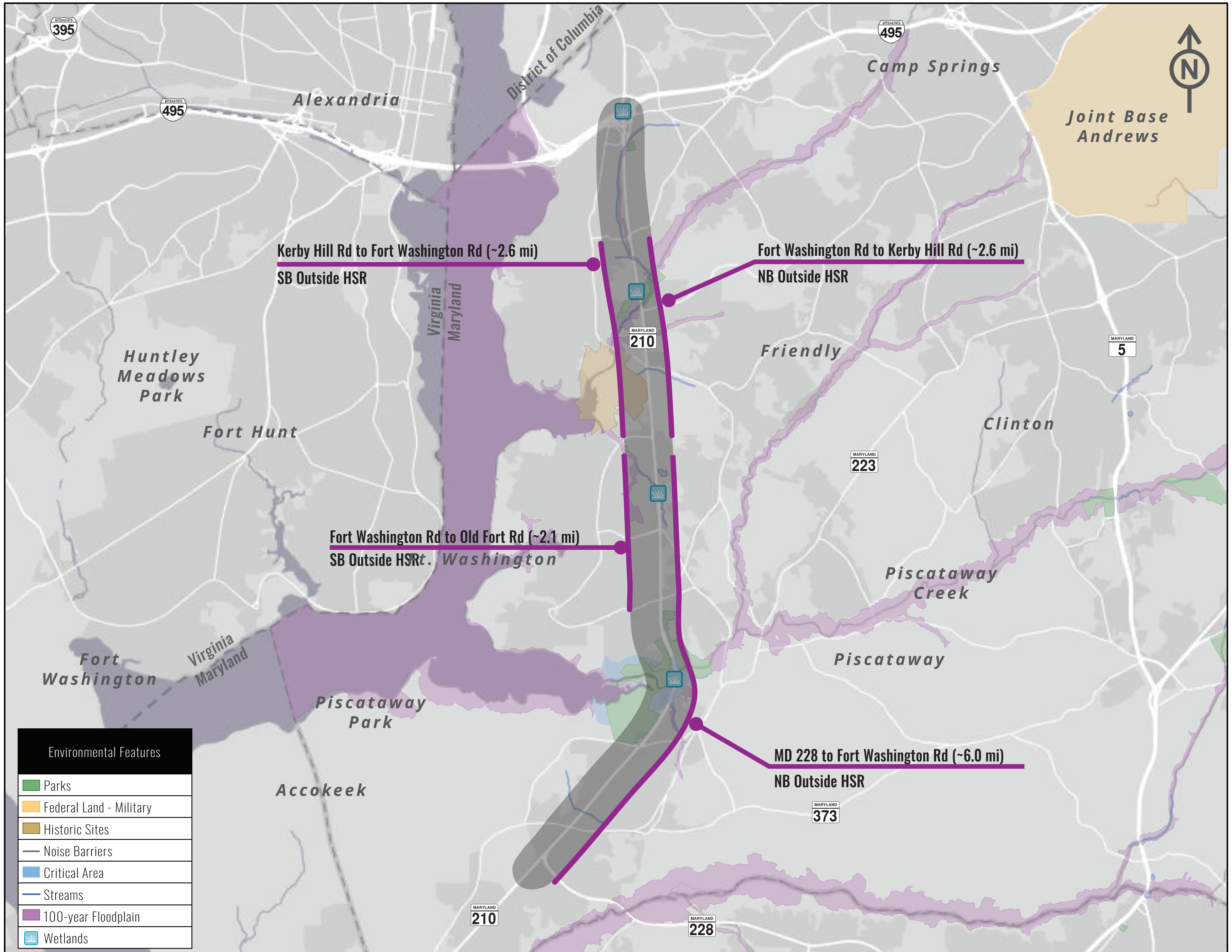
SUB-SYSTEM DEPLOYMENT:

System 5.1.1 (B/C: 90) Tier 1	MD 210 ITS Deployment Deployment of CCTV along US MD 210 between I-495 and MD 228.	PE: $0.1 M CO: $0.9 M Recurring Cost: $21.0 K Annual O&M: $0.1 M
System 5.2.1 (B/C: 16) Tier 1	MD 210 Traffic Signal Upgrade Upgrade existing traffic signals along MD 210 between I-495 and MD 228 to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled and have TSP.	PE: $0.7 M CO: $4.4 M Recurring Cost: $7.9 K Annual O&M: $0.7 M
System 5.3.1 Tier 3	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $0.5 M CO: $3.5 M Annual O&M: $0.2 M

PROGRESS STATUS:

- Evaluate PG County HSR Proposal (completed)
- TSMO to be included as part of NEPA re-evaluation (TBD)

TSMO SYSTEM # 5: ROADWAY OVERVIEW



HARD SHOULDER RUNNING: MD 210

COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	<$1	$1	$1	$9
Construction	$1	$4	$3	$58
Total	$1	$5	$4	$66
Annual recurring costs: $133.1 K		Annual O&M costs: $2.0 M		

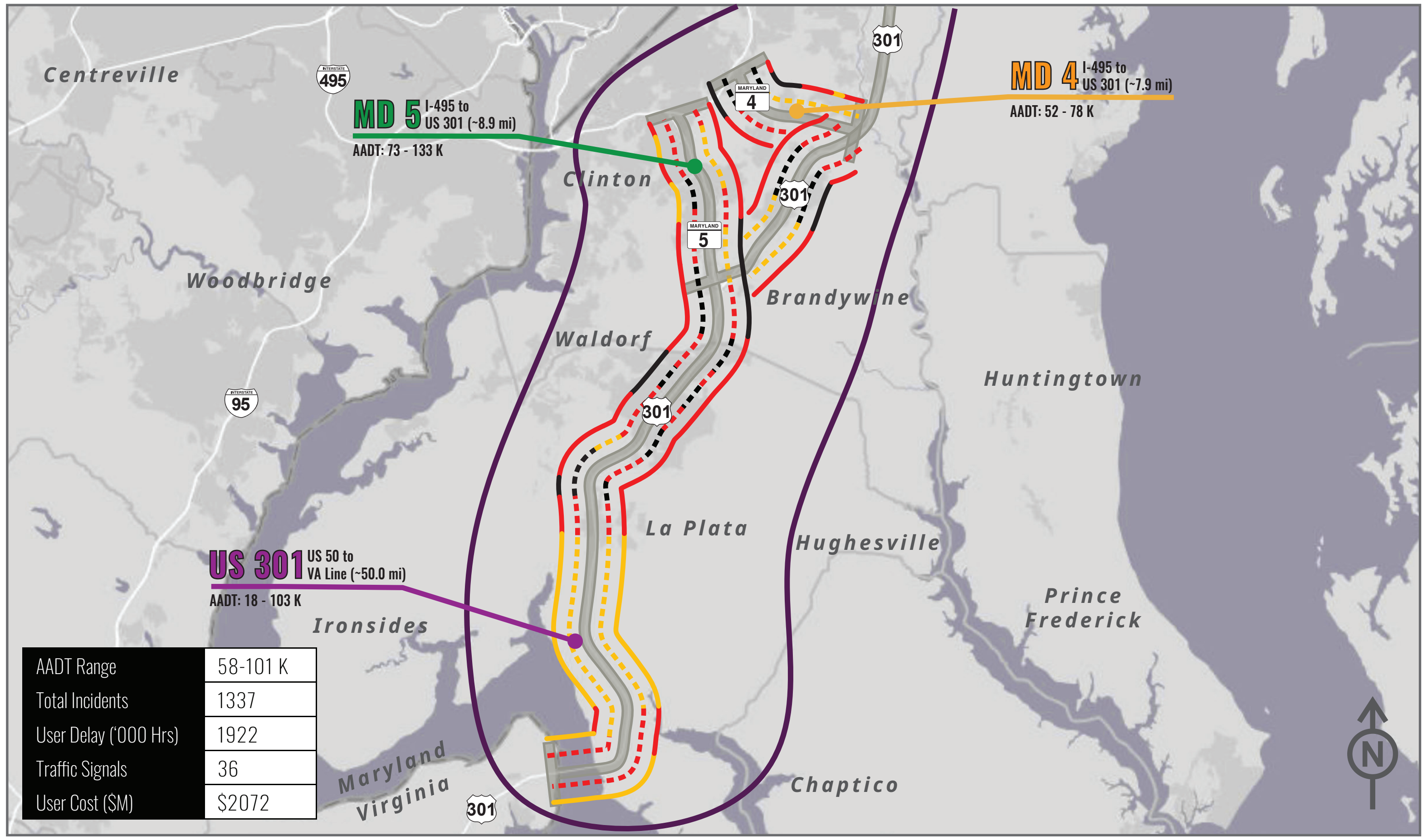
SUB-SYSTEM DEPLOYMENT:

System 5.4.1 (B/C: 6) Tier 3	MD 210 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along MD 210 at key locations.	PE: $1.1 M CO: $7.1 M Recurring Cost: $104.2 K Annual O&M: $1.1 M
System 5.4.2 (B/C: 6) Tier 3	MD 210 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along MD 210 at key locations.	PE: $7.6 M CO: $50.6 M

PROGRESS STATUS:

- Evaluate PG County HSR Proposal (completed)
- TSMO to be included as part of NEPA re-evaluation (TBD)

TSMO SYSTEM # 6

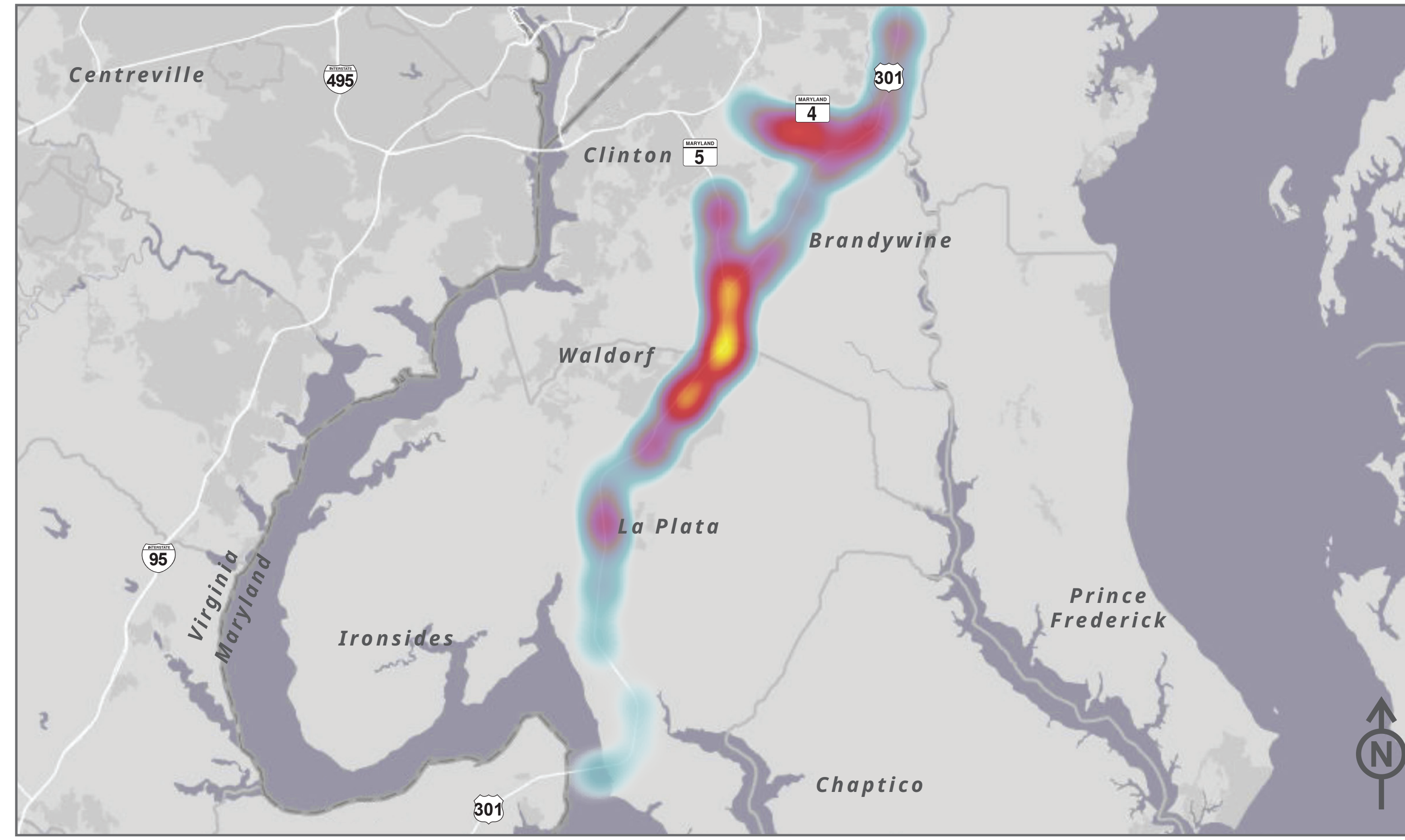


AADT Range	58-101 K
Total Incidents	1337
User Delay ('000 Hrs)	1922
Traffic Signals	36
User Cost ($M)	$2072

UNCONGESTED (**TTI < 1.15**) MODERATE CONGESTION (**1.15 < TTI < 1.3**) HEAVY CONGESTION (**1.3 < TTI < 2.0**) SEVERE CONGESTION (**TTI > 2.0**)

AM TTI PM TTI

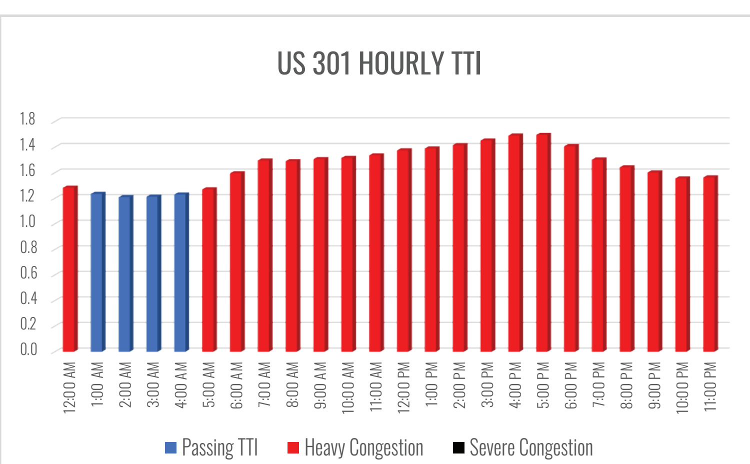
CRASH DENSITY

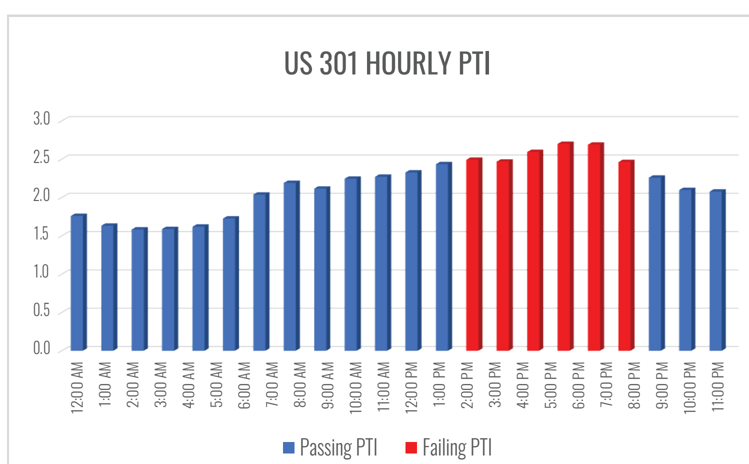


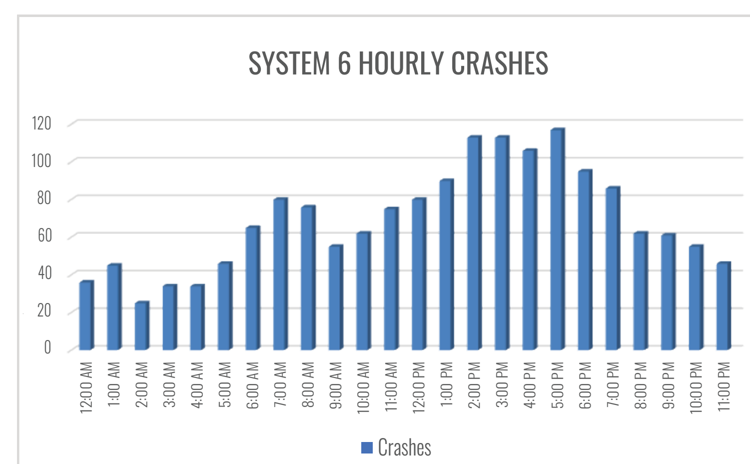
Crash Density: Sparse Dense

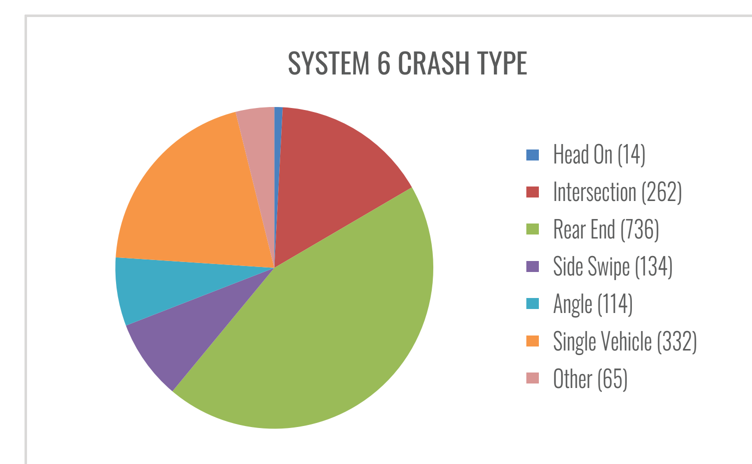
BACKGROUND: TSMO System # 6 improves operations for major traffic movement from Southern Maryland towards Washington DC through Waldorf and La Plata. US 301 is designated as a Maryland Freight Route and segments are part of the critical rural and urban freight corridors. The System experiences heavy congestion during both peak periods in La Plata and Waldorf. South of La Plata, the congestion is related to heavy truck operations, particularly at the Nice Bridge.

SAFETY OVERVIEW: The highest concentrations of crashes are along MD 4 and US 301 between MD 5 and Waldorf. Crash data shows that the highest number of crashes occur in the afternoon and the most common crash type is rear ends. In 2018, there were 1657 crashes reported within TSMO System # 6, with eleven fatalities and 759 injuries.

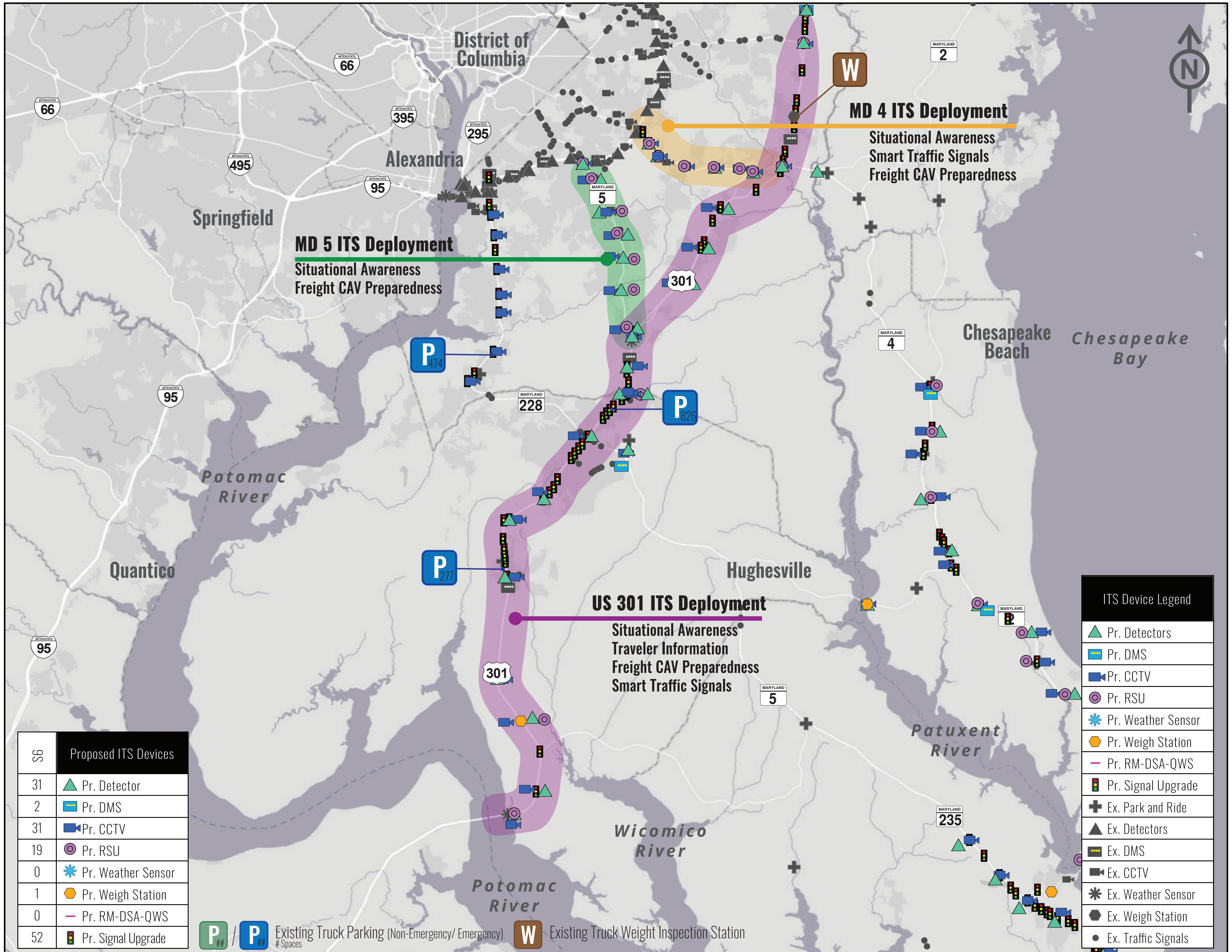








TSMO SYSTEM # 6: ITS OVERVIEW



COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	$1	$5	$10
Construction	$9	$10	$32	$69
Total	$11	$11	$36	$79
Annual recurring costs: $412.7 K		Annual O&M costs: $6.8 M		

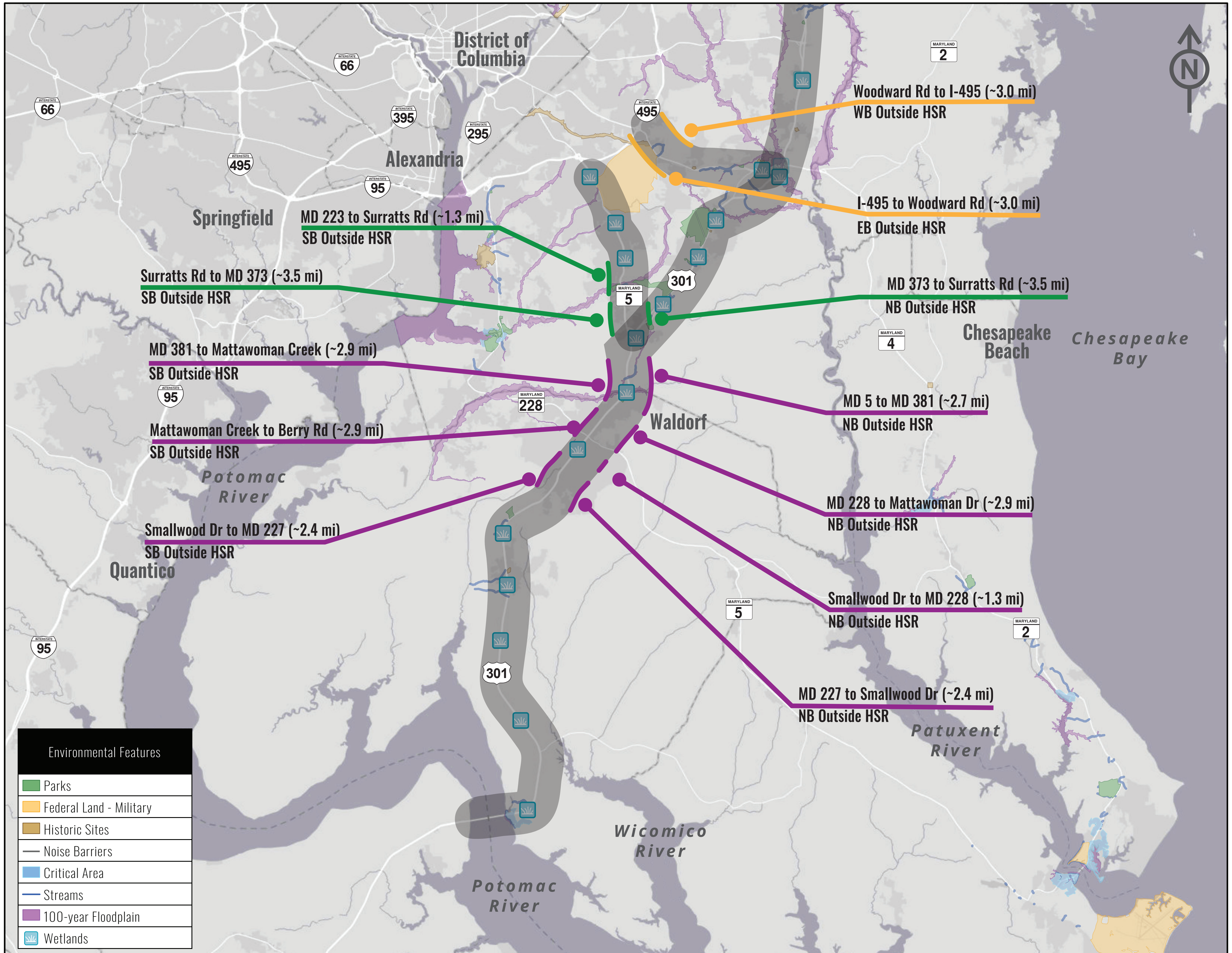
SUB-SYSTEM DEPLOYMENT:

System 6.1.1 (B/C: 6) Tier 1	MD 5 ITS Deployment Deployment of VMS signs, CCTV, traffic detectors, and RSU along MD 5 between I-495 and US 301.	PE: $0.4 M CO: $2.7 M Recurring Cost: $40.0 K Annual O&M: $0.4 M
System 6.1.2 (B/C: 31) Tier 1	MD 4 ITS Deployment Deployment of CCTV, traffic detectors, and RSU along MD 4 between I-495 and US 301.	PE: $0.2 M CO: $1.4 M Recurring Cost: $25.9 K Annual O&M: $0.2 M
System 6.1.3 (B/C: 43) Tier 1	US 301 ITS Deployment Deployment of CCTV, traffic detectors, and RSU along US 301 between US 50 and VA State Line.	PE: $0.8 M CO: $5.1 M Recurring Cost: $67.6 K Annual O&M: $0.8 M
System 6.2.1 (B/C: 16) Tier 1	US 301 Traffic Signal Upgrade Upgrade existing traffic signals along US 301 between US 50 and VA State Line to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled and have TSP.	PE: $1.3 M CO: $8.7 M Recurring Cost: $35.3 K Annual O&M: $1.3 M
System 6.2.2 (B/C: 12) Tier 3	MD 4 Traffic Signal Upgrade Upgrade existing traffic signals along MD 4 between I-495 and US 50 to be fully-actuated, ATMS enabled, and have TSP.	PE: $0.2 M CO: $1.2 M Recurring Cost: $2.2 K Annual O&M: $0.2 M
System 6.3.1 Tier 3	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $4.7 M CO: $31.7 M Annual O&M: $1.5 M

PROGRESS STATUS:

- US 301 Smart Traffic Signals (TRP)
- Hard Running Shoulder (evaluated as part of US 301 planning study)
- Nice Bridge Project (funded - potential situational awareness improvements)

TSMO SYSTEM # 6: ROADWAY OVERVIEW



HARD SHOULDER RUNNING: US 301 | MD 5 | MD 4

COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	$1	$5	$10
Construction	$9	$10	$32	$69
Total	$11	$11	$36	$79
Annual recurring costs: $412.7 K		Annual O&M costs: $6.8 M		

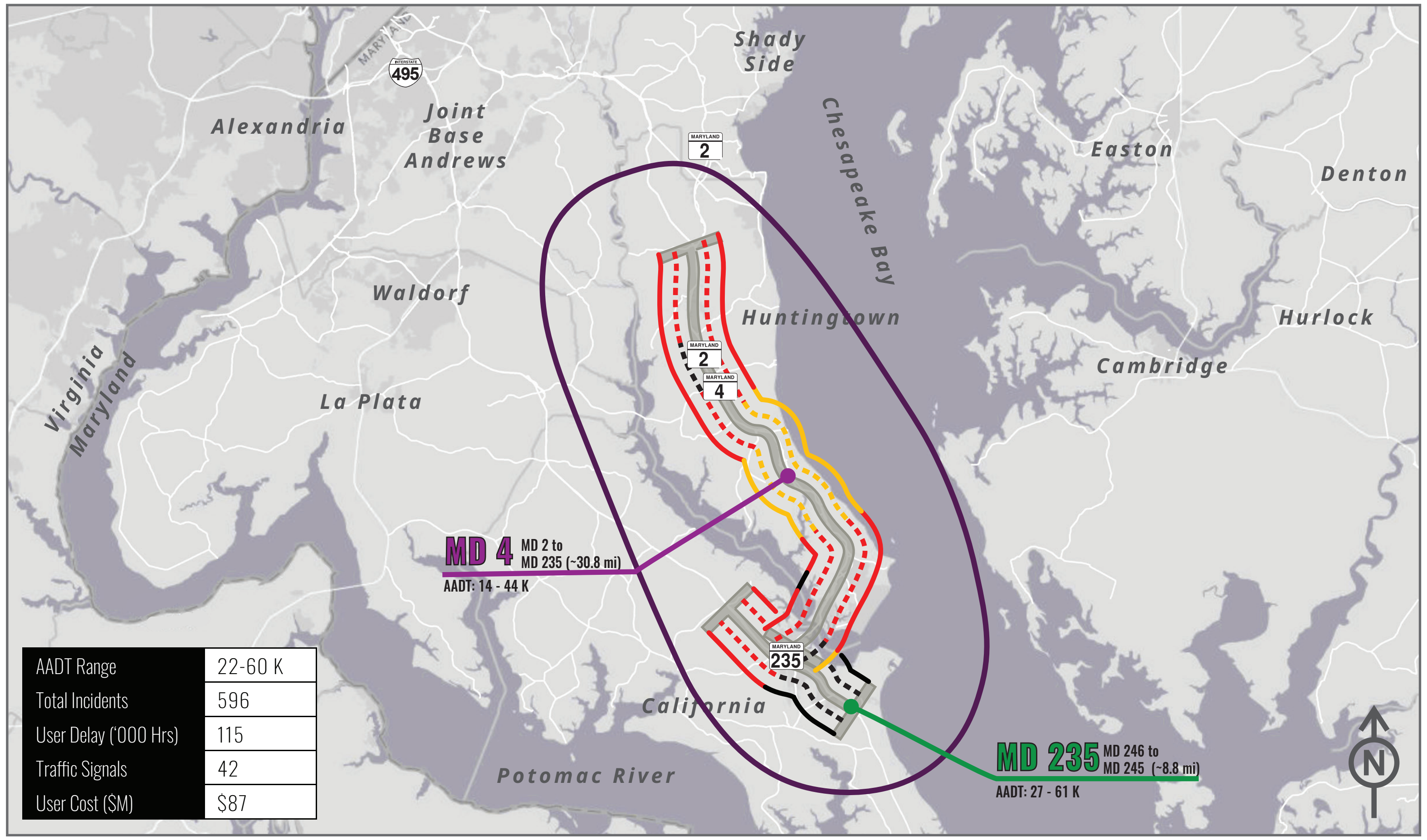
SUB-SYSTEM DEPLOYMENT:

System 6.4.1 (B/C: 1) Tier 3	MD 5 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along MD 5 at key locations.	PE: $0.7 M CO: $4.6 M Recurring Cost: $67.0 K Annual O&M: $0.7 M
System 6.4.2 (B/C: 1) Tier 3	MD 5 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along MD 5 at key locations.	PE: $3.4 M CO: $22.9 M
System 6.4.3 (B/C: 3) Tier 3	MD 4 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection outside hard shoulder running along MD 4 at key locations.	PE: $0.5 M CO: $3.0 M Recurring Cost: $44.6 K Annual O&M: $0.5 M
System 6.4.4 (B/C: 3) Tier 3	MD 4 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along MD 4 at key locations.	PE: $2.1 M CO: $13.8 M
System 6.4.5 (B/C: 5) Tier 3	US 301 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along US 301 at key locations.	PE: $1.3 M CO: $8.9 M Recurring Cost: $130.2 K Annual O&M: $1.3 M
System 6.4.6 (B/C: 5) Tier 3	US 301 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along US 301 at key locations.	PE: $2.3 M CO: $15.7 M

PROGRESS STATUS:

- US 301 Smart Traffic Signals (TRP)
- Hard Running Shoulder (evaluated as part of US 301 planning study)
- Nice Bridge Project (funded - potential situational awareness improvements)

TSMO SYSTEM # 7

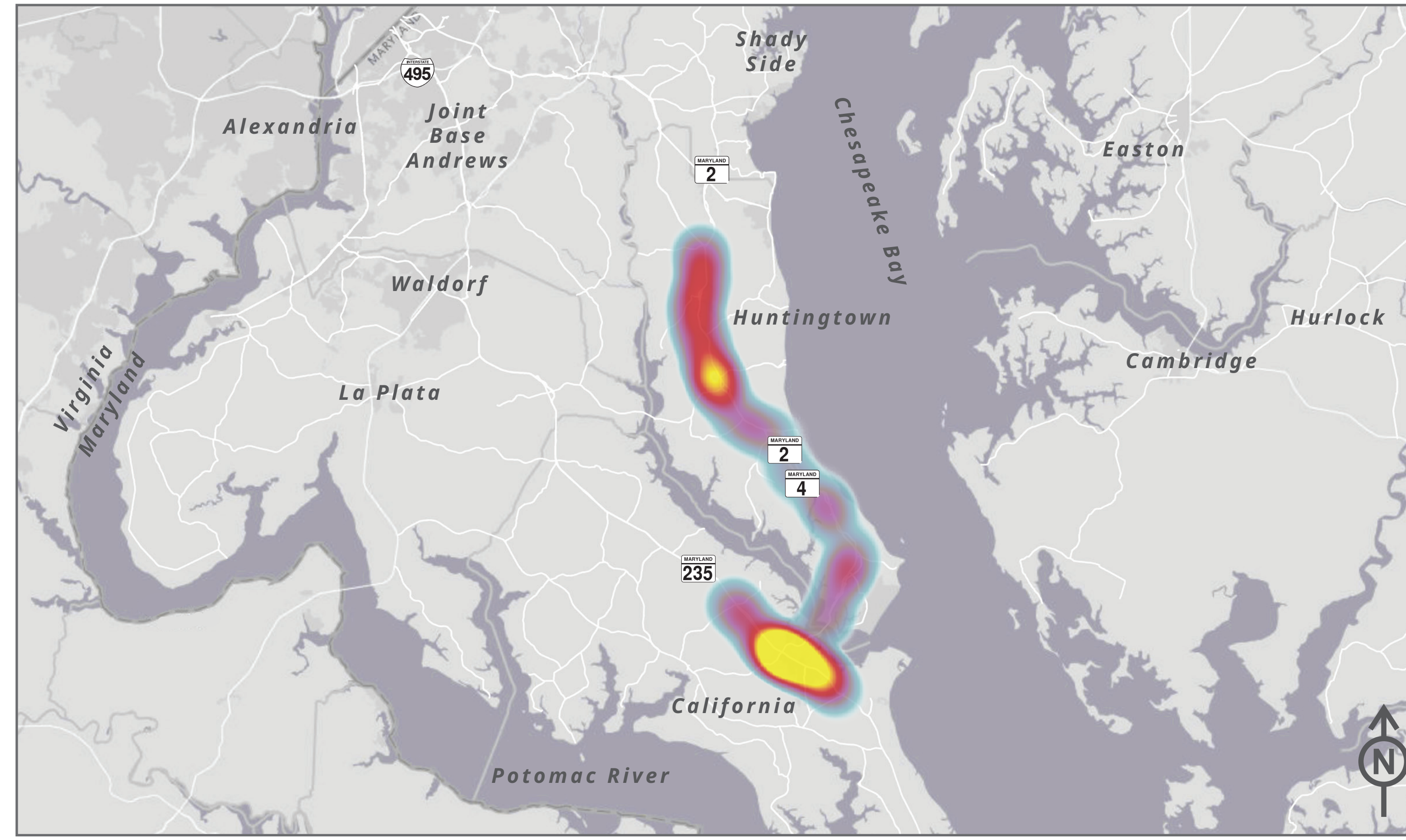


AADT Range	22-60 K
Total Incidents	596
User Delay ('000 Hrs)	115
Traffic Signals	42
User Cost ($M)	$87

UNCONGESTED (**TTI < 1.15**) MODERATE CONGESTION (**1.15 < TTI < 1.3**) HEAVY CONGESTION (**1.3 < TTI < 2.0**) SEVERE CONGESTION (**TTI > 2.0**)

AM TTI PM TTI

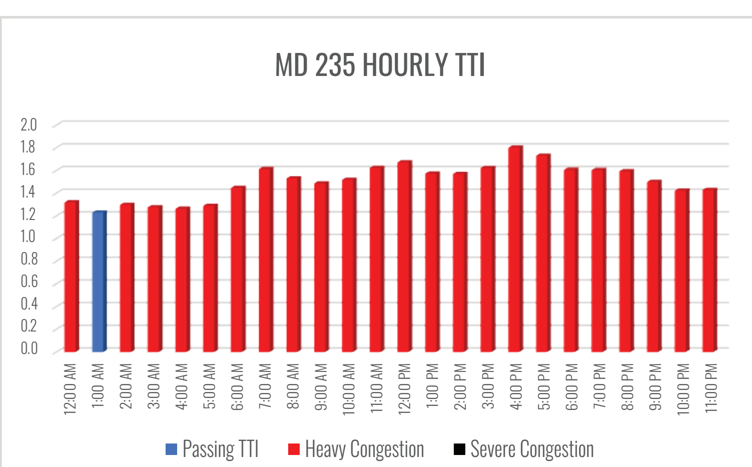
CRASH DENSITY

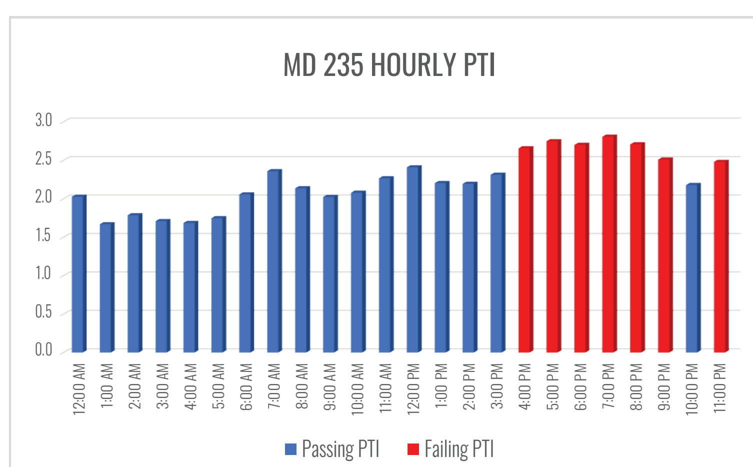


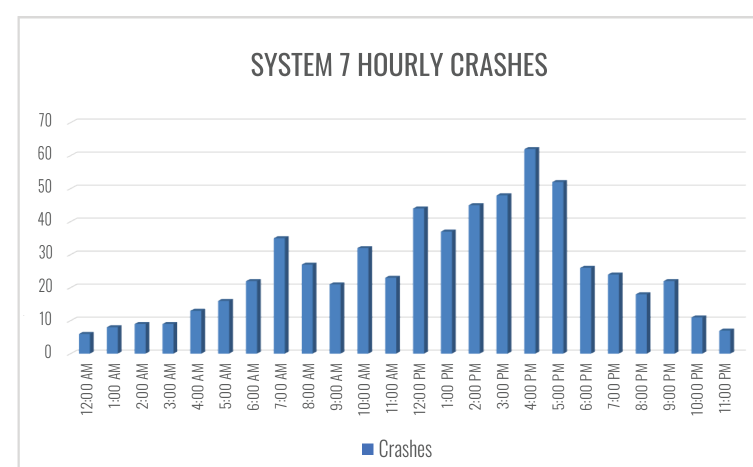
Crash Density: Sparse Dense

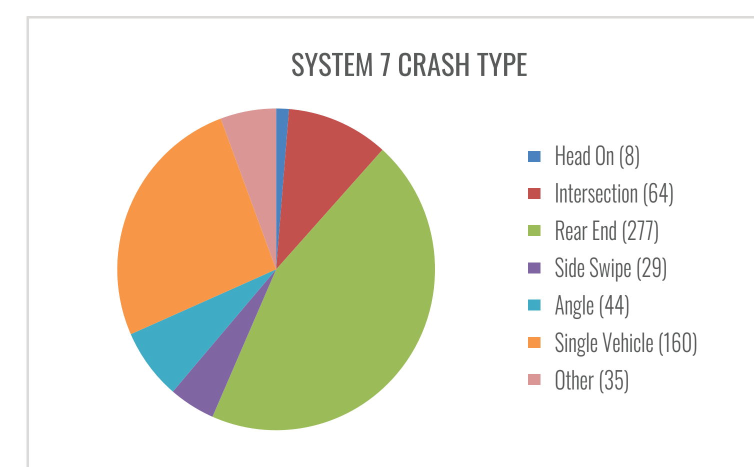
BACKGROUND: System # 7 provides primary north-south access to Calvert County and connects to St. Mary's County. It provides commuters access to Washington DC and the Patuxent Naval Air Station, St. Mary's County's largest employer. The Thomas Johnson bridge connects St. Mary's and Calvert counties over the Patuxent River and serves as an evacuation route for the Calvert Cliffs Nuclear Power Station. High traffic volumes across the bridge during peak travel periods cause frequent delays.

SAFETY OVERVIEW: The highest concentrations of crashes are along MD 235 between MD 4 and MD 237. MD 2/ MD 4 also has high concentration of crashes around Prince Frederick. Crash data shows that the highest number of crashes occur in the afternoon and the most common crash type is rear ends. In 2018, there were 617 crashes reported within TSMO System # 7, with one fatality and 288 injuries.

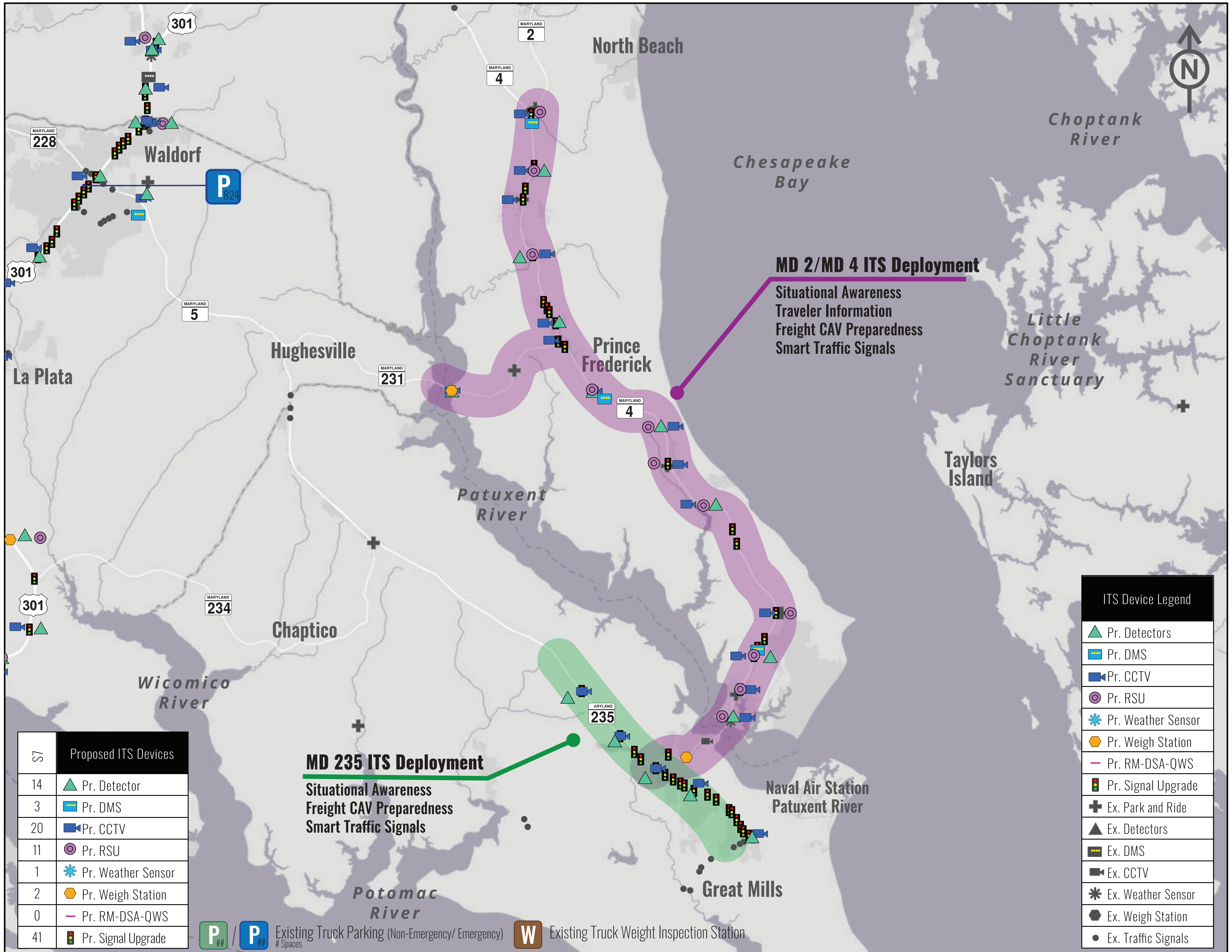








TSMO SYSTEM # 7: ITS OVERVIEW



COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	$1	$0	$N/A
Construction	$8	$7	$2	$N/A
Total	$10	$8	$3	$N/A
Annual recurring costs: $118.7 K		Annual O&M costs: $2.4 M		

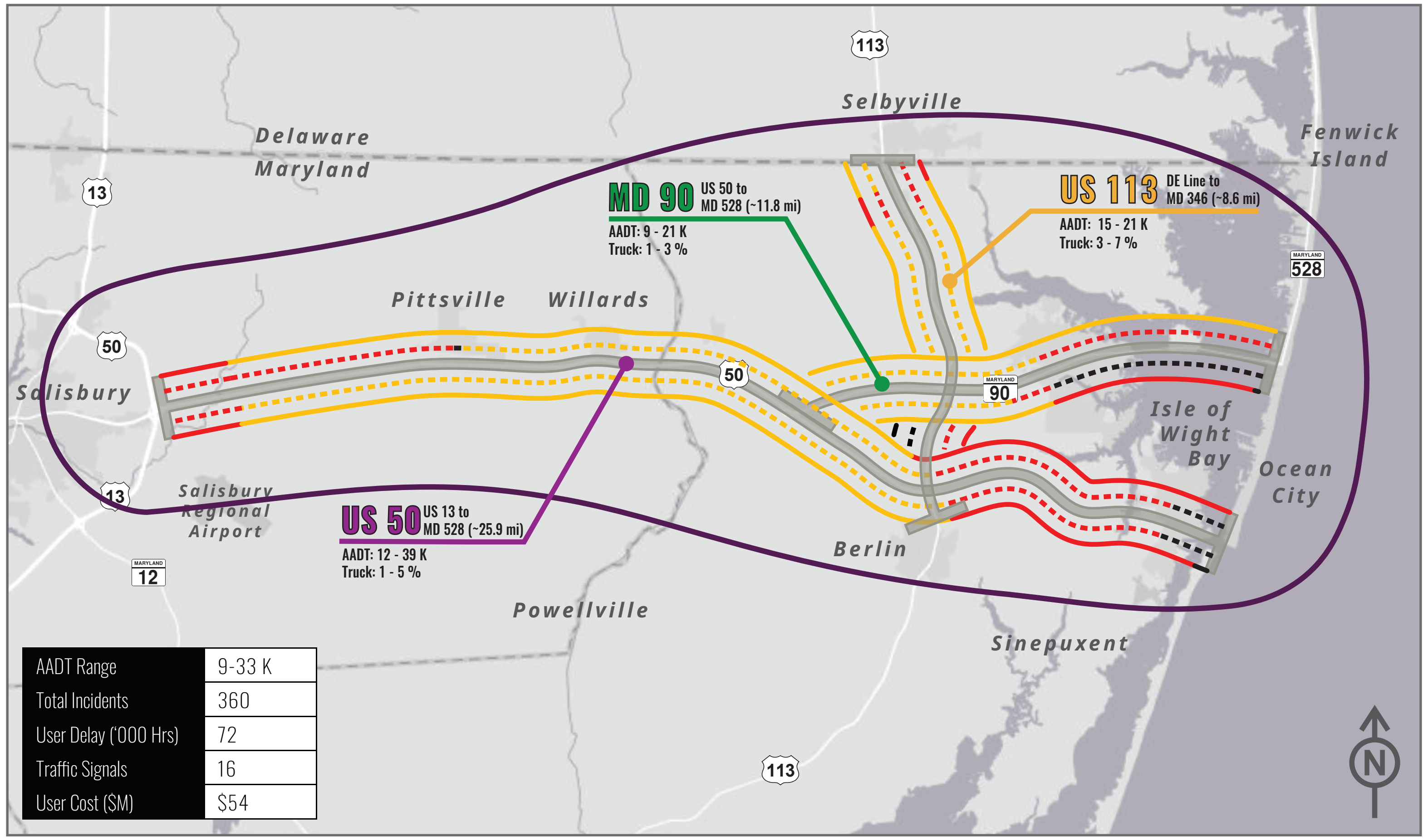
SUB-SYSTEM DEPLOYMENT:

System 7.1.1 (B/C: 10) Tier 1	MD 2/ MD 4 ITS Deployment Deployment of an In-Motion Weight Station, VMS signs, CCTV, traffic detectors, and RSU along MD 2/ MD 4 between MD 2/ MD 4 split and MD 235.	PE: $1.1 M CO: $7.6 M Recurring Cost: $70.6 K Annual O&M: $1.1 M
System 7.1.2 (B/C: 57) Tier 2	MD 235 ITS Deployment Deployment of an In-Motion Weight Station, a Weather station, CCTV, and traffic detectors, along MD 235 between MD 245 and MD 246.	PE: $0.1 M CO: $0.8 M Recurring Cost: $18.6 K Annual O&M: $0.1 M
System 7.2.1 (B/C: 4) Tier 1	MD 2/ MD 4 Traffic Signal Upgrade Upgrade existing traffic signals along MD 2/ MD 4 between MD 2/ MD 4 split and MD 235 to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled and have TSP.	PE: $0.6 M CO: $4.1 M Recurring Cost: $15.1 K Annual O&M: $0.6 M
System 7.2.2 (B/C: 19) Tier 2	MD 235 Traffic Signal Upgrade Upgrade existing traffic signals along MD 235 between MD 245 and MD 246 to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, and ATMS enabled.	PE: $0.4 M CO: $2.5 M Recurring Cost: $14.4 K Annual O&M: $0.4 M
System 7.3.1 Tier 3	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $0.3 M CO: $2.3 M Annual O&M: $0.1 M

PROGRESS STATUS:

- Thomas Johnson Bridge (funded - potential situational awareness improvement)

TSMO SYSTEM # 8

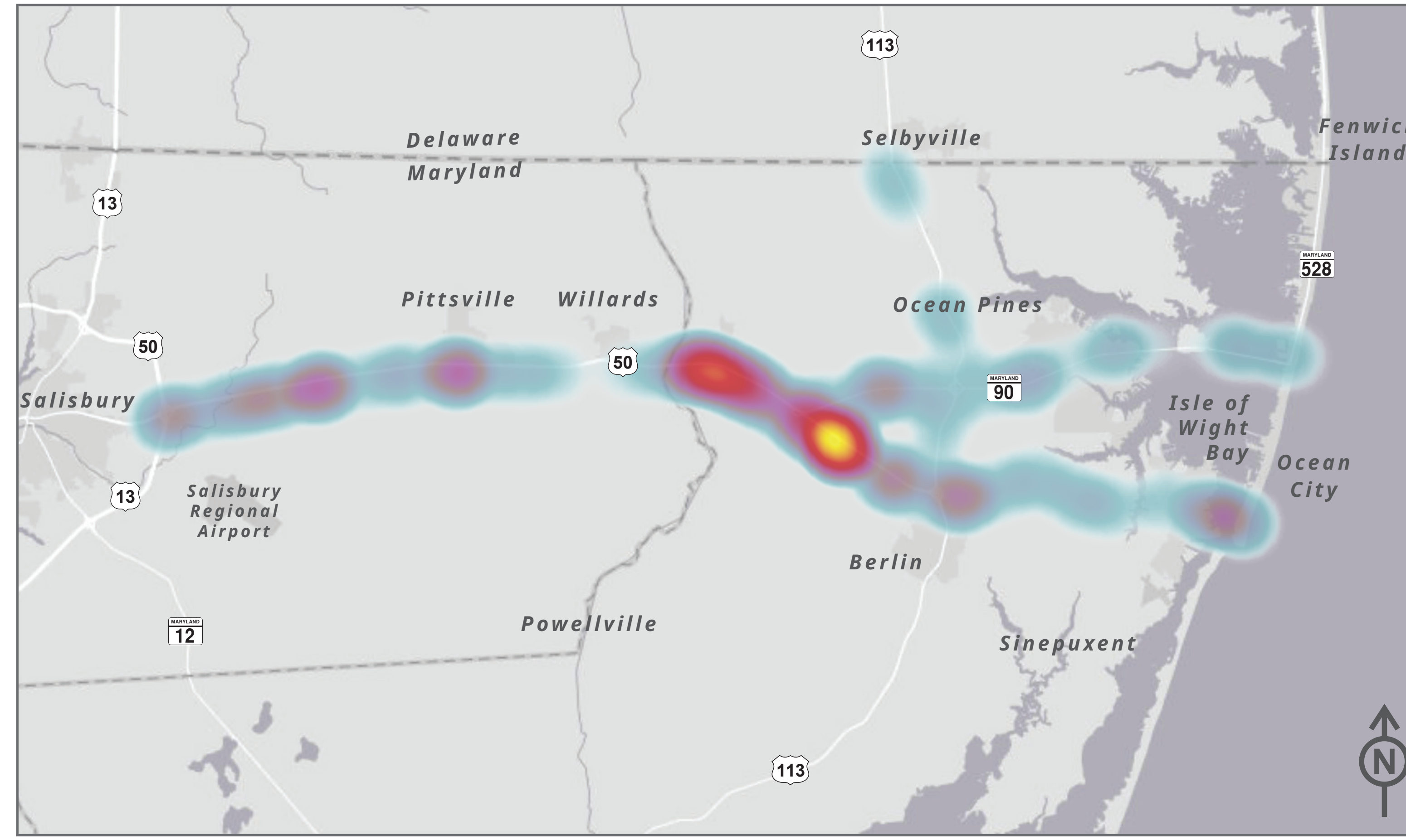


AADT Range	9-33 K
Total Incidents	360
User Delay ('000 Hrs)	72
Traffic Signals	16
User Cost ($M)	$54

UNCONGESTED (TTI < 1.15) MODERATE CONGESTION (1.15 < TTI < 1.3) HEAVY CONGESTION (1.3 < TTI < 2.0) SEVERE CONGESTION (TTI > 2.0)

AM SUMMER TTI PM SUMMER TTI

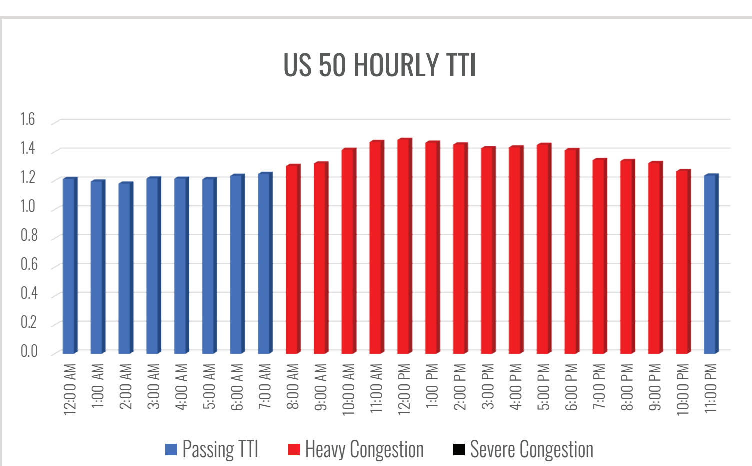
CRASH DENSITY

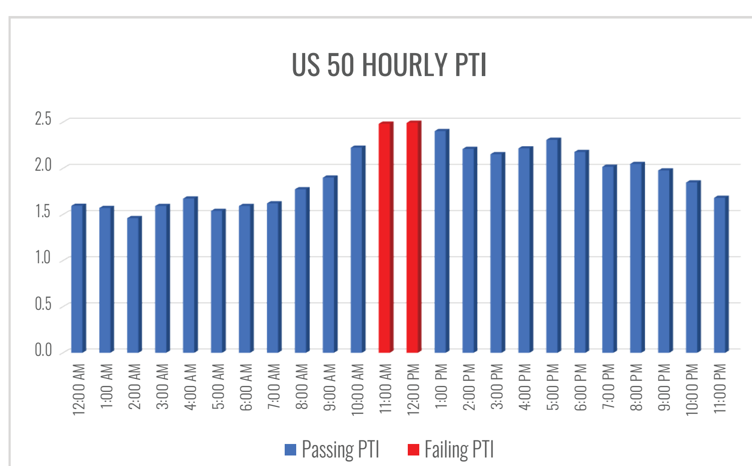


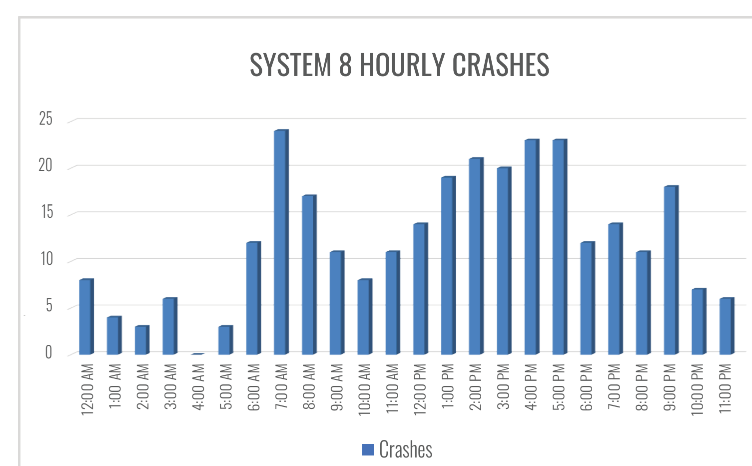
Crash Density: Sparse — Dense

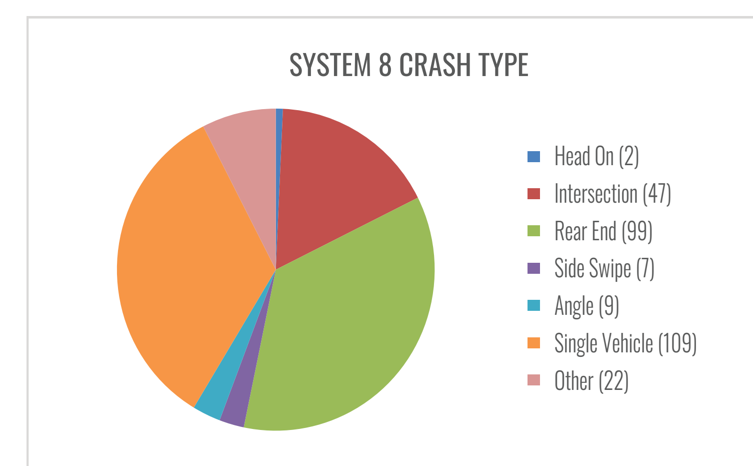
SYSTEM LIMITS: System # 8 provides access to Ocean City, primarily during the summer season. US 50 is also envisioned as a future Freight Corridor. System improvements are compatible with the US 50 Ocean Gateway Study and MD 589 Feasibility Study recommendations.

SAFETY OVERVIEW: The highest concentrations of crashes are along US 50 between MD 610 and east of MD 90. Crash data shows that the highest number of crashes occur between 6:00 AM and 8:00 AM and between 1:00 PM and 5:00 PM when vacationers travel to or return from the beach and the most common crash type is rear ends. In 2018, there were 295 crashes reported within TSMO System # 8, with one fatality and 140 injuries.

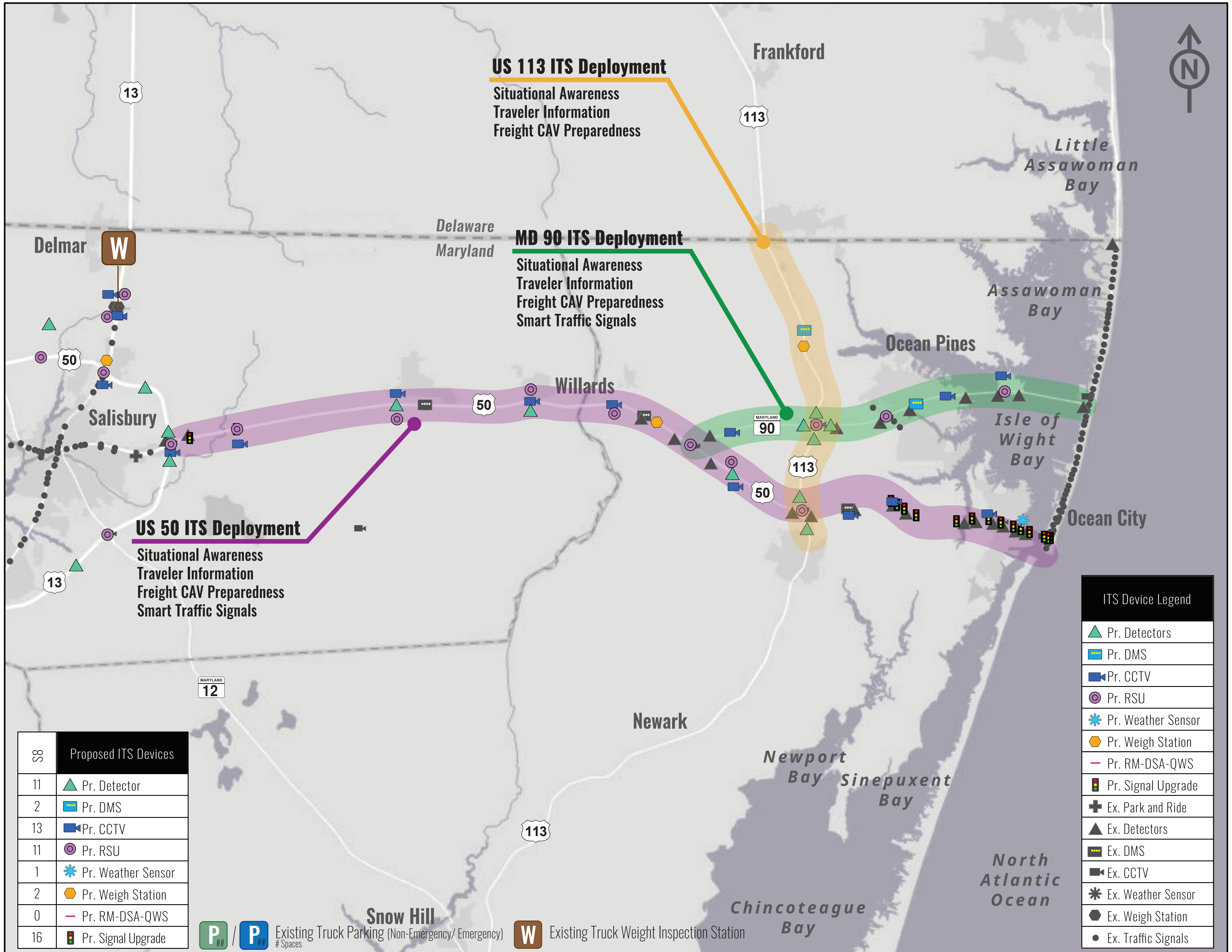








TSMO SYSTEM # 8: ITS OVERVIEW



COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	<$1	<$1	$2
Construction	$6	$2	$1	$14
Total	$7	$2	$2	$16
Annual recurring costs: $113.3 K		Annual O&M costs: $1.8 M		

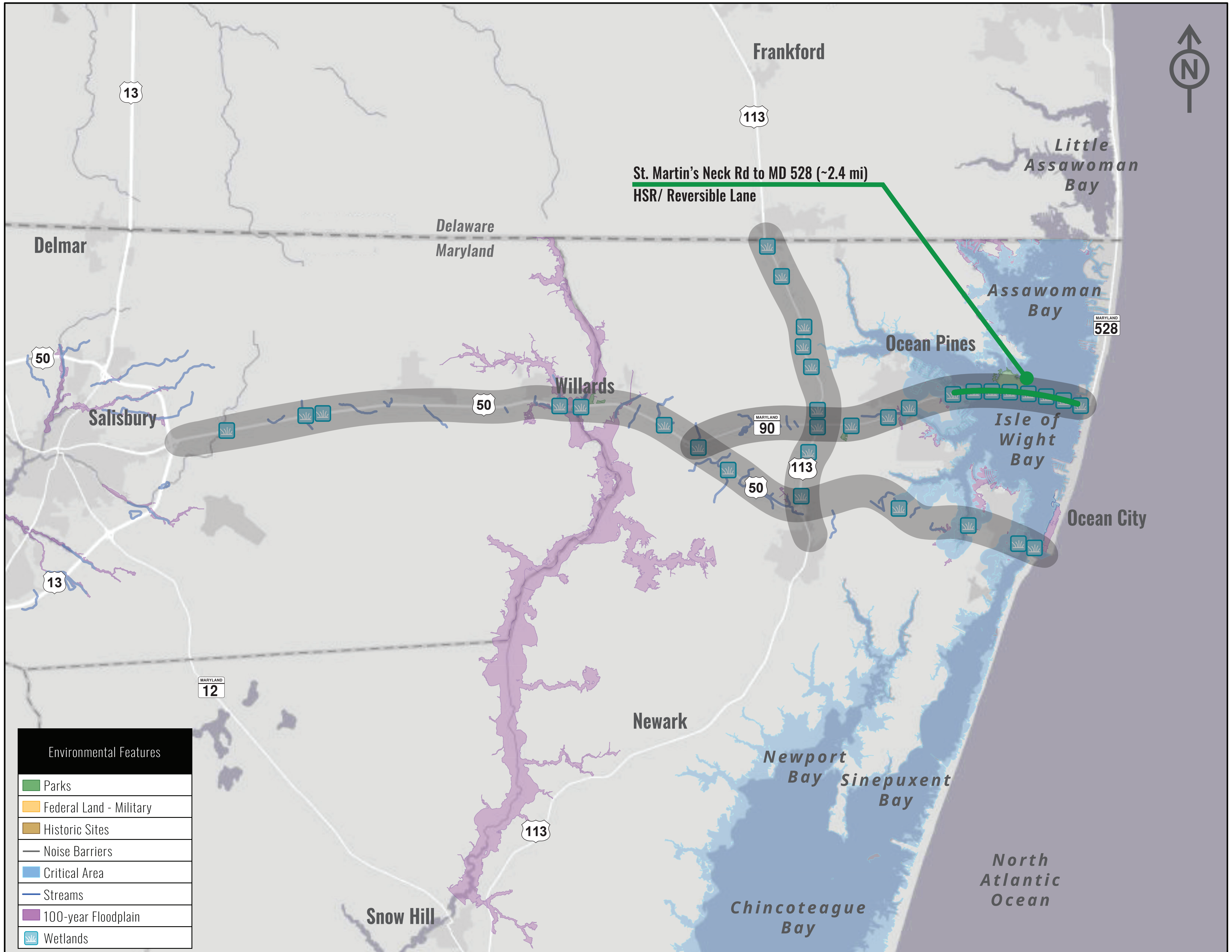
SUB-SYSTEM DEPLOYMENT:

System 8.1.1 (B/C: 2) Tier 1	US 50/ US 13 ITS Deployment Deployment of an In-Motion Weight Station, CCTV, traffic detectors, and RSU along US 50 between US 13 and Ocean City.	PE: $0.5 M CO: $3.3 M Recurring Cost: $42.4 K Annual O&M: $0.5 M
System 8.1.2 (B/C: 1) Tier 1	MD 90 ITS Deployment Deployment of a Weather Station, VMS signs, CCTV, traffic detectors, and RSU along MD 90 between US 113 and Ocean City.	PE: $0.2 M CO: $1.1 M Recurring Cost: $15.6 K Annual O&M: $0.2 M
System 8.1.3 (B/C: 1) Tier 2	US 113 ITS Deployment Deployment of an In-Motion Weight Station, VMS signs, CCTV, traffic detectors, and RSU along US 113 between DE State Line and US 50.	PE: $0.3 M CO: $1.9 M Recurring Cost: $6.6 K Annual O&M: $0.3 M
System 8.2.1 (B/C: 1) Tier 2	US 50 Traffic Signal Upgrade Upgrade existing traffic signals along US 50 between US 13 and Ocean City to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled and have TSP.	PE: $0.3 M CO: $1.9 M Recurring Cost: $11.5 K Annual O&M: $0.3 M
System 8.3.1 Tier 3	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $0.2 M CO: $1.5 M Annual O&M: $0.1 M

PROGRESS STATUS:

- Hard Shoulder Running and Reversible Lane along MD 90 approaching Ocean City
- Smart Signal Upgrade along US 50 from US 13 to Ocean City
- Freight/ CAV ITS upgrade along US 50 from US 13 to Ocean City

TSMO SYSTEM # 8: ROADWAY OVERVIEW



REVERSIBLE LANE: MD 90

COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	<$1	<$1	$2
Construction	$6	$2	$1	$14
Total	$7	$2	$2	$16
Annual recurring costs: $113.3 K	Annual O&M costs: $1.8 M			

SUB-SYSTEM DEPLOYMENT:

System 8.4.1 (B/C: 1) Tier 3	MD 90 Reversible Lane (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for a reversible lane along MD 90 approaching Ocean City.	PE: $0.5 M CO: $3.3 M Recurring Cost: $37.2 K Annual O&M: $0.5 M
System 8.4.2 (B/C: 1) Tier 3	MD 90 Reversible Lane (Roadway) Civil improvements for a reversible lane along MD 90 approaching Ocean City.	PE: $1.7 M CO: $11.0 M

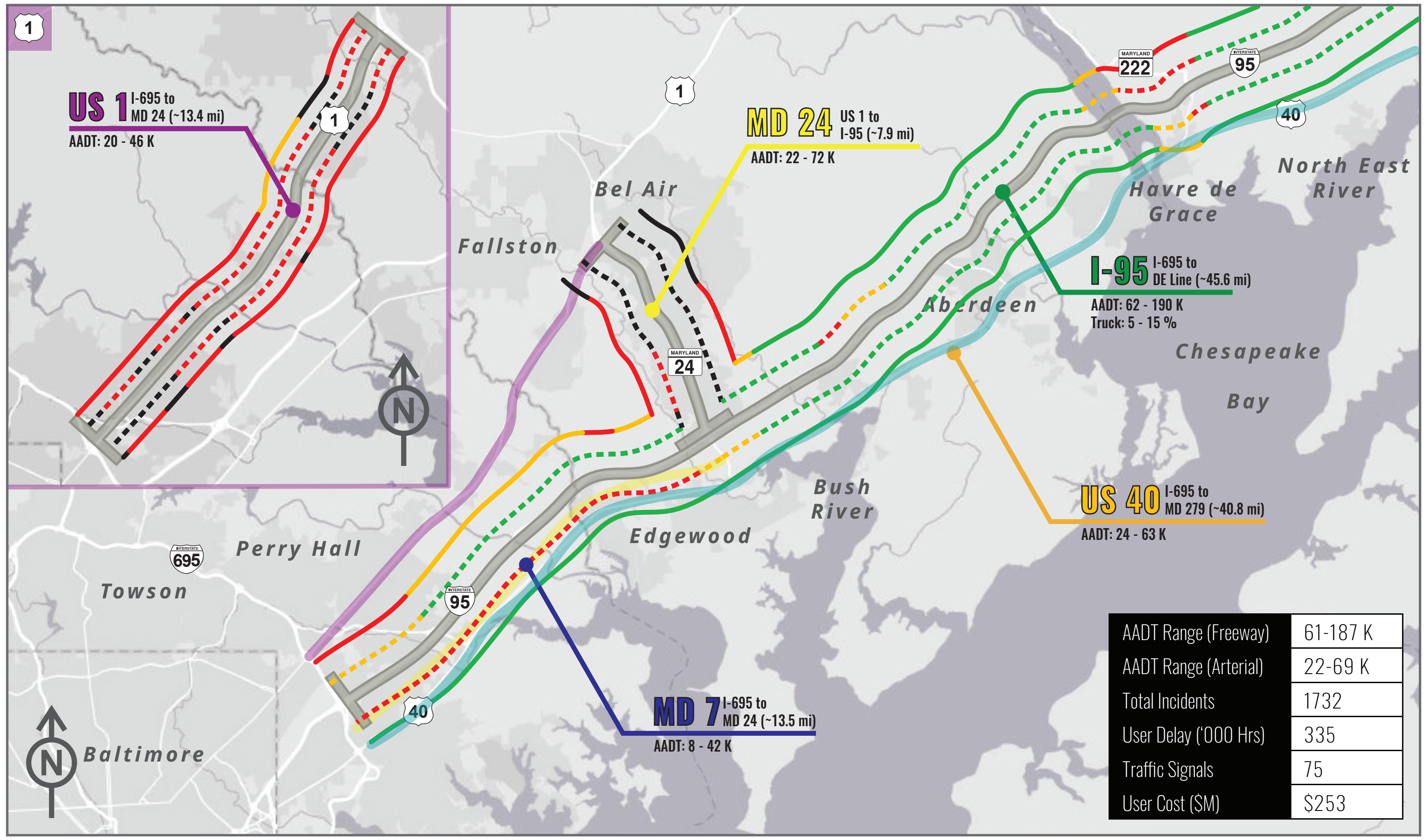
PROGRESS STATUS:

- Hard Shoulder Running and Reversible Lane along MD 90 approaching Ocean City
- Smart Signal Upgrade along US 50 from US 13 to Ocean City
- Freight/ CAV ITS upgrade along US 50 from US 13 to Ocean City

TSMO MASTER PLAN

MARYLAND 24 | INTERSTATE 95 | 1 | 40 | MARYLAND 7

TSMO SYSTEM # 9

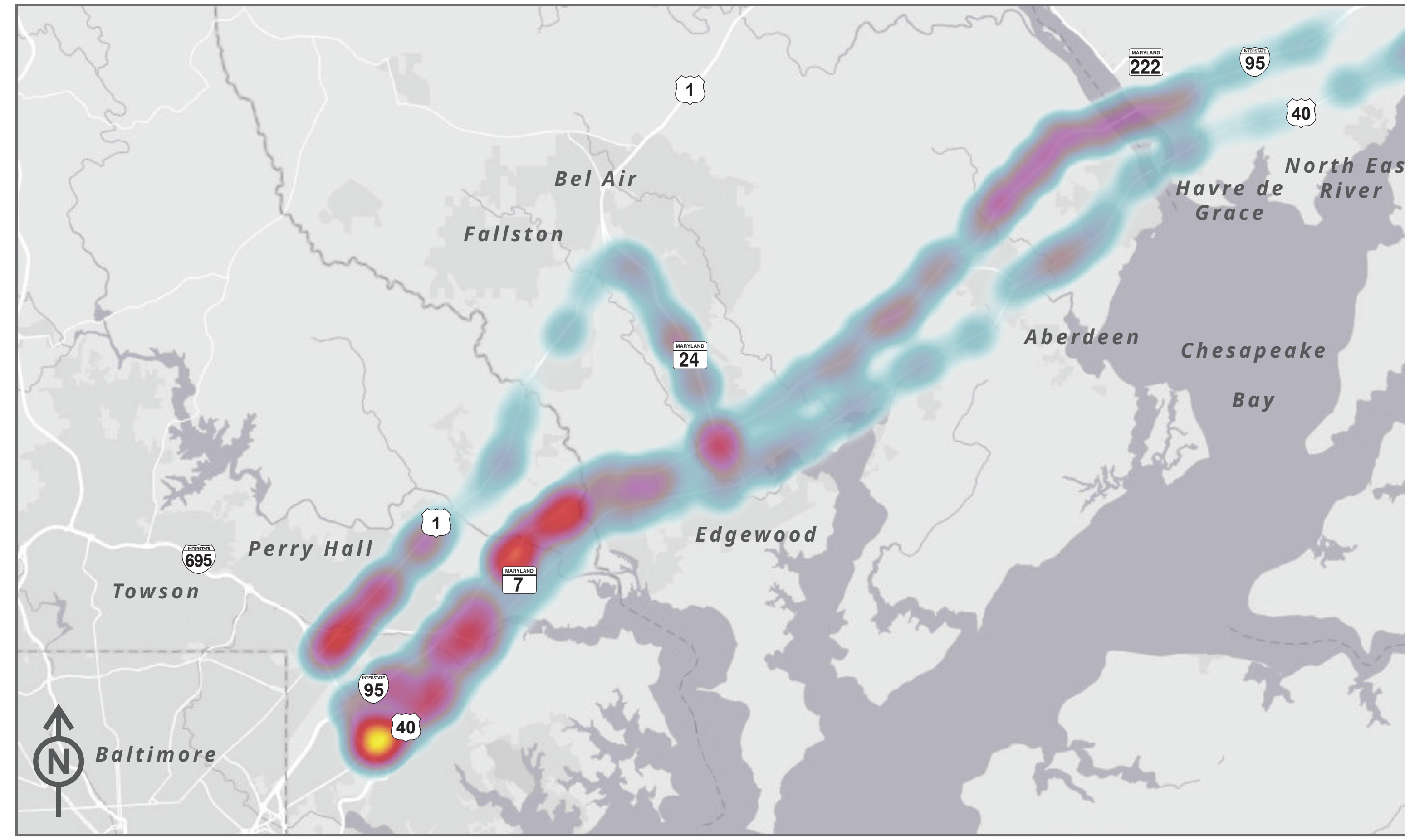


AADT Range (Freeway)	61-187 K
AADT Range (Arterial)	22-69 K
Total Incidents	1732
User Delay ('000 Hrs)	335
Traffic Signals	75
User Cost ($M)	$253

UNCONGESTED (TTI < 1.15) | MODERATE CONGESTION (1.15 < TTI < 1.3) | HEAVY CONGESTION (1.3 < TTI < 2.0) | SEVERE CONGESTION (TTI > 2.0)

AM TTI | PM TTI

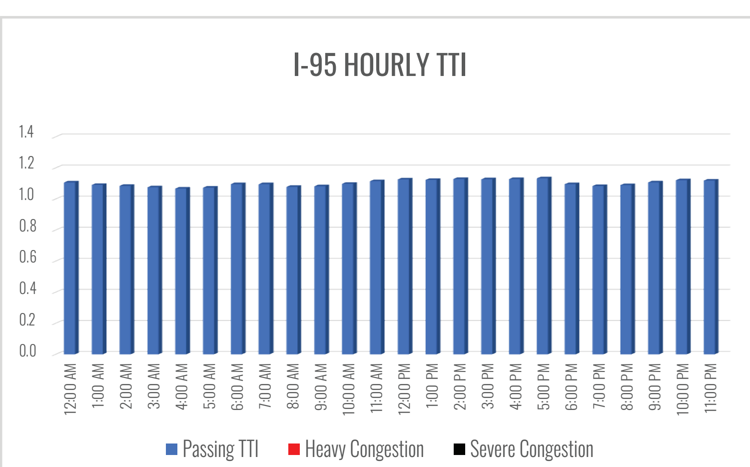
CRASH DENSITY

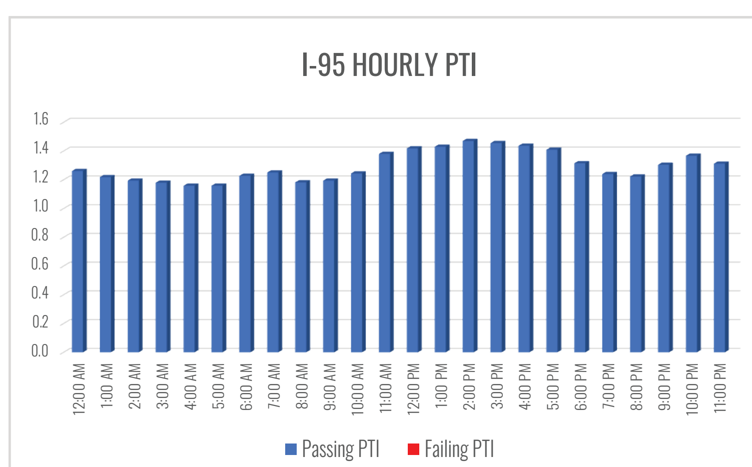


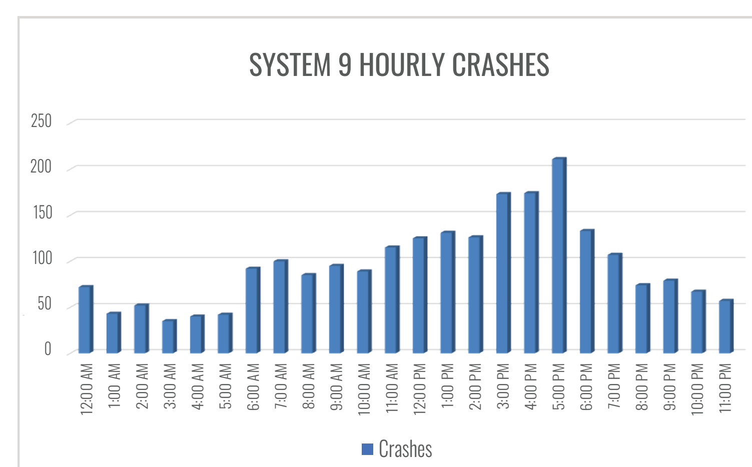
Crash Density: Sparse — Dense

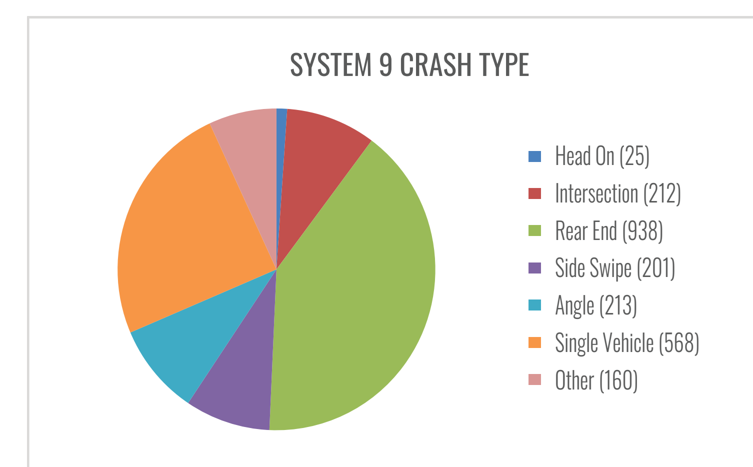
BACKGROUND: TSMO System # 9 improves operations along the I-95 corridor that connects Baltimore with Delaware. Within the system, I-95 has three parallel routes: US 1, MD 7, and US 40. I-95 and US 40 are designated as Maryland Freight Routes. I-95 is also designated as part of the National Highway Freight Network.

SAFETY OVERVIEW: The highest concentrations of crashes are along US 40 around Rossville Boulevard, and along I-95 between New Forge Road and the Baltimore County/ Harford County line. Crash data shows that the highest number of crashes occur during the PM peak and the most common crash type is rear ends. In 2018, there were 2317 crashes reported within TSMO System # 9, with 22 fatalities and 1043 injuries.

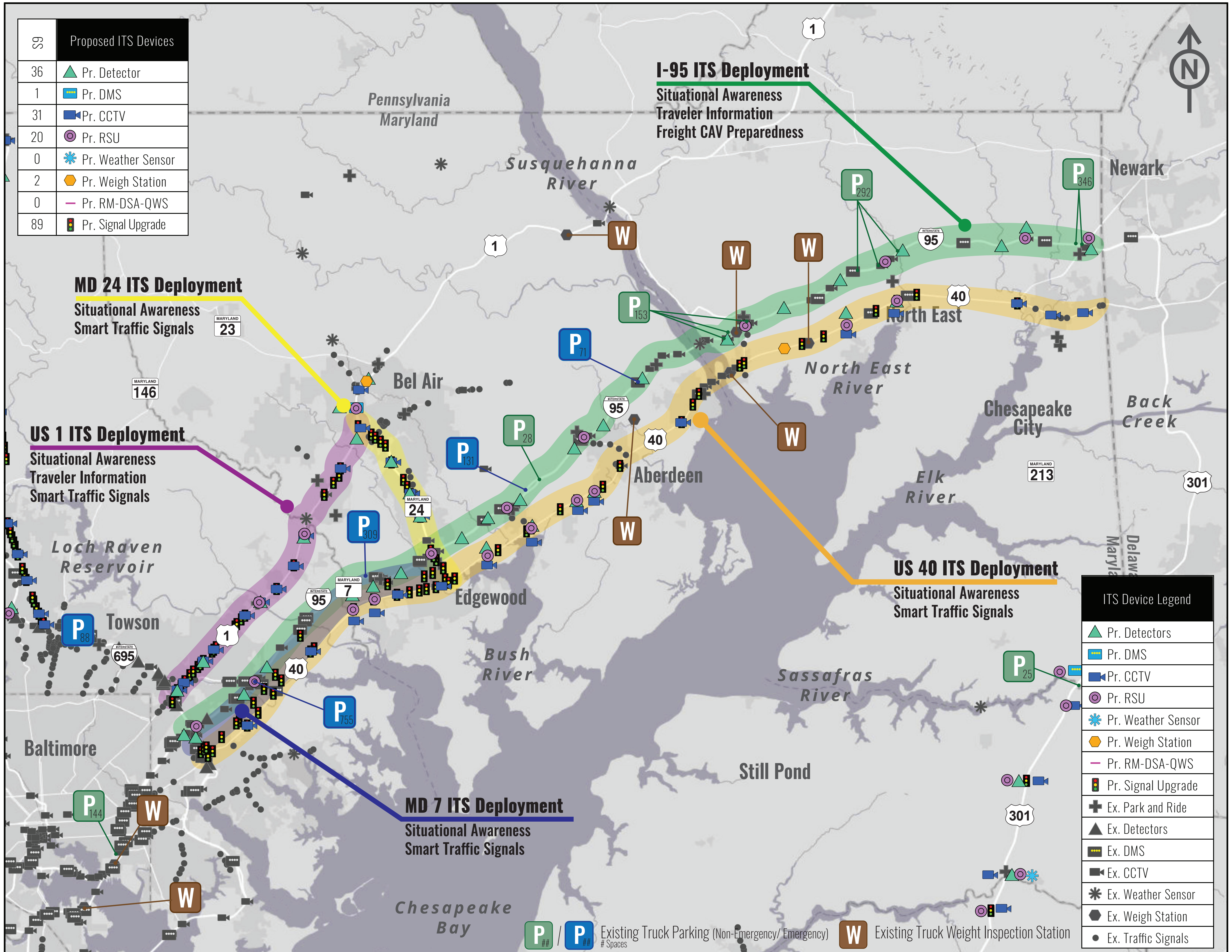








TSMO SYSTEM # 9: ITS OVERVIEW



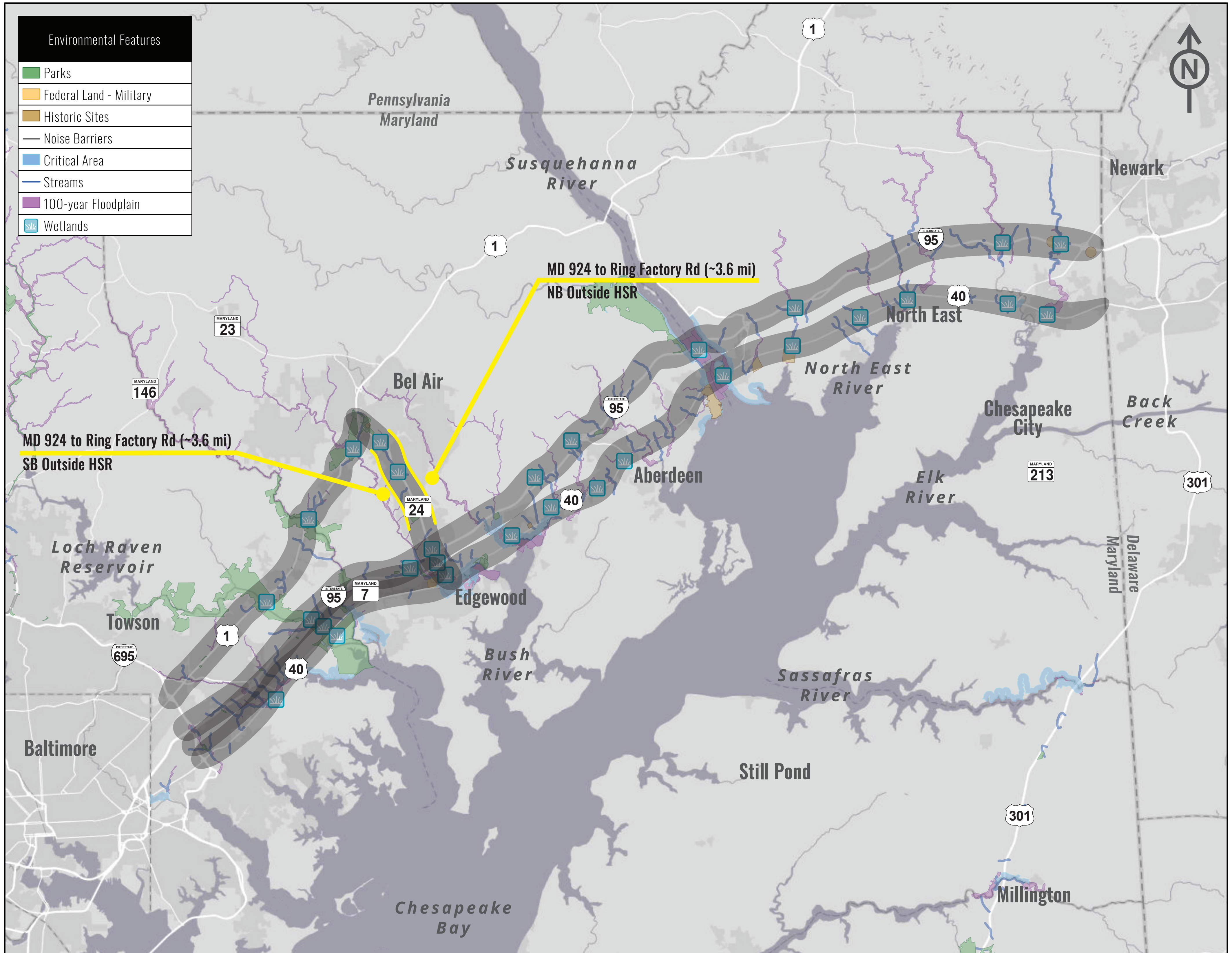
COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$2	$2	$1	$3
Construction	$10	$16	$9	$20
Total	$12	$18	$11	$23
Annual recurring costs: $256.2 K		Annual O&M costs: $4.9 M		

SUB-SYSTEM DEPLOYMENT:

System 9.1.1 (B/C: 39) Tier 2	I-95/ I-695 ITS Deployment Deployment traffic detectors, and RSU along I-95 between I-695 and DE State Line.	PE: $0.2 M CO: $1.6 M Recurring Cost: $19.4 K Annual O&M: $0.2 M
System 9.1.2 (B/C: 8) Tier 2	US 1 ITS Deployment Deployment of an In-Motion Weight Station, VMS signs, CCTV, traffic detectors, and RSU along US 1 between I-695 and US 1 Bypass.	PE: $0.6 M CO: $4.0 M Recurring Cost: $46.9 K Annual O&M: $0.6 M
System 9.1.3 (B/C: 33) Tier 2	US 40 ITS Deployment Deployment of an In-Motion Weight Station, CCTV along US 40 between I-695 and DE State Line.	PE: $0.6 M CO: $4.1 M Recurring Cost: $62.5 K Annual O&M: $0.6 M
System 9.1.4 (B/C: 49) Tier 1	MD 24 ITS Deployment Deployment of CCTV along MD 24 between US 1 and I-95.	PE: $0.1 M CO: $0.5 M Recurring Cost: $11.2 K Annual O&M: $0.1 M
System 9.2.1 (B/C: 1) Tier 1	US 1 Traffic Signal Upgrade Upgrade existing traffic signals along US 1 between I-695 and US 1 Bypass to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled and have TSP and Queue Jumping.	PE: $0.7 M CO: $5.0 M Recurring Cost: $17.3 K Annual O&M: $0.7 M
System 9.2.2 (B/C: 2) Tier 2	MD 24 Traffic Signal Upgrade Upgrade existing traffic signals along MD 24 between US 1 and I-95 to be equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled and have TSP.	PE: $0.2 M CO: $1.3 M Recurring Cost: $ 9.4 K Annual O&M: $0.2 M
System 9.2.3 (B/C: 5) Tier 2	US 40 Traffic Signal Upgrade Upgrade existing traffic signals along US 40 between I-695 and DE State Line to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled and have TSP.	PE: $1.2 M CO: $8.0 M Recurring Cost: $27.4 K Annual O&M: $1.2 M
System 9.2.4 (B/C: 1) Tier 3	MD 7 Traffic Signal Upgrade Upgrade existing traffic signals along MD 7 between I-695 and US 40 to be equipped with S-Cabinets, have Video Detection, have CAV Equipment, and ATMS enabled.	PE: $0.2 M CO: $1.5 M Recurring Cost: $10.1 K Annual O&M: $0.2 M
System 9.3.1 Tier 3	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $1.4 M CO: $9.3 M Annual O&M: $0.4 M

TSMO SYSTEM # 9: ROADWAY OVERVIEW



HARD SHOULDER RUNNING: MD 24

COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$2	$2	$1	$3
Construction	$10	$16	$9	$20
Total	$12	$18	$11	$23
Annual recurring costs: $256.2 K		Annual O&M costs: $4.9 M		

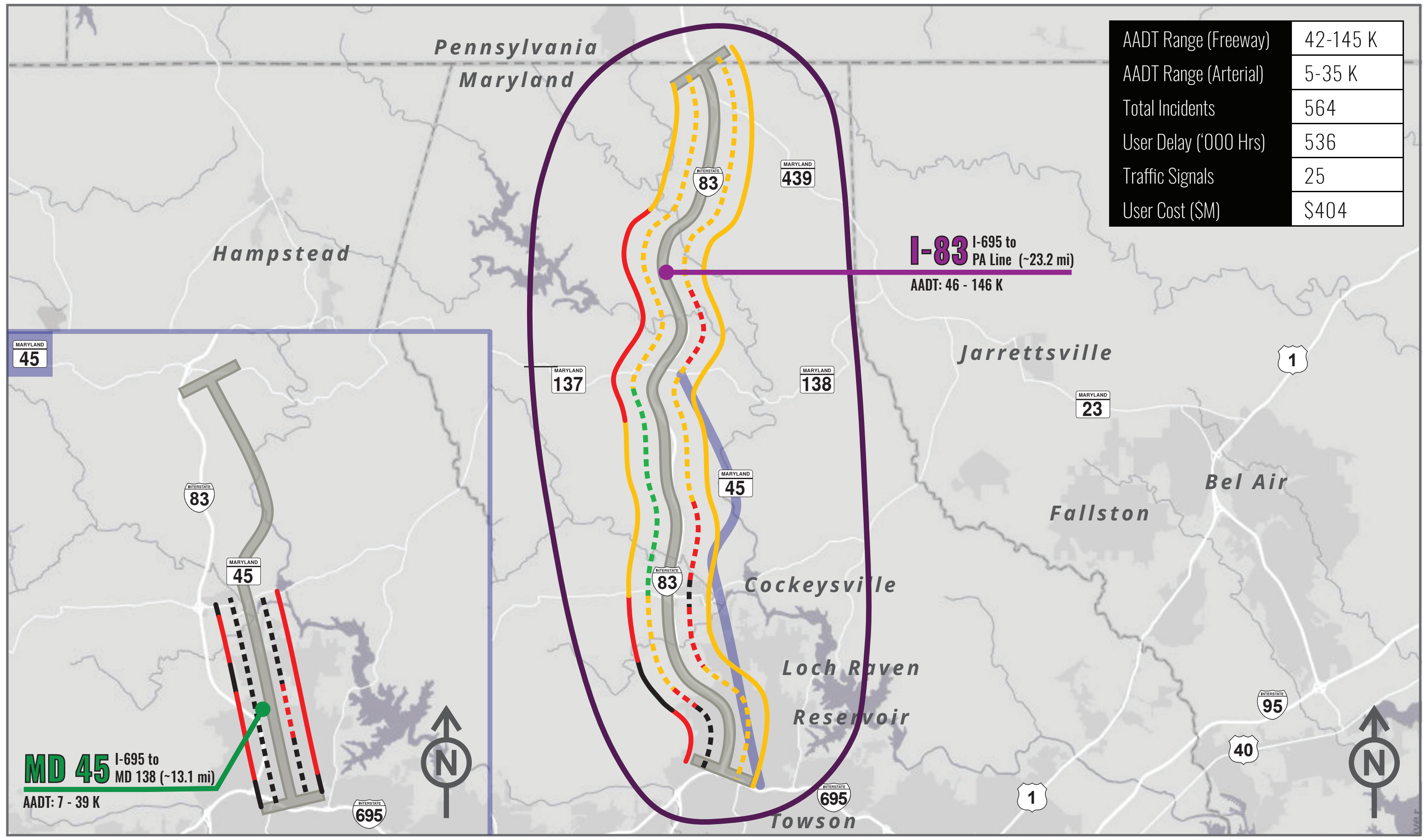
SUB-SYSTEM DEPLOYMENT:

System 9.4.1 (B/C: 2) Tier 3	MD 24 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along MD 24 at key locations.	PE: $0.5 M CO: $3.6 M Recurring Cost: $52.1 K Annual O&M: $0.5 M
System 9.4.2 (B/C: 2) Tier 3	MD 24 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along MD 24 at key locations.	PE: $2.5 M CO: $16.5 M

PROGRESS STATUS:

- I-95 Managed Lane System (MdTA)
- US 40 Hatem Bridge All Electronic Tolling (MdTA)
- Concept of Operations (TBD)

TSMO SYSTEM # 10

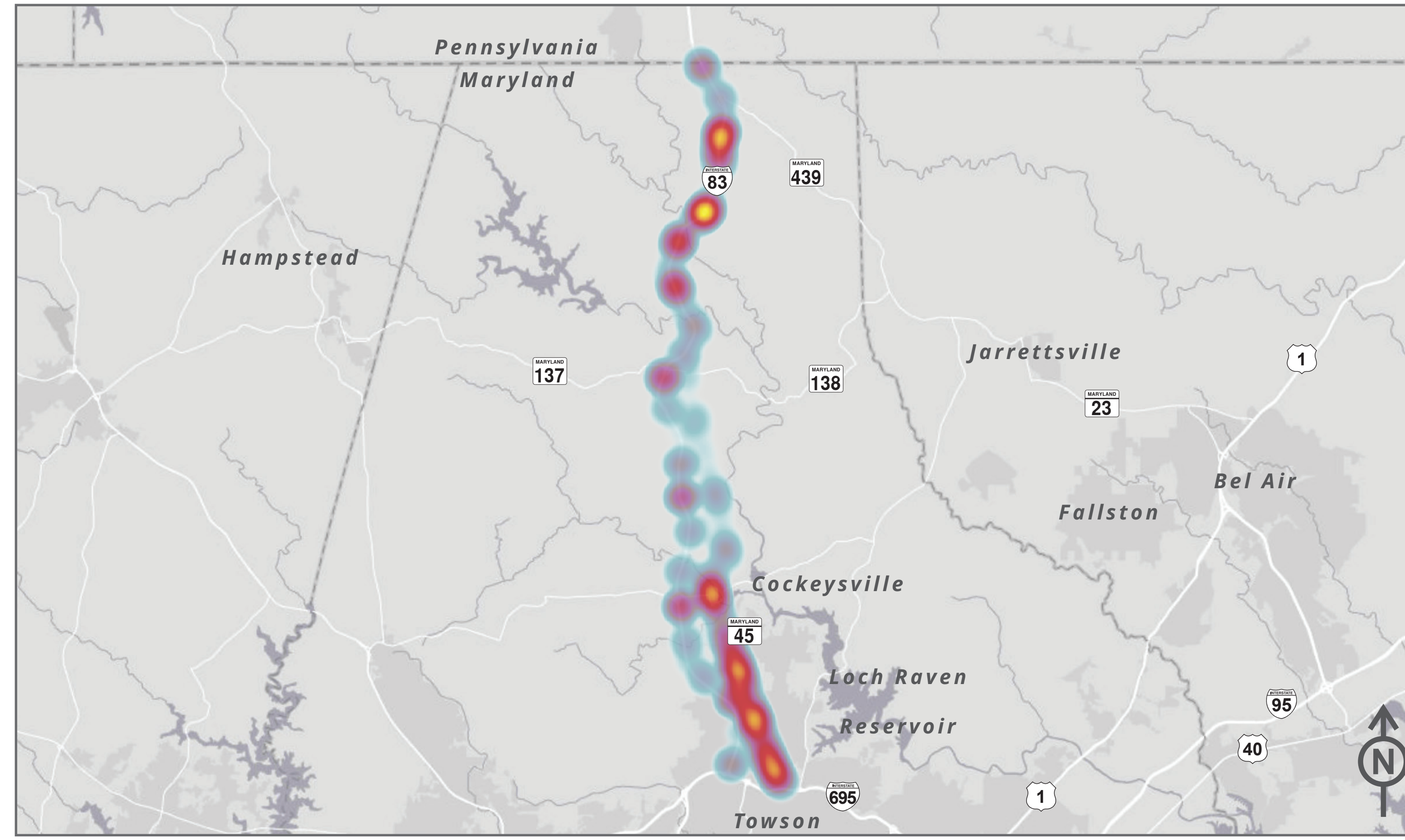


AADT Range (Freeway)	42-145 K
AADT Range (Arterial)	5-35 K
Total Incidents	564
User Delay ('000 Hrs)	536
Traffic Signals	25
User Cost ($M)	$404

UNCONGESTED (**TTI < 1.15**) MODERATE CONGESTION (**1.15 < TTI < 1.3**) HEAVY CONGESTION (**1.3 < TTI < 2.0**) SEVERE CONGESTION (**TTI > 2.0**)

AM TTI PM TTI

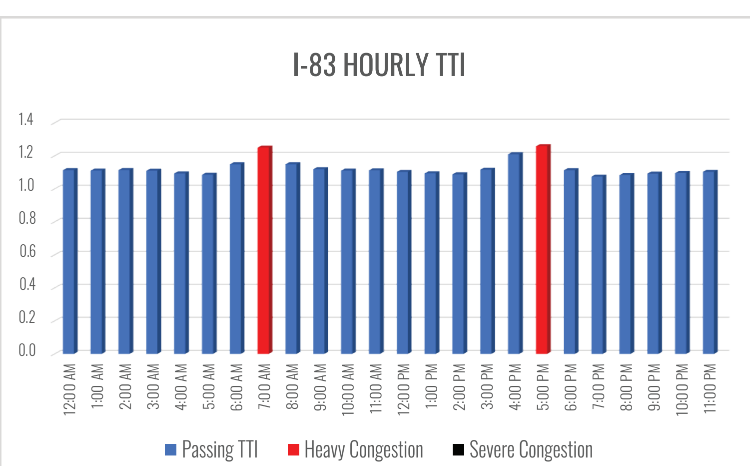
CRASH DENSITY

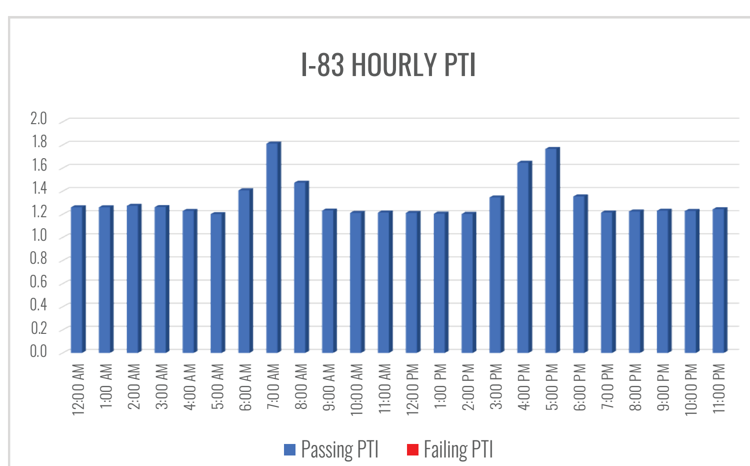


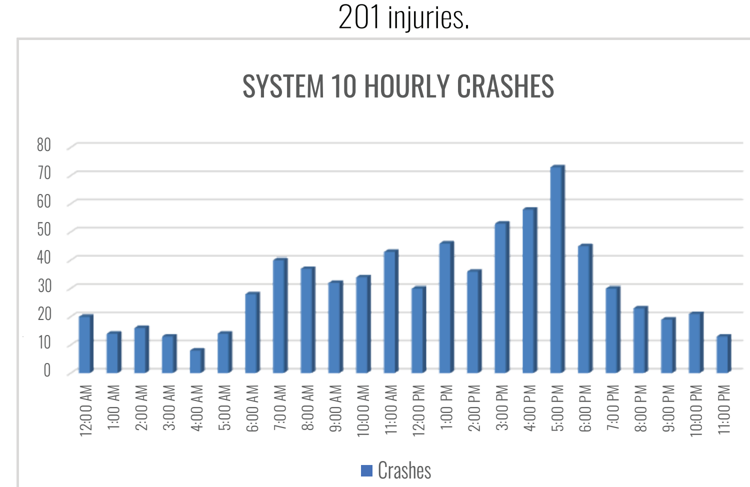
Crash Density: Sparse Dense

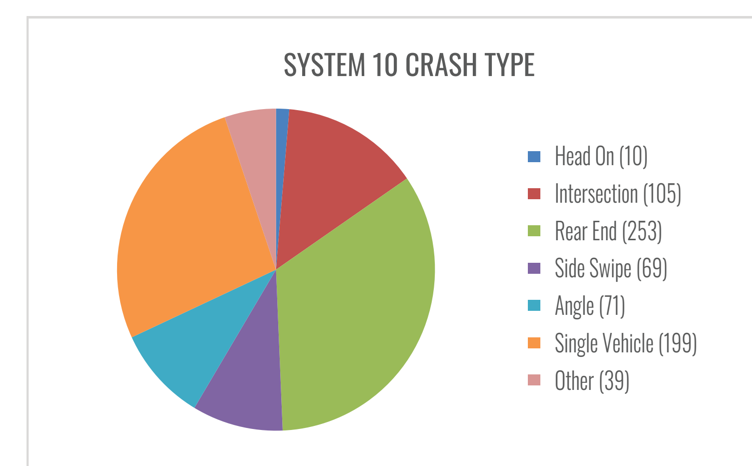
BACKGROUND: TSMO System # 10 improves operations along the north-south corridor connecting the City of Baltimore with northern locations up to the PA State Line. Traffic operations reflect the commuter pattern, with heavy congestion approaching I-695 in the morning and returning in the afternoon. I-83 is designated as a Maryland Freight Route and is part of the National Highway Freight Network. MD 45 has been identified as potential transit corridor.

SAFETY OVERVIEW: The highest concentrations of crashes are along I-83 around the interchange with MD 45 and south of MD 439. The highest concentration of crashes along MD 45 is near I-695, Timonium Road, Padonia Road, and between MD 145 and Shawan Road. Crash data shows that the highest number of crashes occurs during the PM peak and the most common crash type is rear ends. In 2018, there were 746 crashes reported within TSMO System # 10, with five fatalities and 201 injuries.

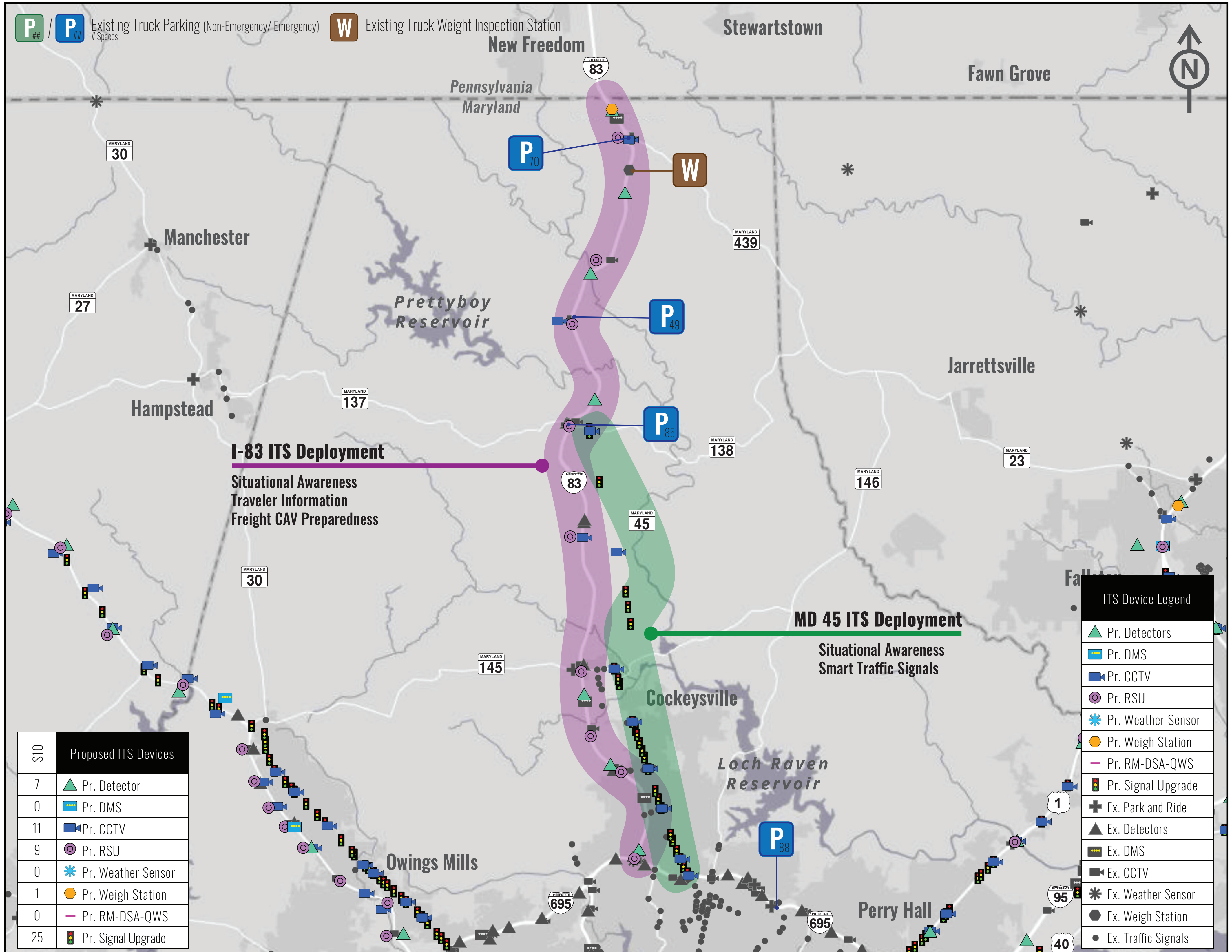








TSMO SYSTEM # 10: ITS OVERVIEW



COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	$1	$2	$6
Construction	$3	$4	$16	$40
Total	$4	$4	$18	$46
Annual recurring costs: $154.8 K		Annual O&M costs: $2.7 M		

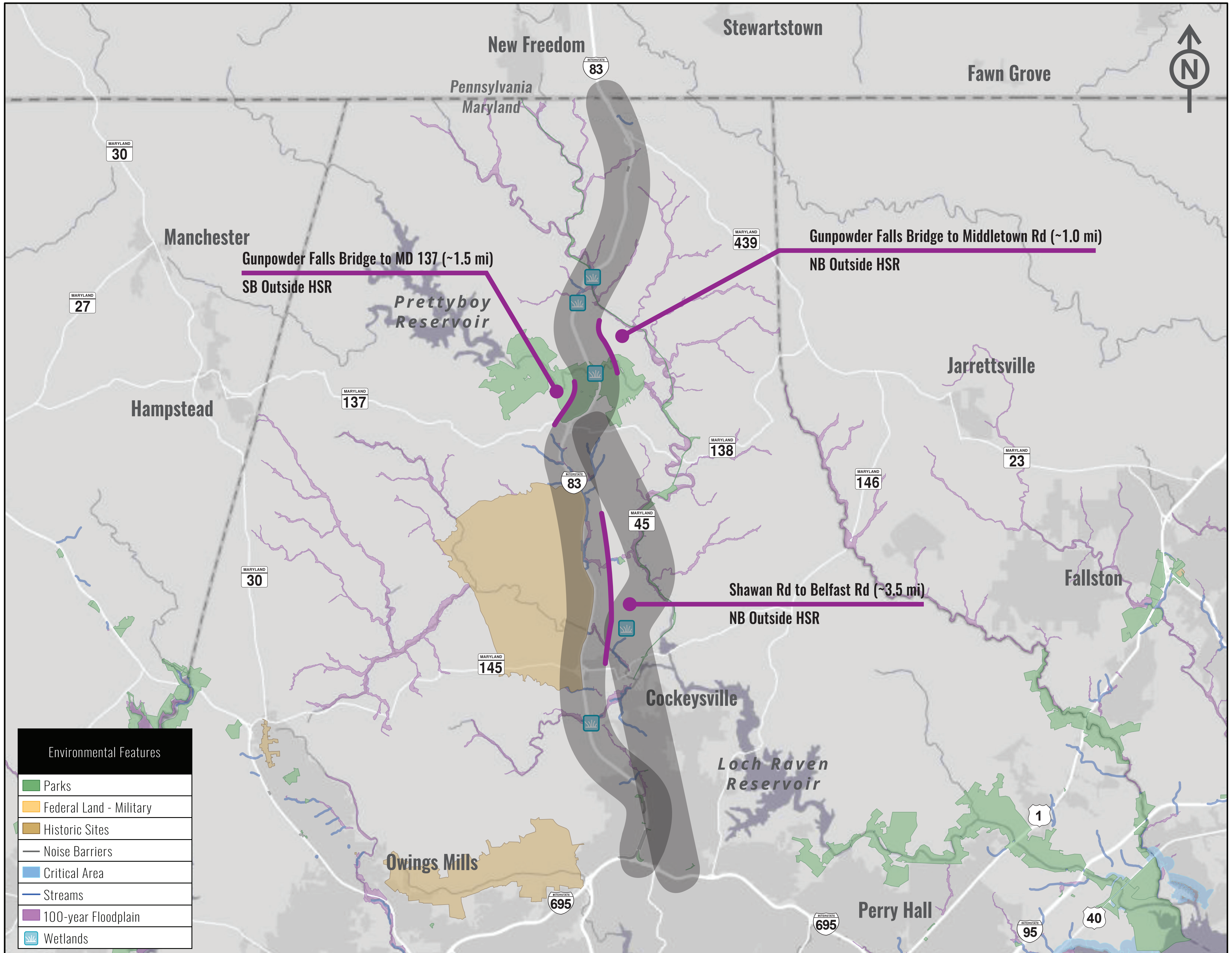
SUB-SYSTEM DEPLOYMENT:

System 10.1.1 (B/C: 16) Tier 1	I-83 ITS Deployment Deployment of an In-Motion Weight Station, CCTV, traffic detectors, and RSU along I-83 between I-695 and PA State Line.	PE: $0.4 M CO: $2.5 M Recurring Cost: $23.5 K Annual O&M: $0.4 M
System 10.1.2 (B/C: 39) Tier 1	MD 45 ITS Deployment Deployment of CCTV along MD 45 between I-695 and PA State Line.	PE: $0.2 M CO: $1.0 M Recurring Cost: $24.0 K Annual O&M: $0.2 M
System 10.2.1 (B/C: 6) Tier 1	MD 45 Traffic Signal Upgrade Upgrade existing traffic signals along MD 45 between I-695 and PA State Line to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled and have TSP.	PE: $0.6 M CO: $3.7 M Recurring Cost: $18.0 K Annual O&M: $0.6 M
System 10.3.1 Tier 2	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $2.3 M CO: $15.5 M Annual O&M: $0.7 M

PROGRESS STATUS:

- Concept of Operations (TBD)

TSMO SYSTEM # 10: ROADWAY OVERVIEW



HARD SHOULDER RUNNING: I-83

COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	$1	$2	$6
Construction	$3	$4	$16	$40
Total	$4	$4	$18	$46
Annual recurring costs: $154.8 K		Annual O&M costs: $2.7 M		

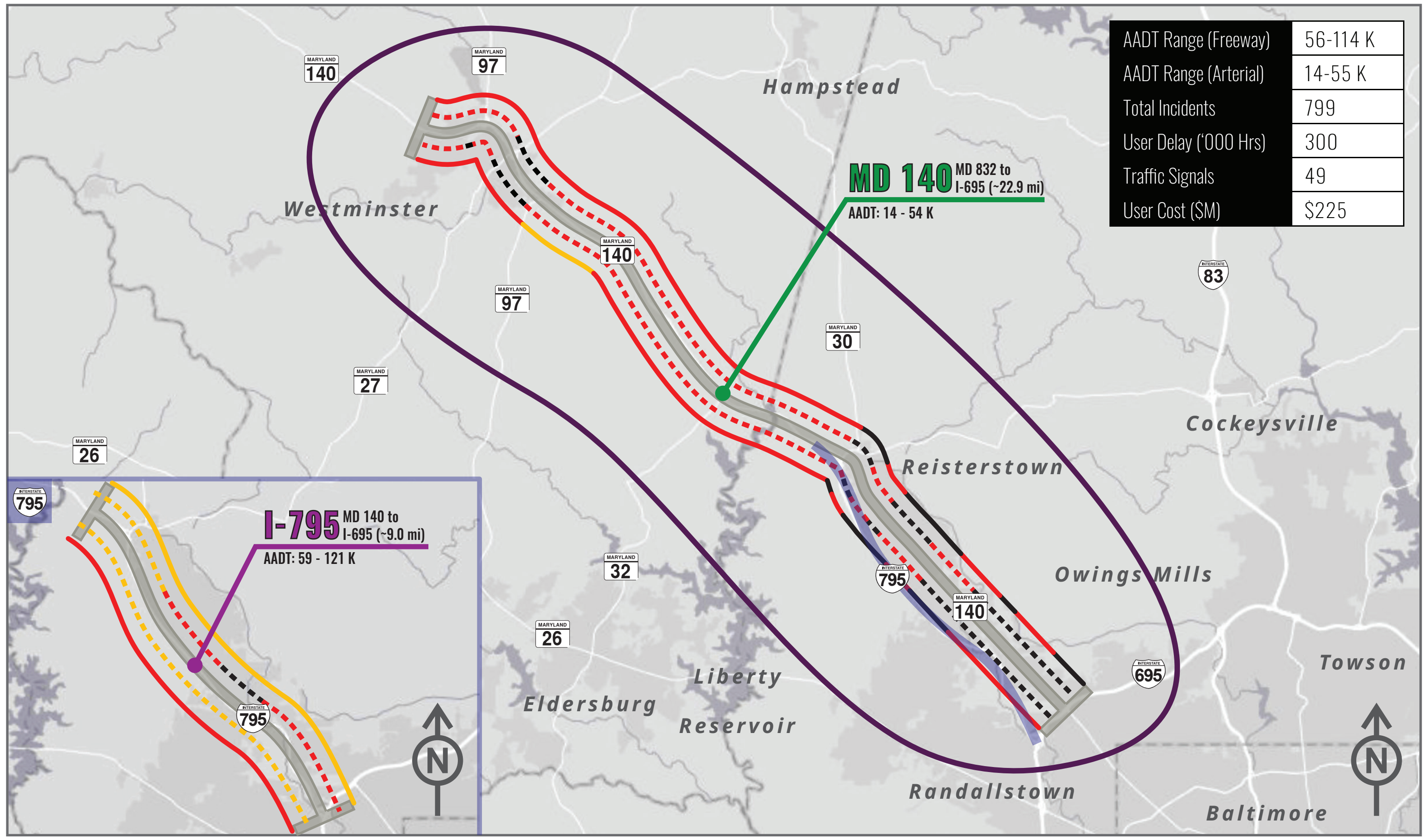
SUB-SYSTEM DEPLOYMENT:

System 10.4.1 (B/C: 2) Tier 3	I-83 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along I-83 at key locations.	PE: $0.9 M CO: $6.1 M Recurring Cost: $89.3 K Annual O&M: $0.9 M
System 10.4.2 (B/C: 2) Tier 3	I-83 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along I-83 at key locations.	PE: $5.1 M CO: $33.9 M

PROGRESS STATUS:

- Concept of Operations (TBD)

TSMO SYSTEM # 11

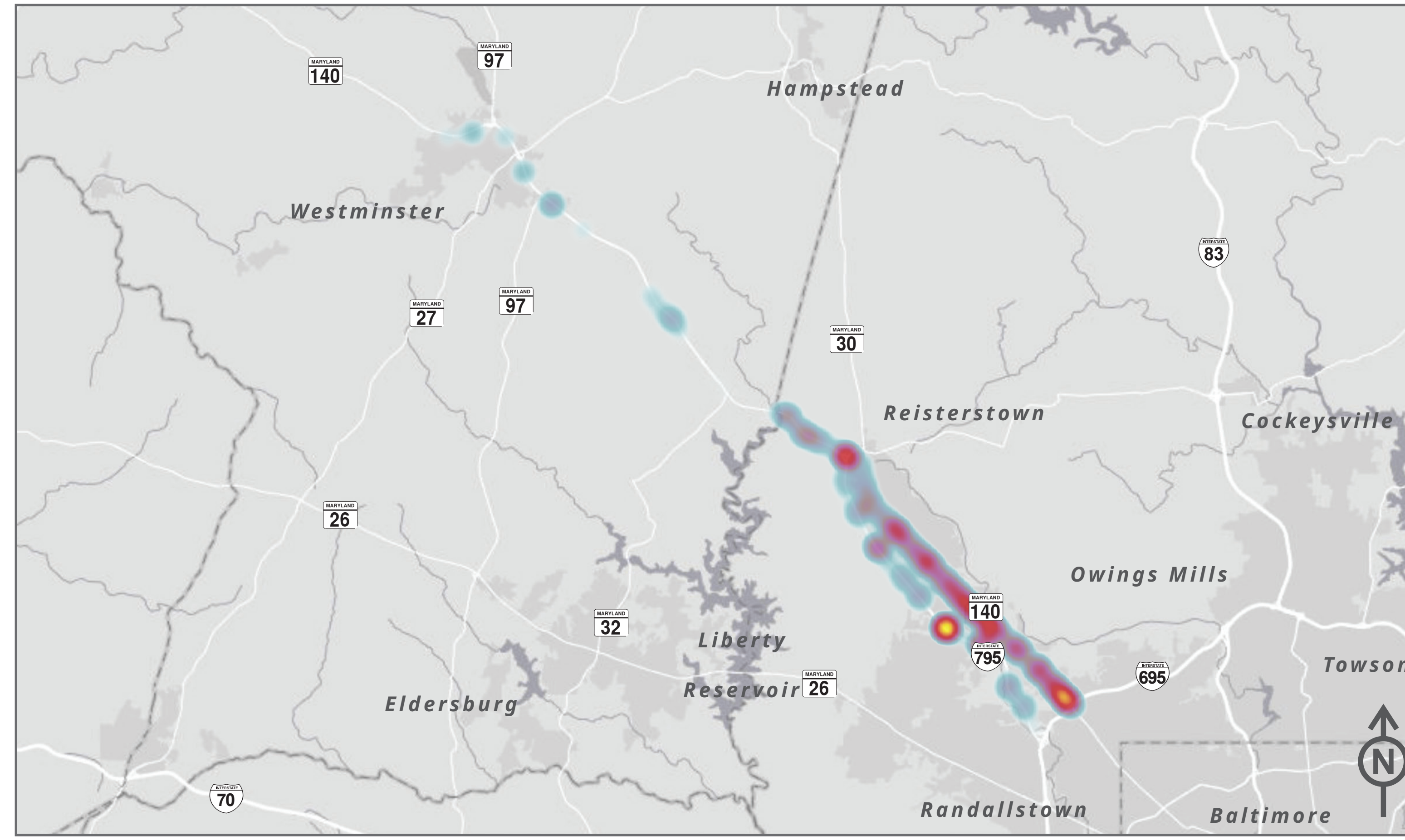


AADT Range (Freeway)	56-114 K
AADT Range (Arterial)	14-55 K
Total Incidents	799
User Delay ('000 Hrs)	300
Traffic Signals	49
User Cost ($M)	$225

UNCONGESTED (**TTI < 1.15**) MODERATE CONGESTION (**1.15 < TTI < 1.3**) HEAVY CONGESTION (**1.3 < TTI < 2.0**) SEVERE CONGESTION (**TTI > 2.0**)

AM TTI PM TTI

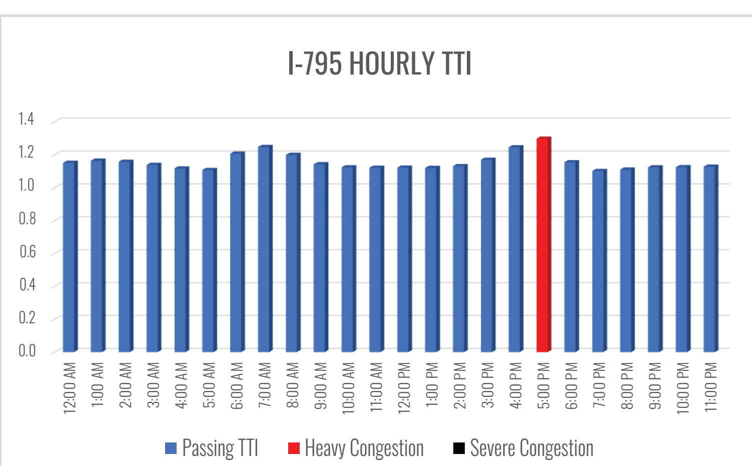
CRASH DENSITY

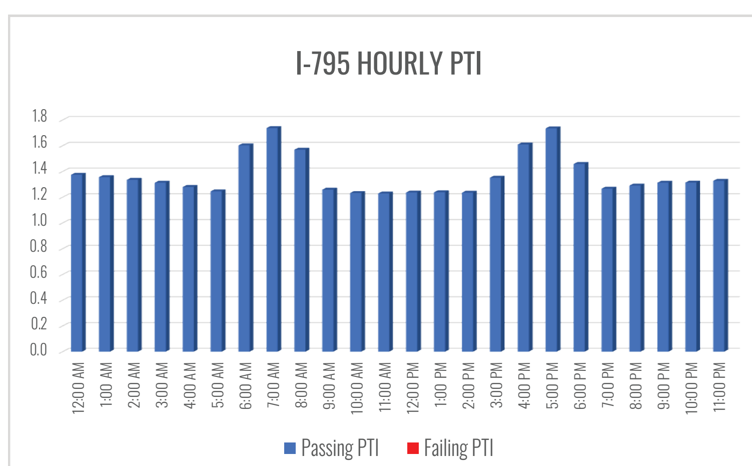


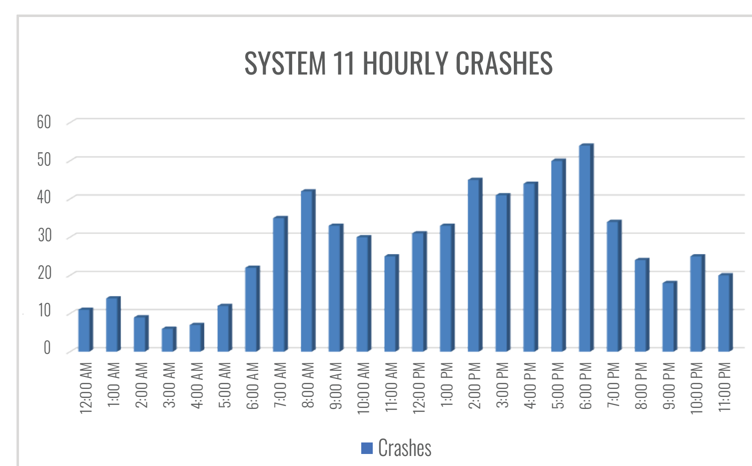
Crash Density: Sparse Dense

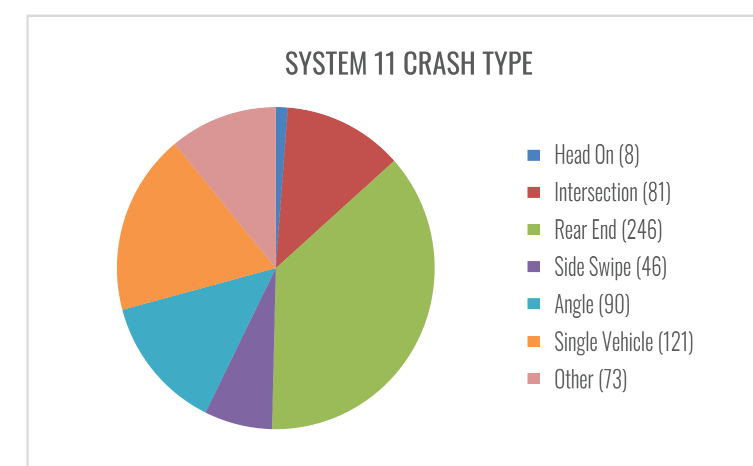
BACKGROUND: TSMO System # 11 connects Baltimore with locations northwest, traversing Reisterstown and connecting to Westminster. Traffic operations follow commuter patterns, with heavy southbound traffic in the morning, and heavy northbound traffic in the afternoon. The system includes the Baltimore Light Rail that parallels I-795. I-795 is a Maryland Freight Corridor and part of the National Highway Freight Network. MD 140 has been identified as a potential transit corridor.

SAFETY OVERVIEW: The highest concentration of crashes along I-795 is at the interchange with Owings Mills Boulevard. The highest concentration of crashes along MD 140 is near I-695 and near MD 128. Crash data shows that the highest numbers of crashes occur during the AM and PM peak and the most common crash type is rear ends. In 2018, there were 665 crashes reported within TSMO System # 11, with one fatality and 339 injuries.

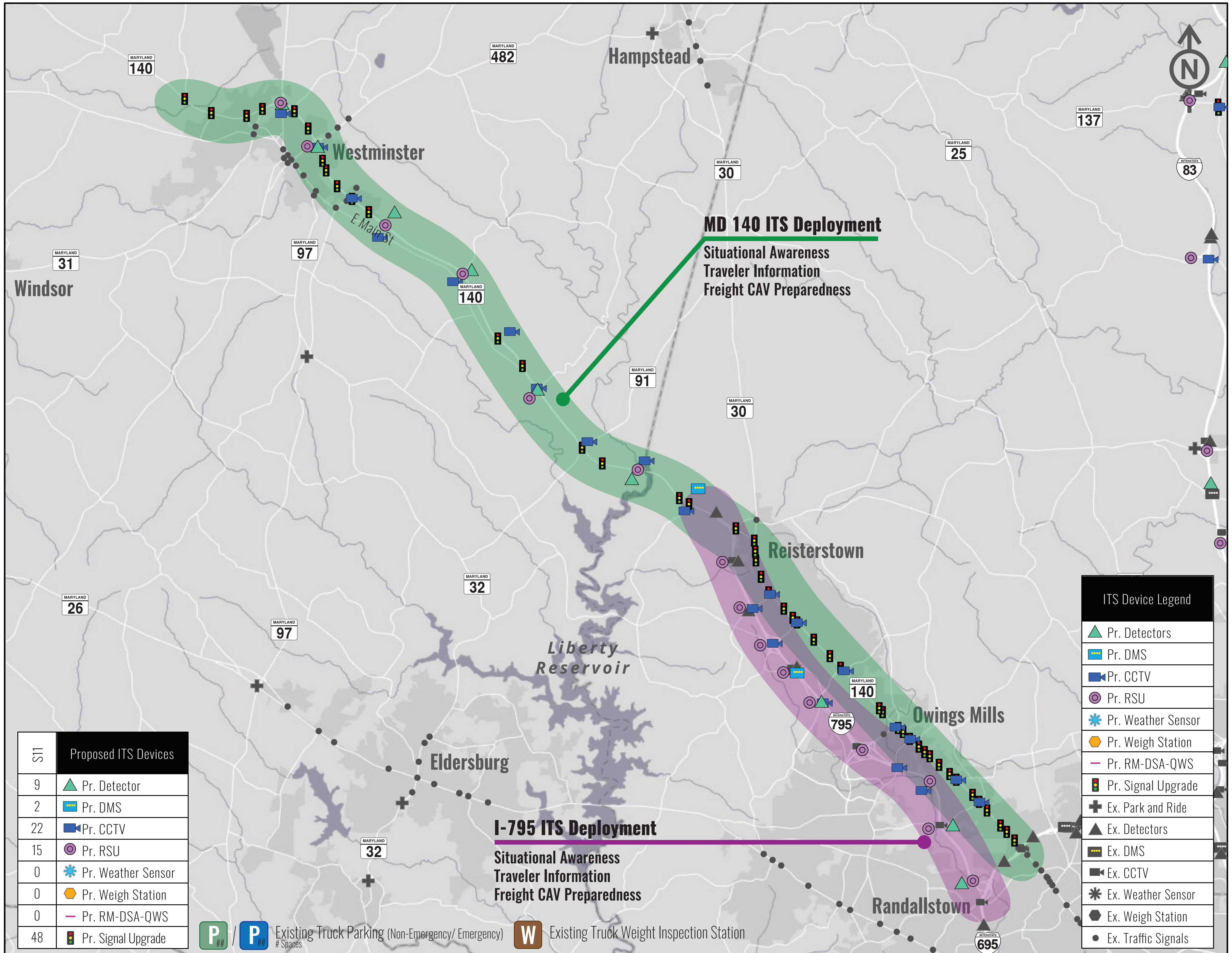








TSMO SYSTEM # 11: ITS OVERVIEW



COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	$1	$1	$4
Construction	$5	$7	$9	$27
Total	$6	$8	$11	$31
Annual recurring costs: $178.8 K		Annual O&M costs: $2.9 M		

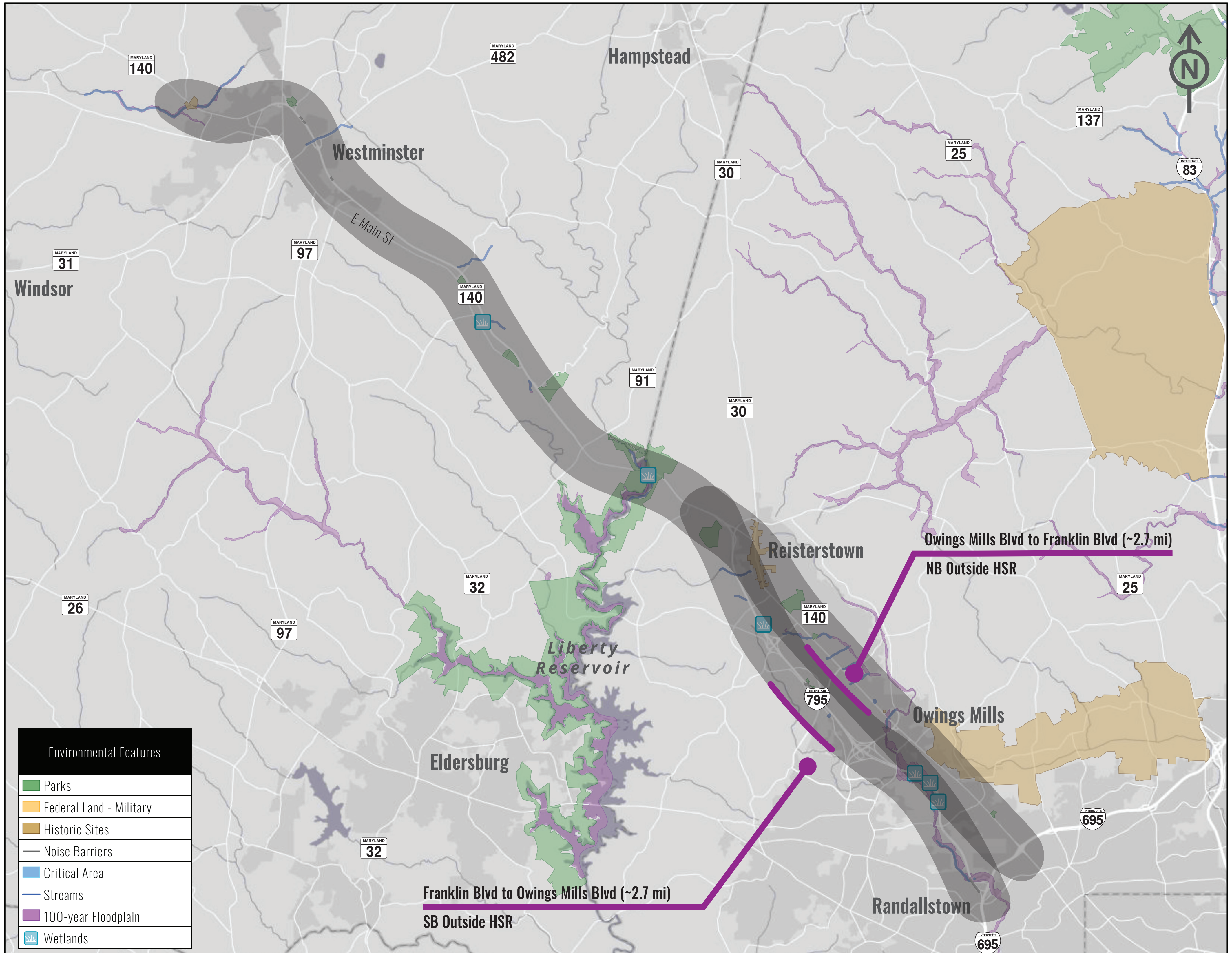
SUB-SYSTEM DEPLOYMENT:

System 11.1.1 (B/C: 14) Tier 1	I-795 ITS Deployment Deployment of CCTV, traffic detectors, and RSU along I-795 between I-695 and MD 140.	PE: $0.3 M CO: $2.0 M Recurring Cost: $24.4 K Annual O&M: $0.3 M
System 11.1.2 (B/C: 27) Tier 2	MD 140 ITS Deployment Deployment of VMS signs, and CCTV along MD 140 between I-695 and MD 97.	PE: $0.5 M CO: $3.4 M Recurring Cost: $60.4 K Annual O&M: $0.5 M
System 11.2.1 (B/C: 7) Tier 2	MD 140 Traffic Signal Upgrade Upgrade existing traffic signals along MD 140 between I-695 and MD 97 to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled and have TSP.	PE: $1.1 M CO: $7.3 M Recurring Cost: $34.6 K Annual O&M: $1.1 M
System 11.3.1 Tier 3	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $1.4 M CO: $9.2 M Annual O&M: $0.4 M

PROGRESS STATUS:

- Concept of Operations (TBD)

TSMO SYSTEM # 11: ROADWAY OVERVIEW



HARD SHOULDER RUNNING: I-795

COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	$1	$1	$4
Construction	$5	$7	$9	$27
Total	$6	$8	$11	$31
Annual recurring costs: $178.8 K		Annual O&M costs: $2.9 M		

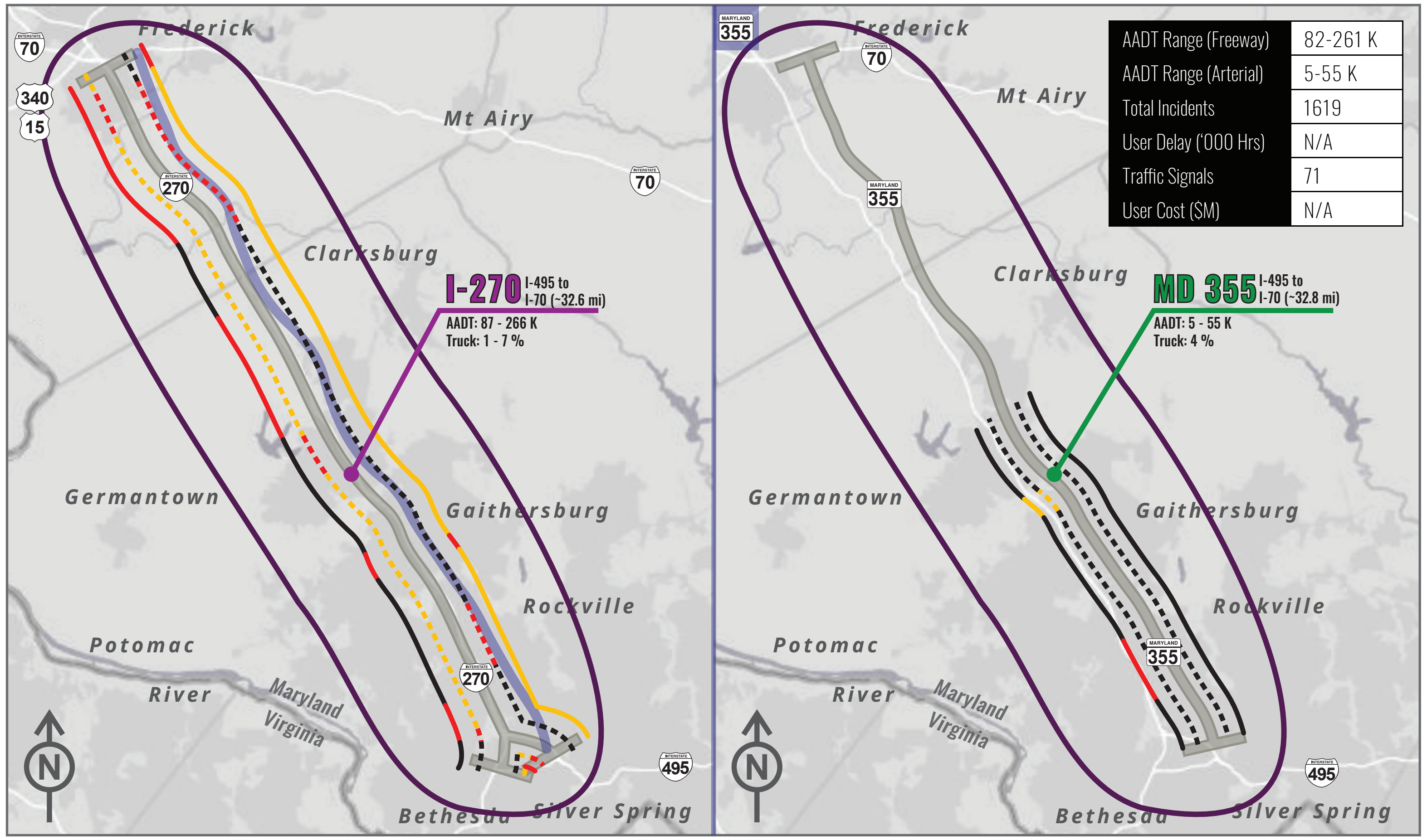
SUB-SYSTEM DEPLOYMENT:

System 11.4.1 (B/C: 5) Tier 3	I-795 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along I-795 at key locations.	PE: $0.6 M CO: $4.1 M Recurring Cost: $59.5 K Annual O&M: $0.6 M
System 11.4.2 (B/C: 5) Tier 3	I-795 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along I-795 at key locations.	PE: $3.4 M CO: $22.9 M

PROGRESS STATUS:

- Concept of Operations (TBD)

TSMO SYSTEM # 12

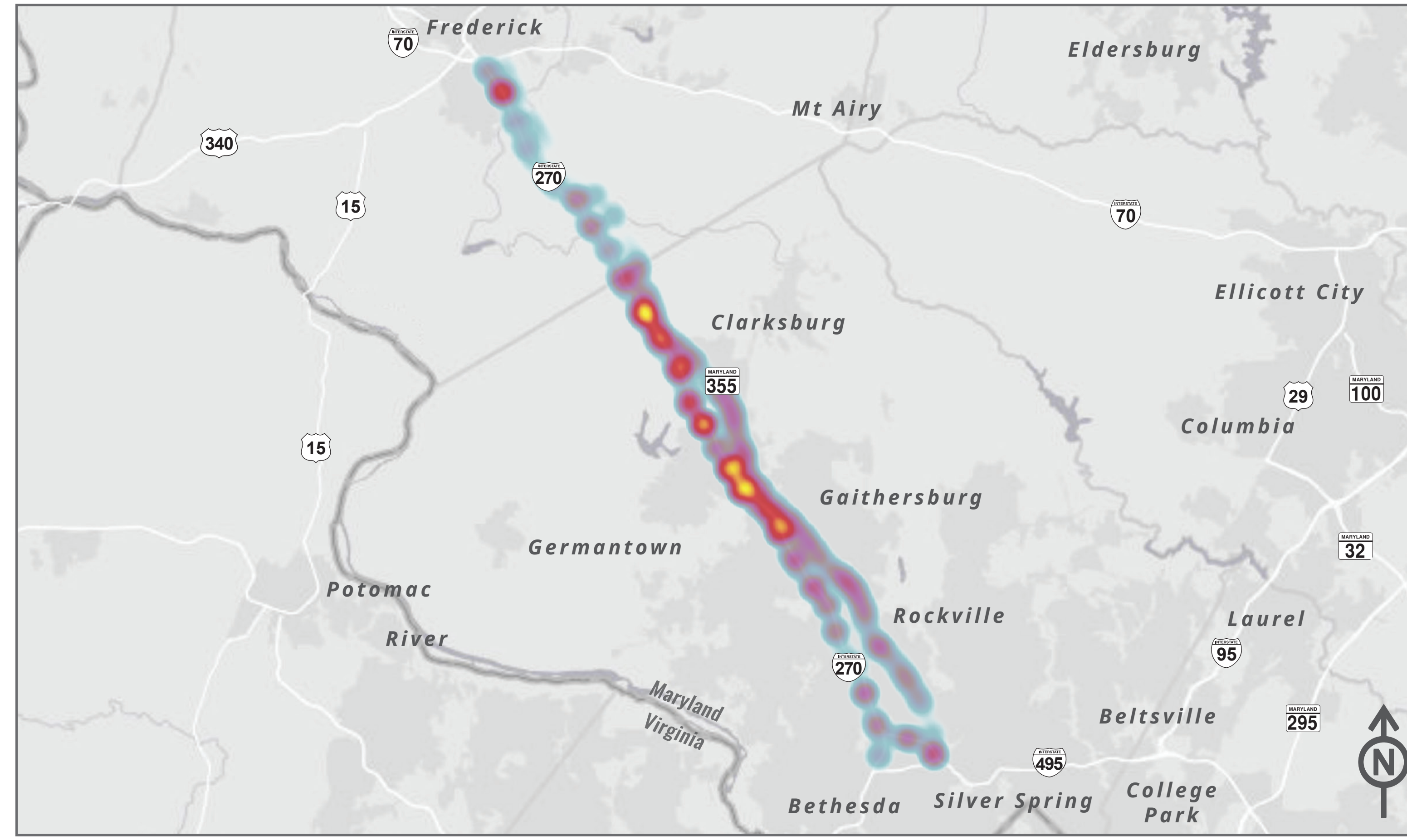


AADT Range (Freeway)	82-261 K
AADT Range (Arterial)	5-55 K
Total Incidents	1619
User Delay ('000 Hrs)	N/A
Traffic Signals	71
User Cost ($M)	N/A

UNCONGESTED (**TTI < 1.15**) MODERATE CONGESTION (**1.15 < TTI < 1.3**) HEAVY CONGESTION (**1.3 < TTI < 2.0**) SEVERE CONGESTION (**TTI > 2.0**)

AM TTI PM TTI

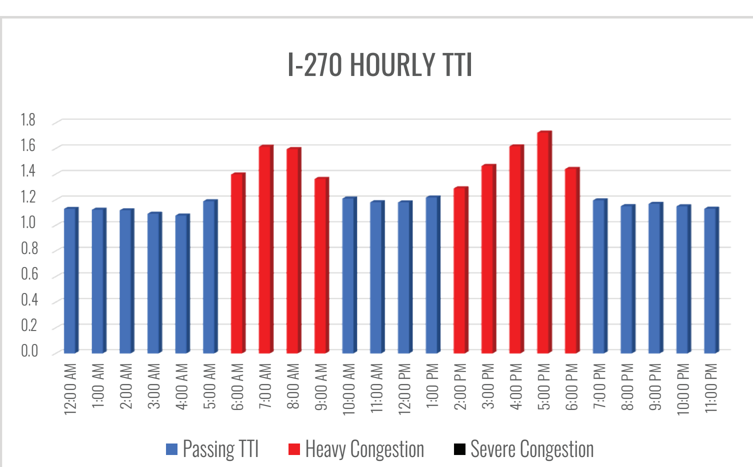
CRASH DENSITY

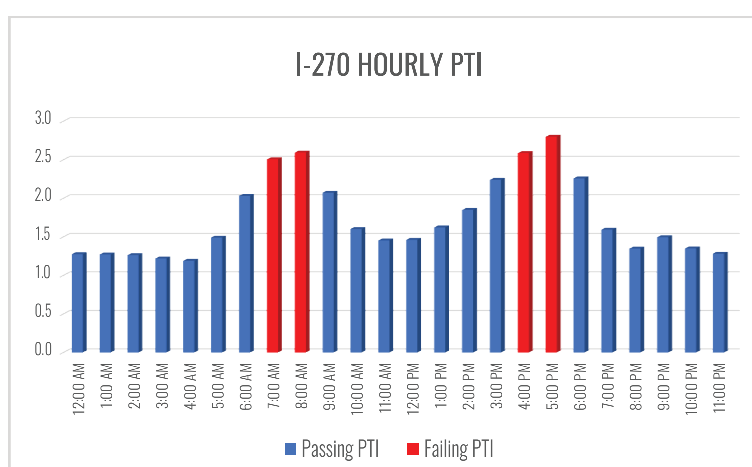


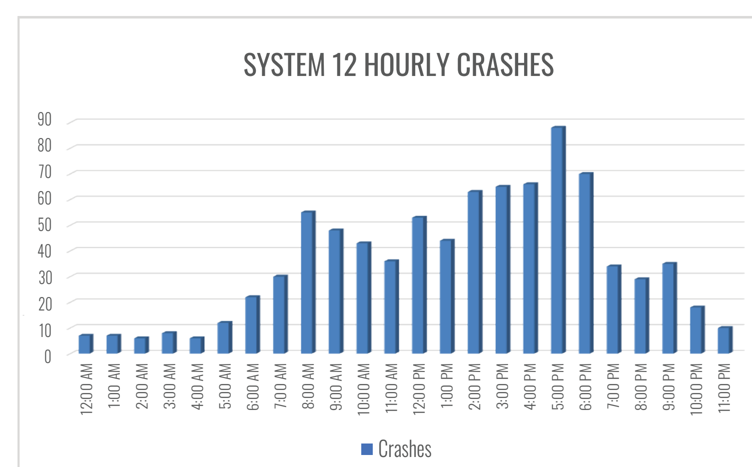
Crash Density: Sparse Dense

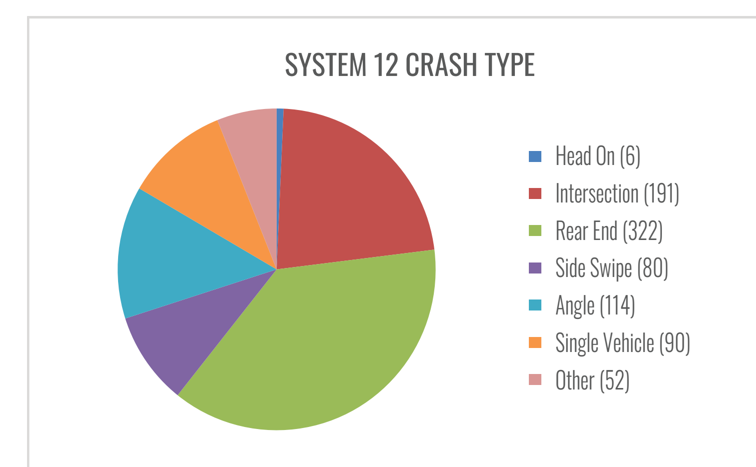
BACKGROUND: TSMO System # 12 connects Washington DC with the City of Frederick and locations north, connecting to US 15 and I-70. I-270 is currently being upgraded as part of the ICM project, and is part of the Governor's Traffic Relief Plan, and will include ETLs in the future. I-270 is a Maryland Freight Route and is part of the National Highway Freight Network. The system runs parallel to the Red Line Metrorail. MD 355 has been identified as a potential transit corridor.

SAFETY OVERVIEW: The highest concentrations of crashes occur along I-270 at the interchange between Gaithersburg and Clarksburg and around the MD 85 interchange. Crash data shows that the highest numbers of crashes occur during the AM and PM peak and the most common crash type is rear ends. In 2018, there were 855 crashes reported within TSMO System # 12, with three fatalities and 531 injuries.

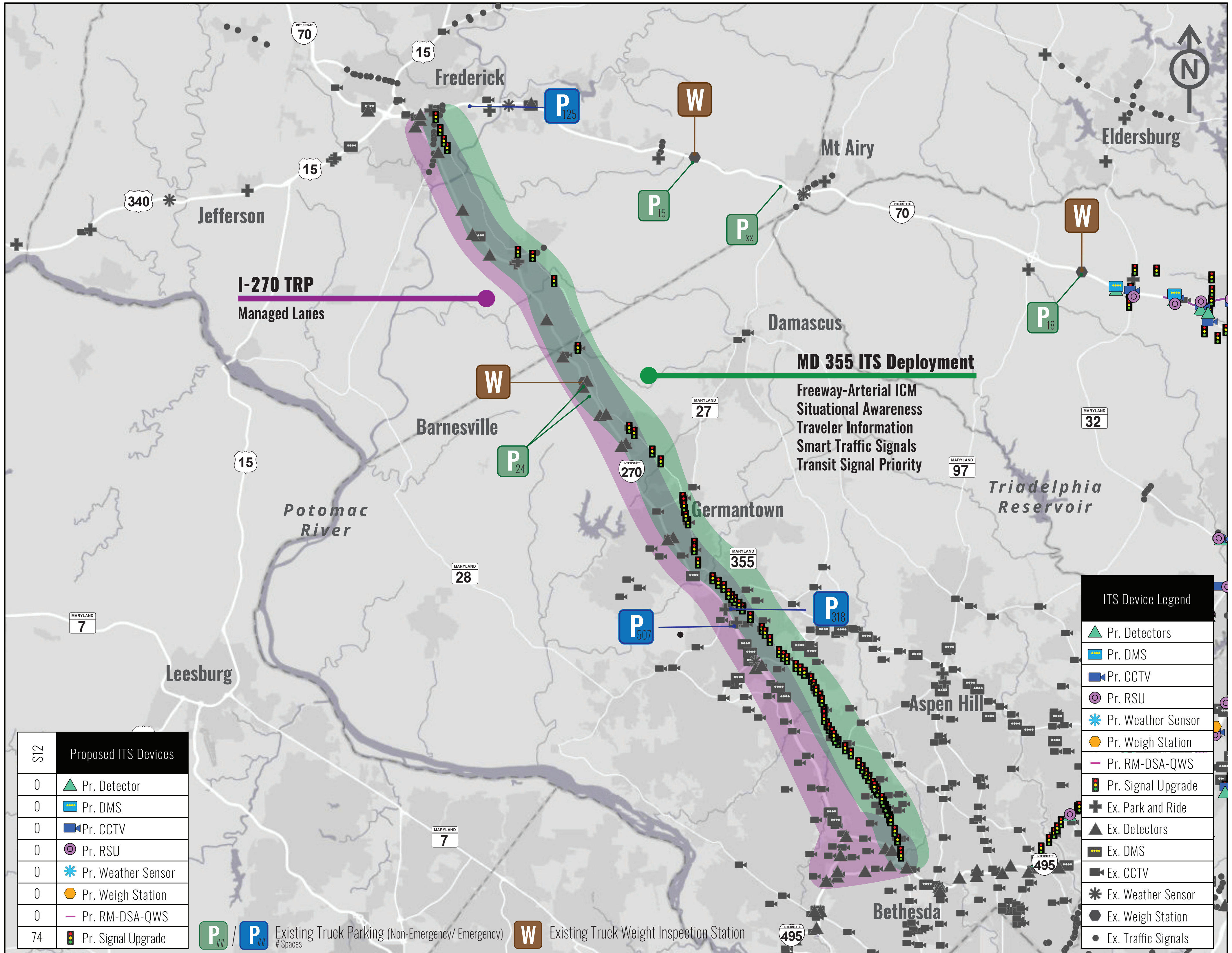








TSMO SYSTEM # 12: ITS OVERVIEW



COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	$3	$1	$N/A
Construction	$5	$18	$8	$N/A
Total	$5	$20	$9	$N/A
Annual recurring costs: $161.3 K		Annual O&M costs: $3.7 M		

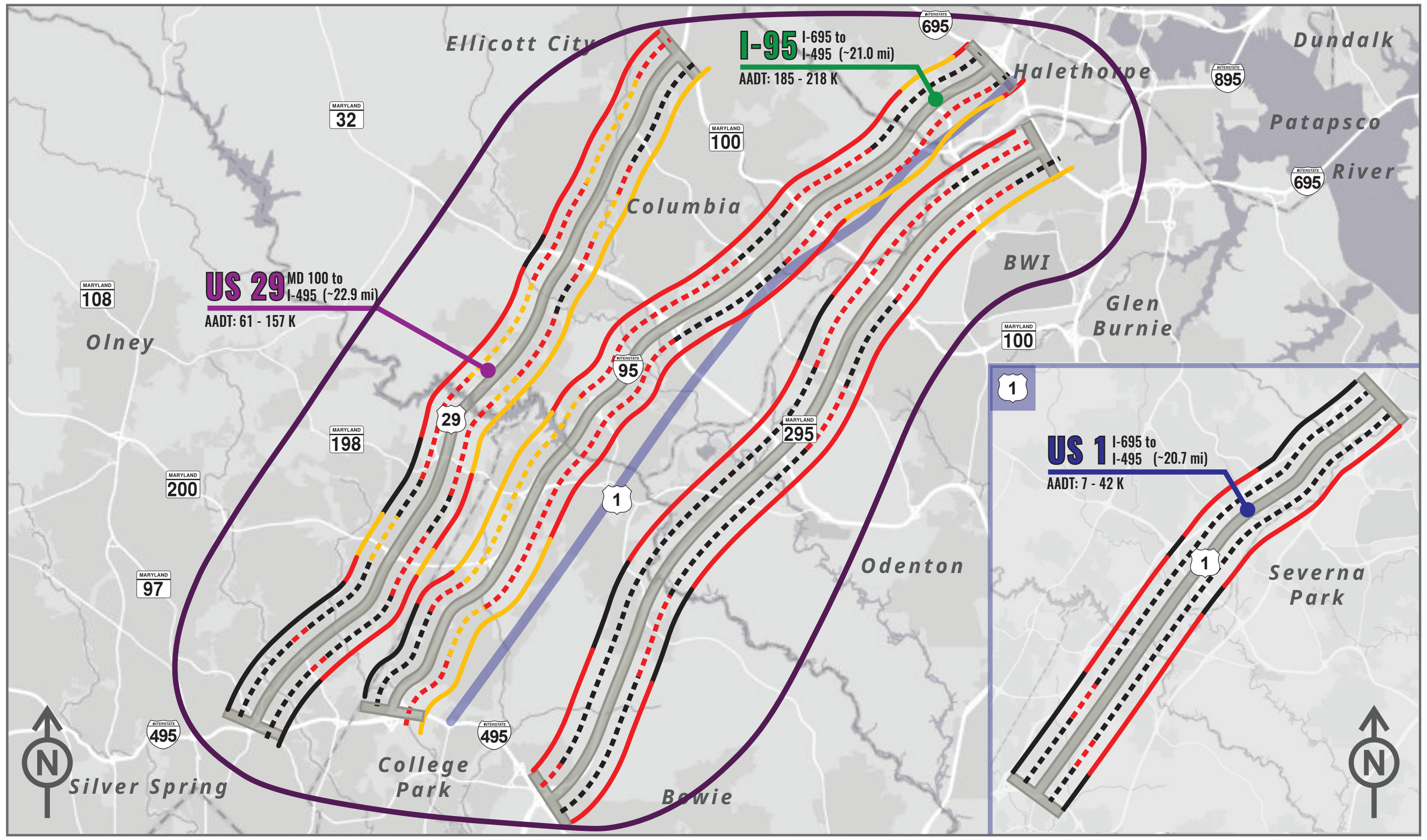
SUB-SYSTEM DEPLOYMENT:

System 12.1.1 (B/C: 18) Tier 1	MD 355 ITS Deployment Deployment of CCTV along MD 355 between I-495 and I-70.	PE: $0.7 M CO: $4.6 M Recurring Cost: $108.0 K Annual O&M: $0.7 M
System 12.2.1 (B/C: 1) Tier 2	MD 355 Traffic Signal Upgrade Upgrade existing traffic signals along MD 355 between I-495 and I-70 to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled and have TSP.	PE: $2.7 M CO: $17.8 M Recurring Cost: $53.3 K Annual O&M: $2.7 M
System 12.3.1 Tier 2	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $1.2 M CO: $8.0 M Annual O&M: $0.4 M

PROGRESS STATUS:

- I-270 ICM (ongoing)
- I-270 TRP (ongoing)

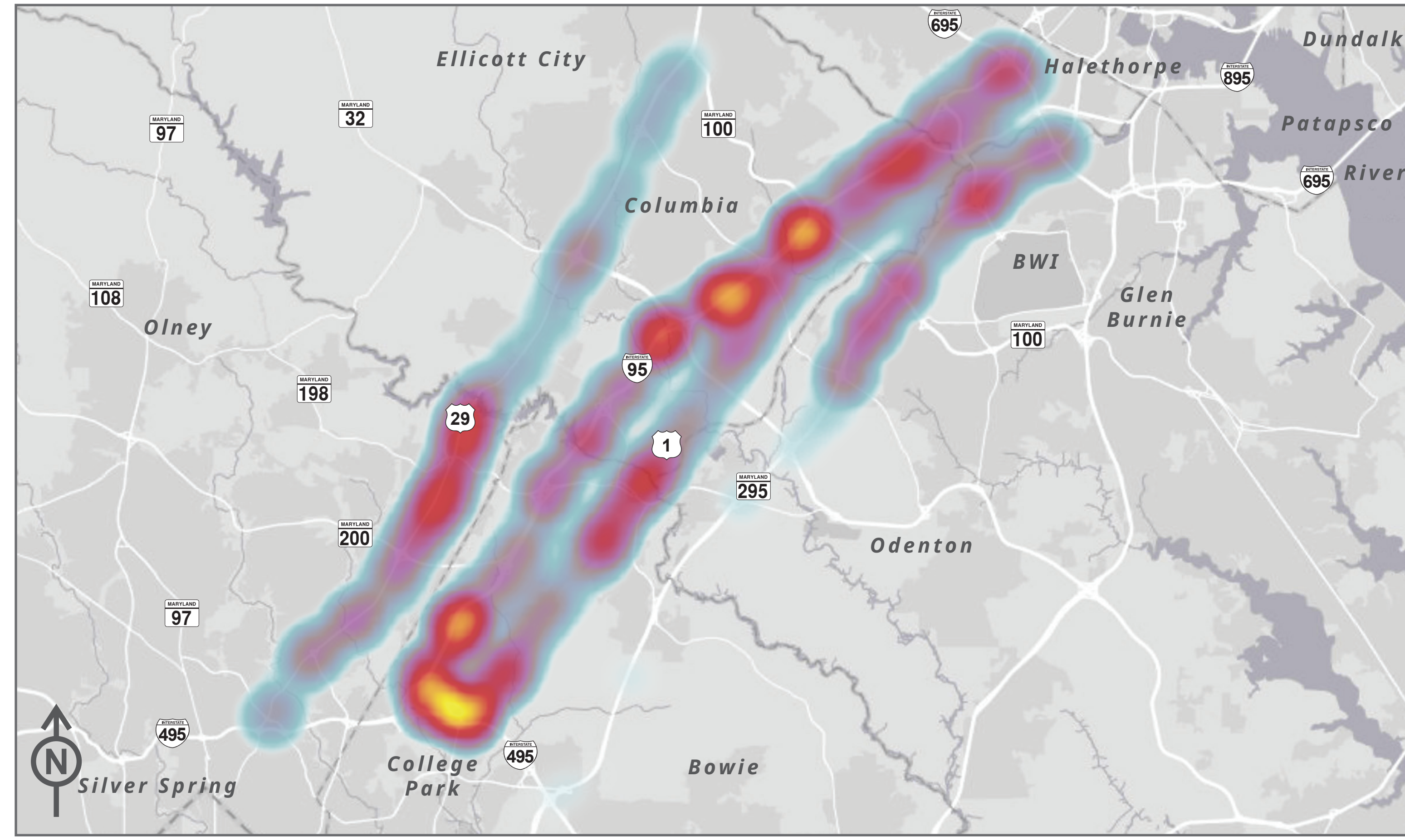
TSMO SYSTEM # 13



UNCONGESTED (TTI < 1.15) MODERATE CONGESTION (1.15 < TTI < 1.3) HEAVY CONGESTION (1.3 < TTI < 2.0) SEVERE CONGESTION (TTI > 2.0)

AM TTI PM TTI

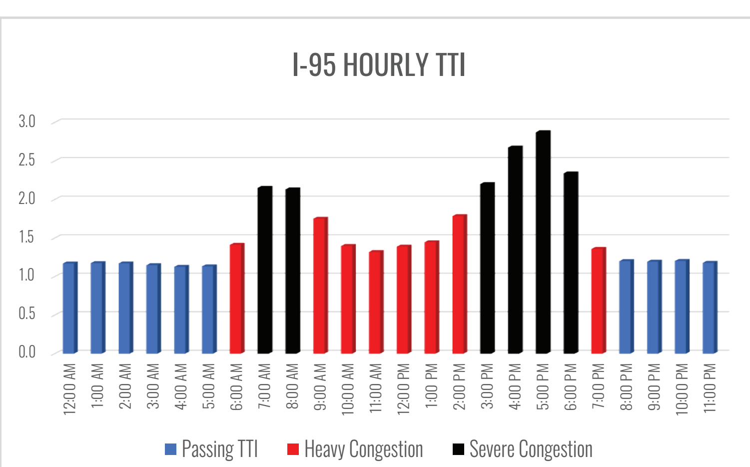
CRASH DENSITY

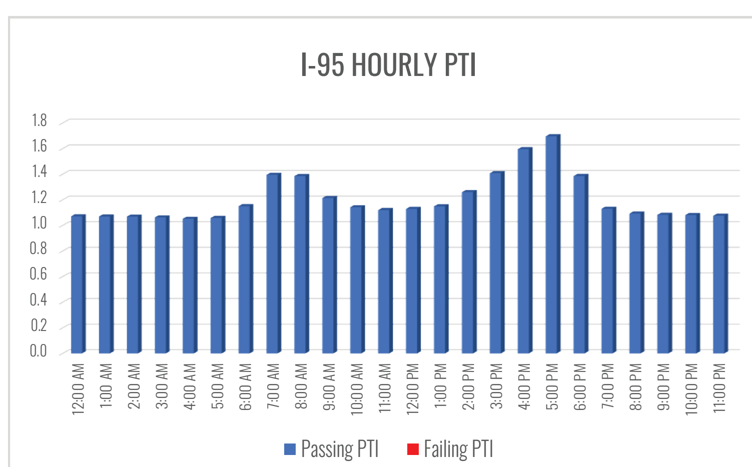


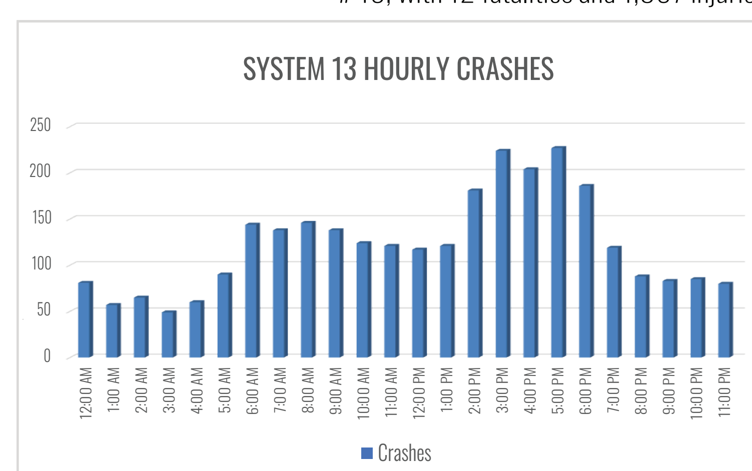
Crash Density: Sparse Dense

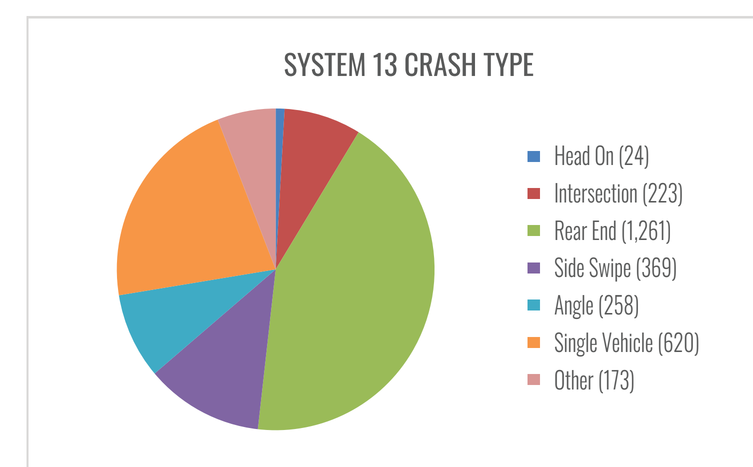
BACKGROUND: TSMO System # 13 provides critical connection between Washington DC and Baltimore and is part of the I-95 corridor. Parallel freeways and arterials include US 29, US 1, and MD 295. MD 295 is part of the Governor's Traffic Relief Plan. I-95 is a Maryland Fright Route and is part of the National Highway Freight Network. US 29 and US 1 have been identified as potential transit corridors. Local plans include BRT on US 29.

SAFETY OVERVIEW: The highest concentrations of crashes occur along I-95 north and south of MD 175 (overall area with TSMO System 2), south of MD 32, and at the interchanges with MD 212 and I-495. US 1 also has a high concentration of crashes surrounding the interchange with I-495. Crash data shows that the highest numbers of crashes occur during the AM and PM peak and the most common crash type is rear ends. In 2018, there were 2,928 crashes reported within TSMO System # 13, with 12 fatalities and 1,067 injuries.

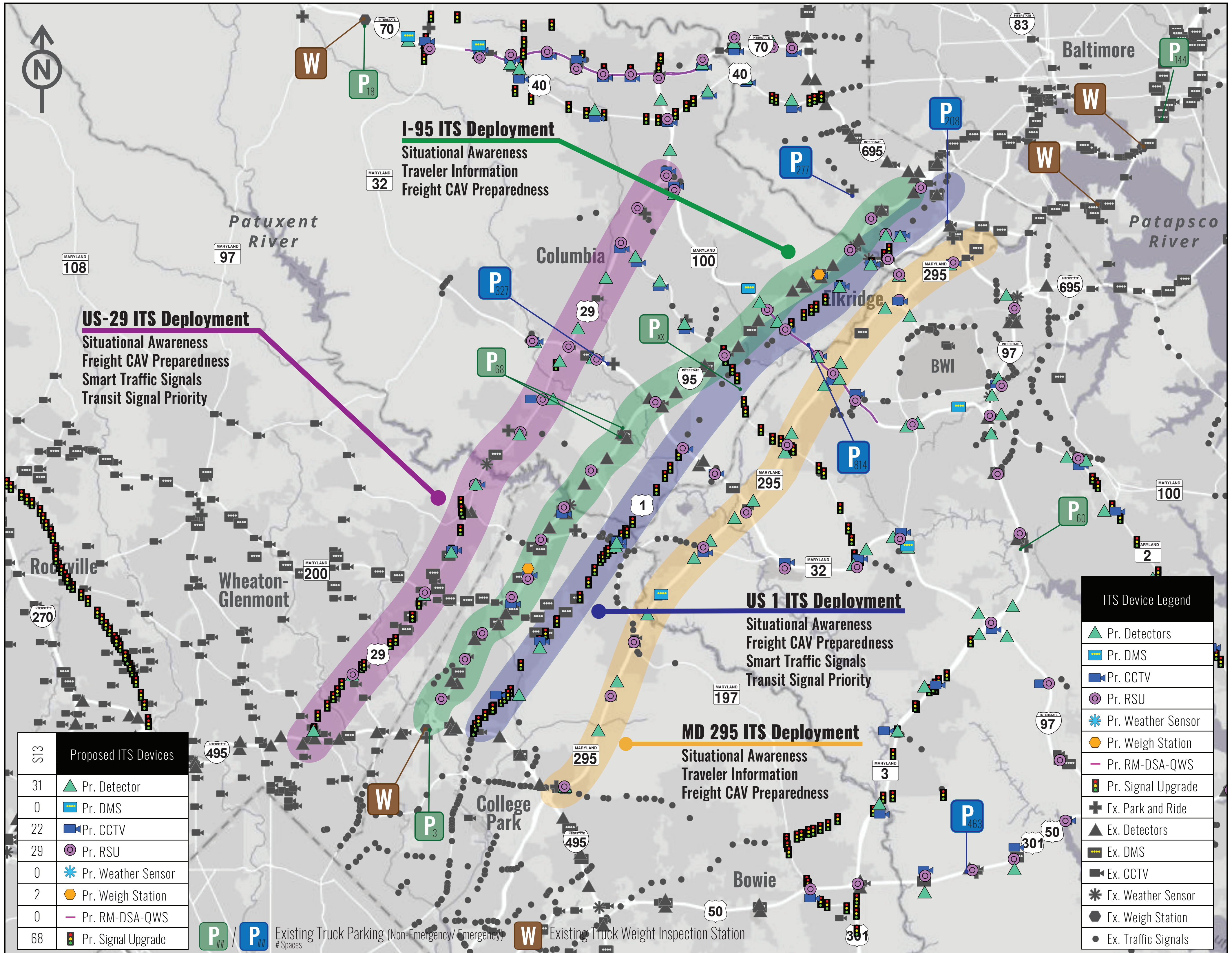








TSMO SYSTEM # 13: ITS OVERVIEW



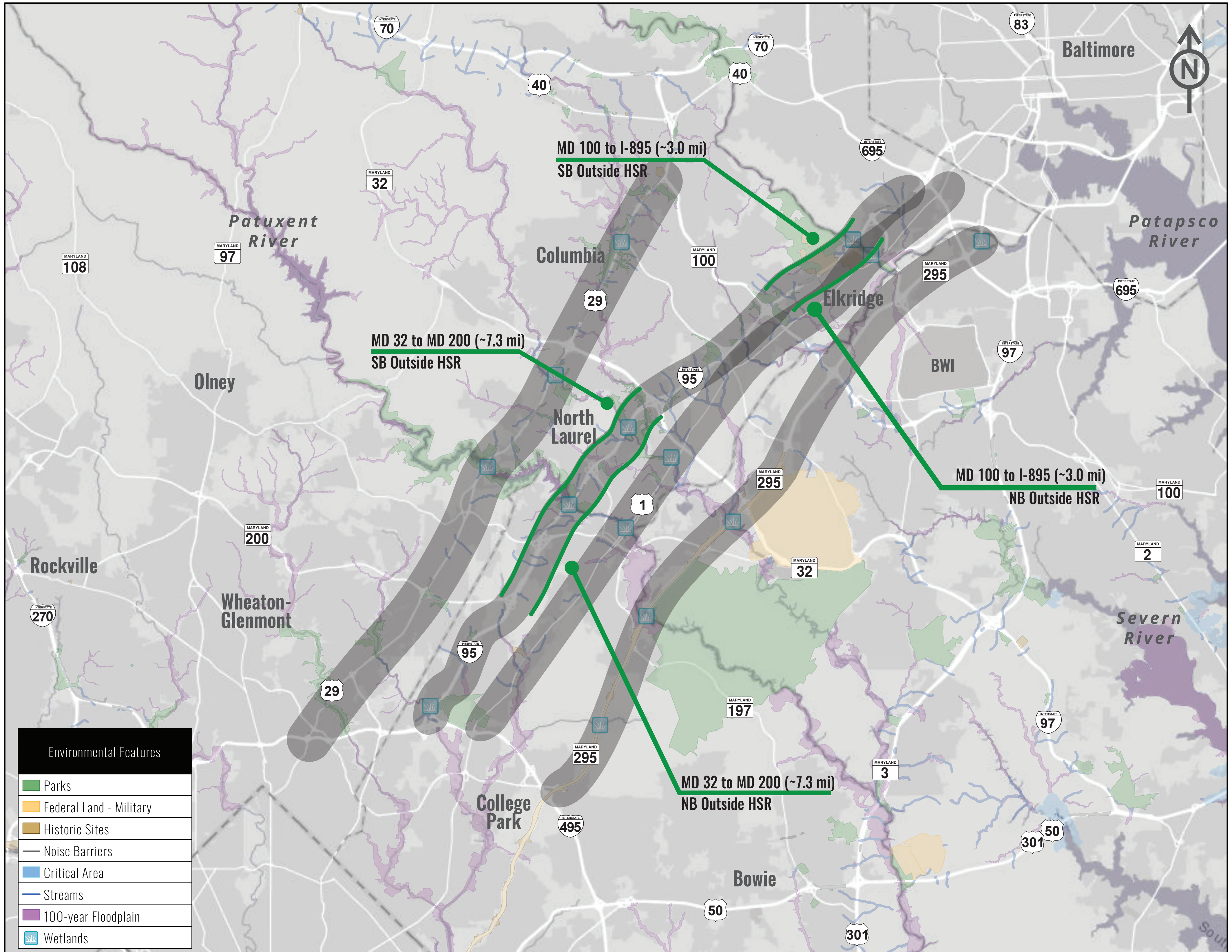
COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	$2	$3	$9
Construction	$9	$13	$19	$63
Total	$10	$15	$22	$72
Annual recurring costs: $280.2 K		Annual O&M costs: $5.4 M		

SUB-SYSTEM DEPLOYMENT:

System 13.1.1 (B/C: 40) Tier 2	I-95 ITS Deployment Deployment of In-Motion Weight Stations, a Weather Station, CCTV, and RSU along I-95 between I-495 and I-695.	PE: $0.6 M CO: $3.7 M Recurring Cost: $25.9 K Annual O&M: $0.6 M
System 13.1.2 (B/C: 71) Tier 1	US 29 ITS Deployment Deployment of CCTV, traffic detectors, and RSU along US 29 between MD 100 and I-495.	PE: $0.2 M CO: $1.4 M Recurring Cost: $25.0 K Annual O&M: $0.2 M
System 13.1.3 (B/C: 132) Tier 1	MD 295 ITS Deployment Deployment of traffic detectors and RSU along MD 295 between I-495 and I-695.	PE: $0.1 M CO: $0.7 M Recurring Cost: $10.2 K Annual O&M: $0.1 M
System 13.1.4 (B/C: 10) Tier 2	I-195 ITS Deployment Deployment of CCTV, traffic detectors, and RSU along I-195 between I-95 and MD 170.	PE: $0.1 M CO: $0.6 M Recurring Cost: $8.0 K Annual O&M: $0.1 M
System 13.1.5 (B/C: 45) Tier 2	MD 32 ITS Deployment Deployment of CCTV and traffic detectors along MD 32 between US 29 and I-95.	PE: $0.1 M CO: $0.4 M Recurring Cost: $5.9 K Annual O&M: $0.1 M
System 13.1.6 (B/C: 19) Tier 2	MD 175 ITS Deployment Deployment of CCTV along MD 175 between US 29 and I-95.	PE: $0.1 M CO: $0.5 M Recurring Cost: $11.2 K Annual O&M: $0.1 M
System 13.1.7 (B/C: 62) Tier 2	US 1 ITS Deployment Deployment of CCTV and detectors along US 1 between I-495 and I-695.	PE: $0.2 M CO: $1.2 M Recurring Cost: $26.0 K Annual O&M: $0.2 M
System 13.2.1 (B/C: 3) Tier 1	US 1 Traffic Signal Upgrade Upgrade existing traffic signals along US 1 between I-495 and I-695 to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled and have TSP.	PE: $1.2 M CO: $7.8 M Recurring Cost: $33.8 K Annual O&M: $1.2 M
System 13.2.2 (B/C: 5) Tier 2	US 29 Traffic Signal Upgrade Upgrade existing traffic signals along US 29 between MD 198 and I-495 fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, ATMS enabled and have TSP.	PE: $0.8 M CO: $5.4 M Recurring Cost: $15.1 K Annual O&M: $0.8 M
System 13.3.1 Tier 3	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $2.8 M CO: $18.9 M Annual O&M: $0.9 M

TSMO SYSTEM # 13: ROADWAY OVERVIEW



HARD SHOULDER RUNNING: I-95

COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	$2	$3	$9
Construction	$9	$13	$19	$63
Total	$10	$15	$22	$72
Annual recurring costs: $280.2 K		Annual O&M costs: $5.4 M		

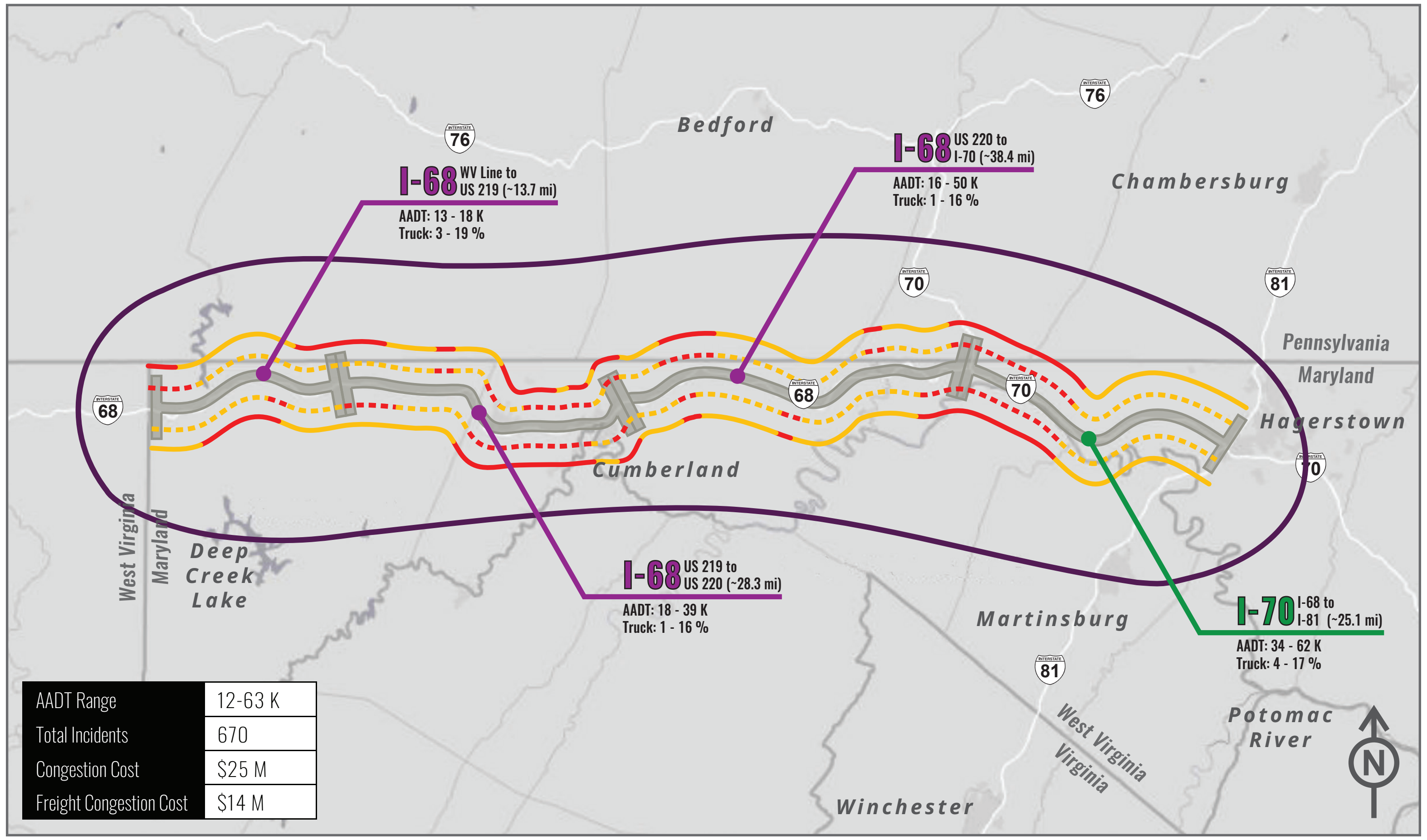
SUB-SYSTEM DEPLOYMENT:

System 13.4.1 (B/C: 1) Tier 3	I-95 Hard Shoulder Running (ITS) Deployment of dynamic lane controls, fixed cameras, CCTV, Communication and ITS equipment, and fiber connection for outside hard shoulder running along I-95 at key locations.	PE: $1.2 M CO: $8.2 M Recurring Cost: $119.0 K Annual O&M: $1.2 M
System 13.4.2 (B/C: 1) Tier 3	I-95 Hard Shoulder Running (Roadway) Civil improvements for outside hard shoulder running along I-95 at key locations.	PE: $8.2 M CO: $54.7 M

PROGRESS STATUS:

- Baltimore-Washington Concept of Operations (completed)
- I-95 Active Traffic Management Study (in design)
- US 1 Smart Traffic Signal (ongoing)

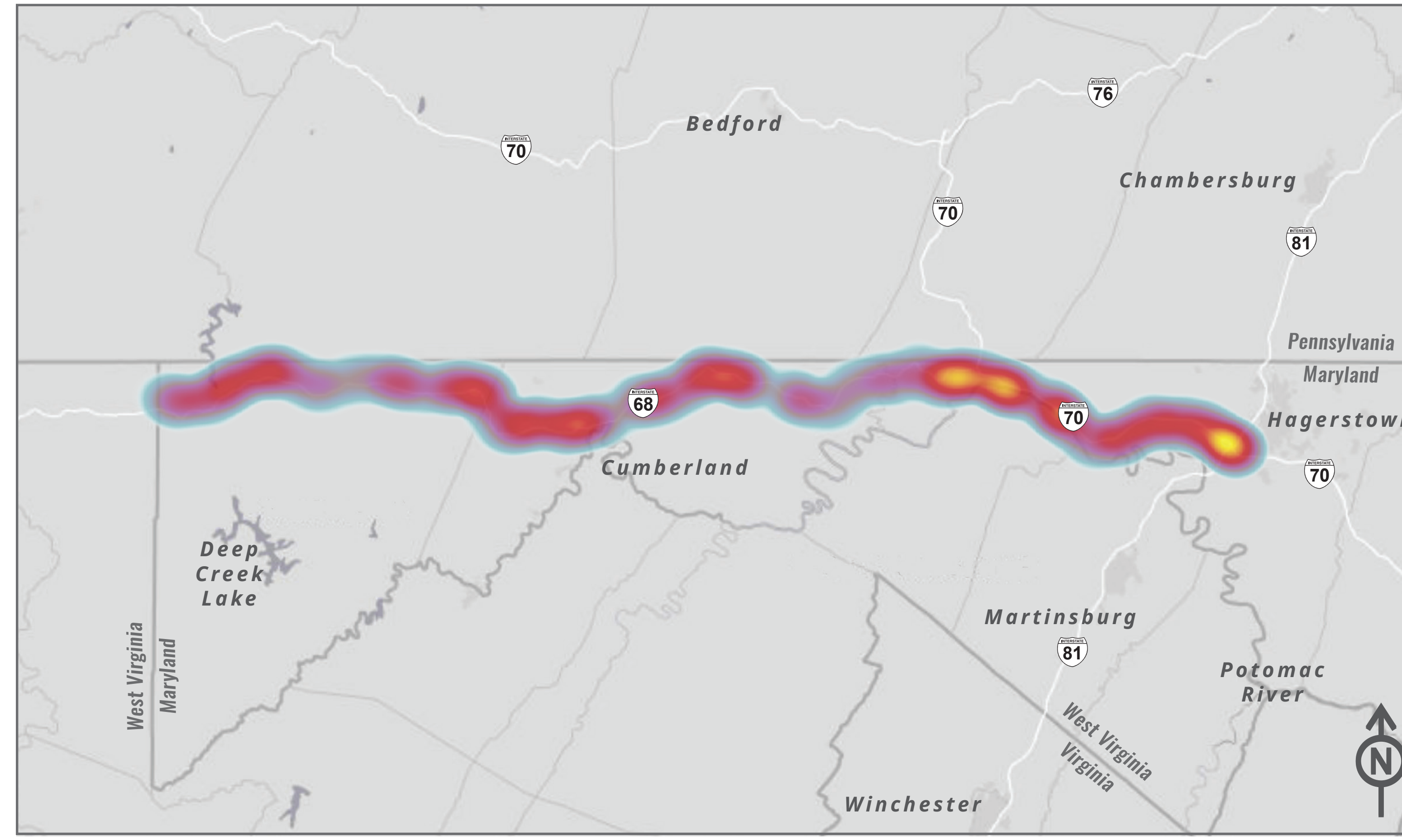
TSMO SYSTEM # 14



UNCONGESTED (TTI < 1.15) MODERATE CONGESTION (1.15 < TTI < 1.3) HEAVY CONGESTION (1.3 < TTI < 2.0) SEVERE CONGESTION (TTI > 2.0)

AM TTI (Freight) PM TTI (Freight)

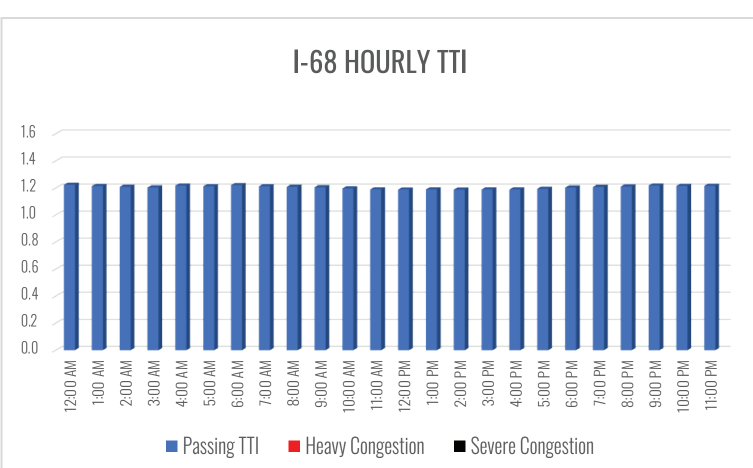
CRASH DENSITY

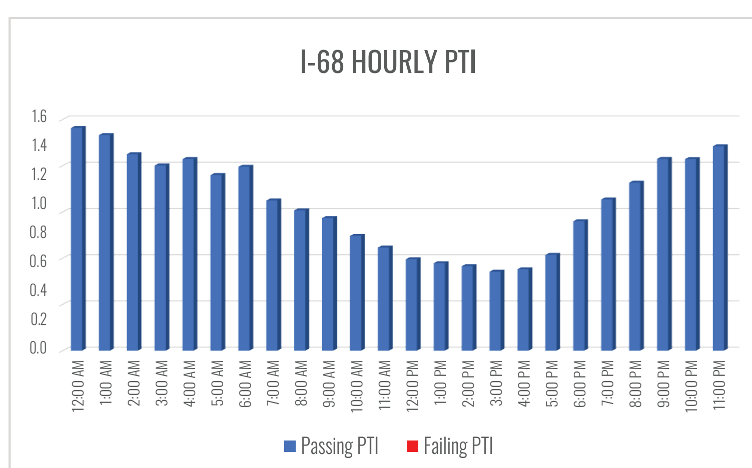


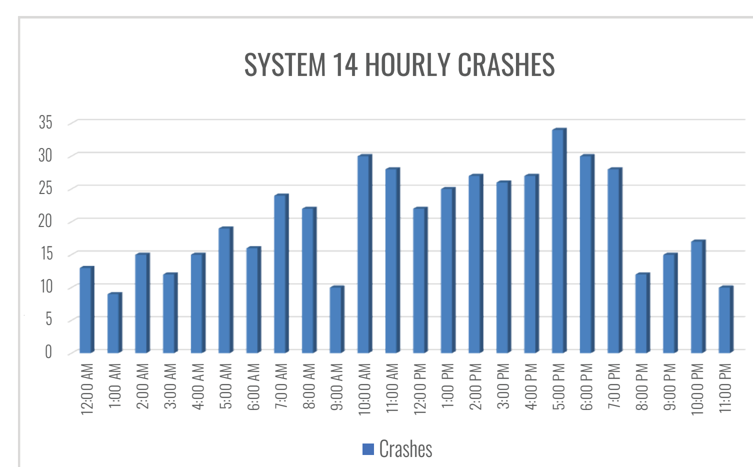
Crash Density: Sparse Dense

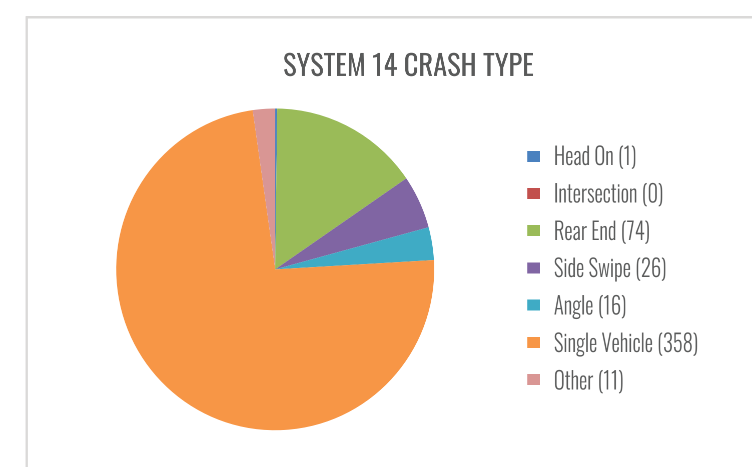
BACKGROUND: TSMO System # 14 is the critical east-west link supporting the Baltimore-Washington metropolitan region and supports import and export supply chains to and from the Port of Baltimore and Maryland markets. I-70 and I-68 are Maryland Freight Routes and part of the National Highway Freight Network. Key commodities in the region supported include mining, agriculture, and retail supporting over 24K businesses and 326K jobs. TSMO System # 14 experiences illegal truck parking and congestion.

SAFETY OVERVIEW: The highest concentrations of crashes occur along I-70 around Hagerstown and along the stretch of highway paralleling the Potomac River. I-68 has the highest concentration of crashes west of Hancock. Crash data shows that the highest number of crashes occur between 10:00 AM and 7:00 PM and the most common crash type is single vehicle crashes. In 2018, there were 486 crashes reported within TSMO System # 14, with four fatalities and 215 injuries.

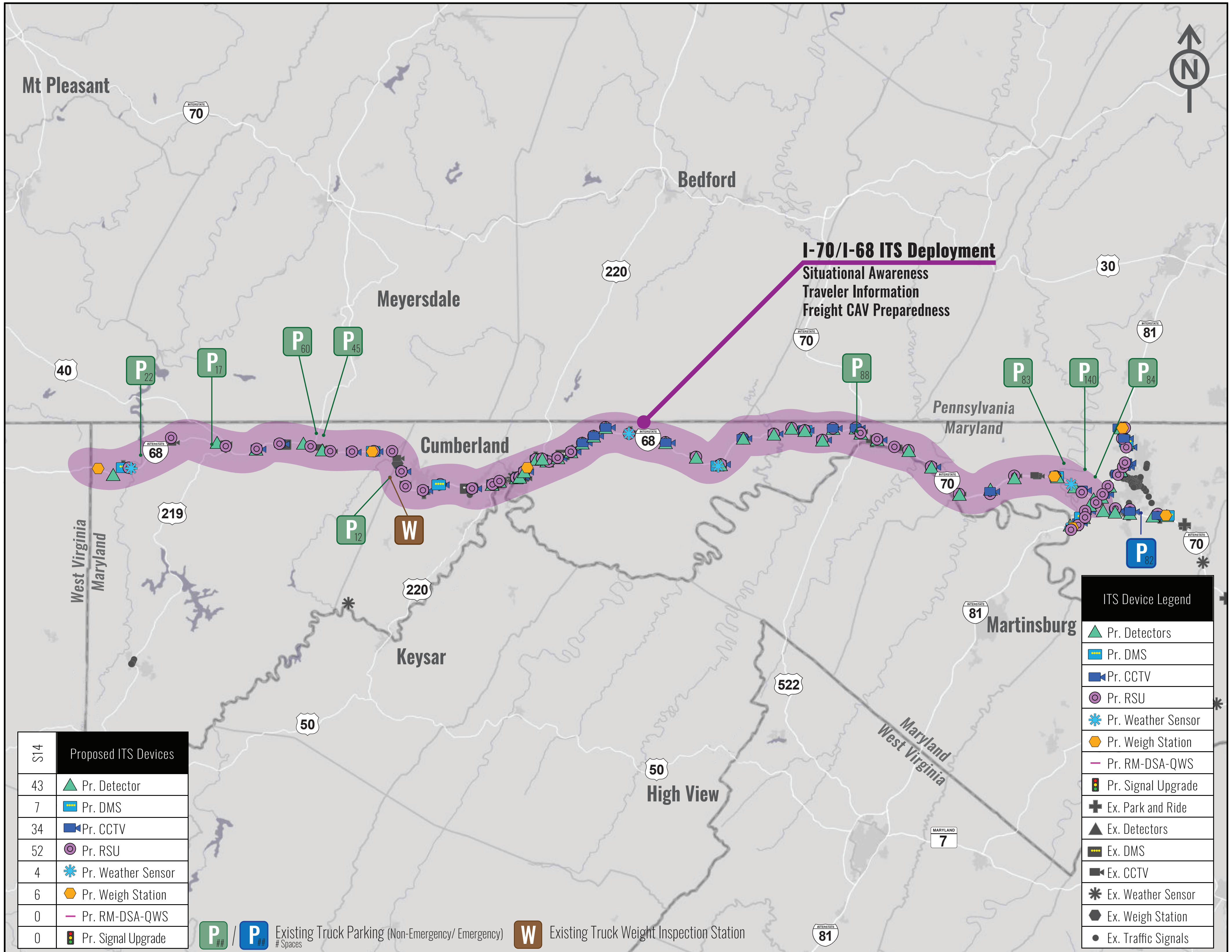








TSMO SYSTEM # 14: ITS OVERVIEW



COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$6	$N/A	$2	$N/A
Construction	$37	$N/A	$14	$N/A
Total	$42	$N/A	$16	$N/A
Annual recurring costs: $431.9 K		Annual O&M costs: $6.2 M		

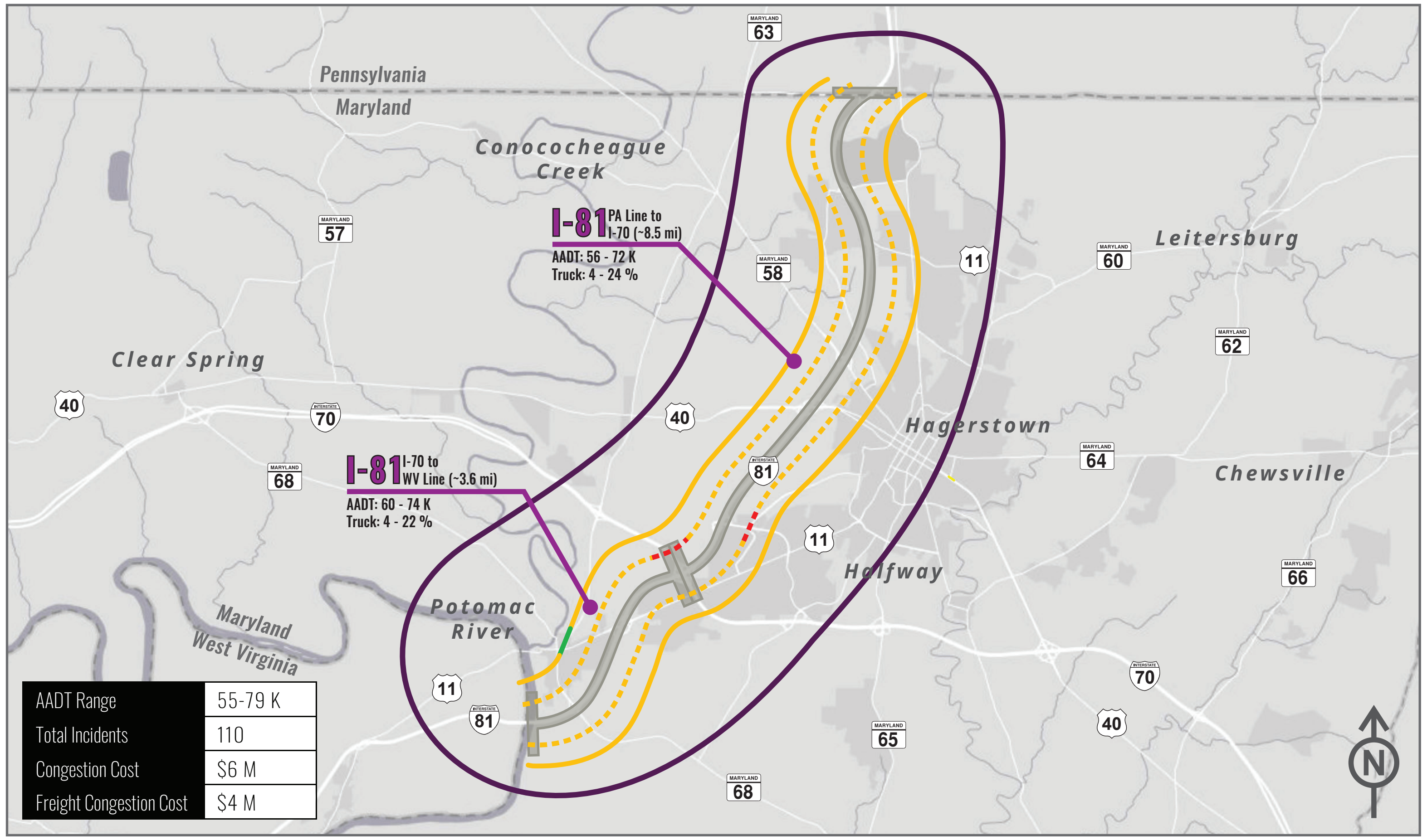
SUB-SYSTEM DEPLOYMENT:

System 14.1.1 (B/C: 2) Tier 3	I-68 ITS Deployment Deployment of In-Motion Weight Stations, Weather Stations, VMS signs, CCTV, traffic detectors, and RSU along I-68 between I-70 and WVA State Line.	PE: $3.7 M CO: $24.6 M Recurring Cost: $287.0 K Annual O&M: $3.7 M
System 14.1.2 (B/C: 3) Tier 3	I-70 ITS Deployment Deployment of a Weather Station, VMS signs, CCTV, traffic detectors, and RSU along I-70 between I-68 and MD 65.	PE: $1.8 M CO: $12.3 M Recurring Cost: $144.8K Annual O&M: $1.8 M
System 14.3.1 Tier 3	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $2.1 M CO: $13.9 M Annual O&M: $0.6 M

PROGRESS STATUS:

- Concept of Operations (TBD)

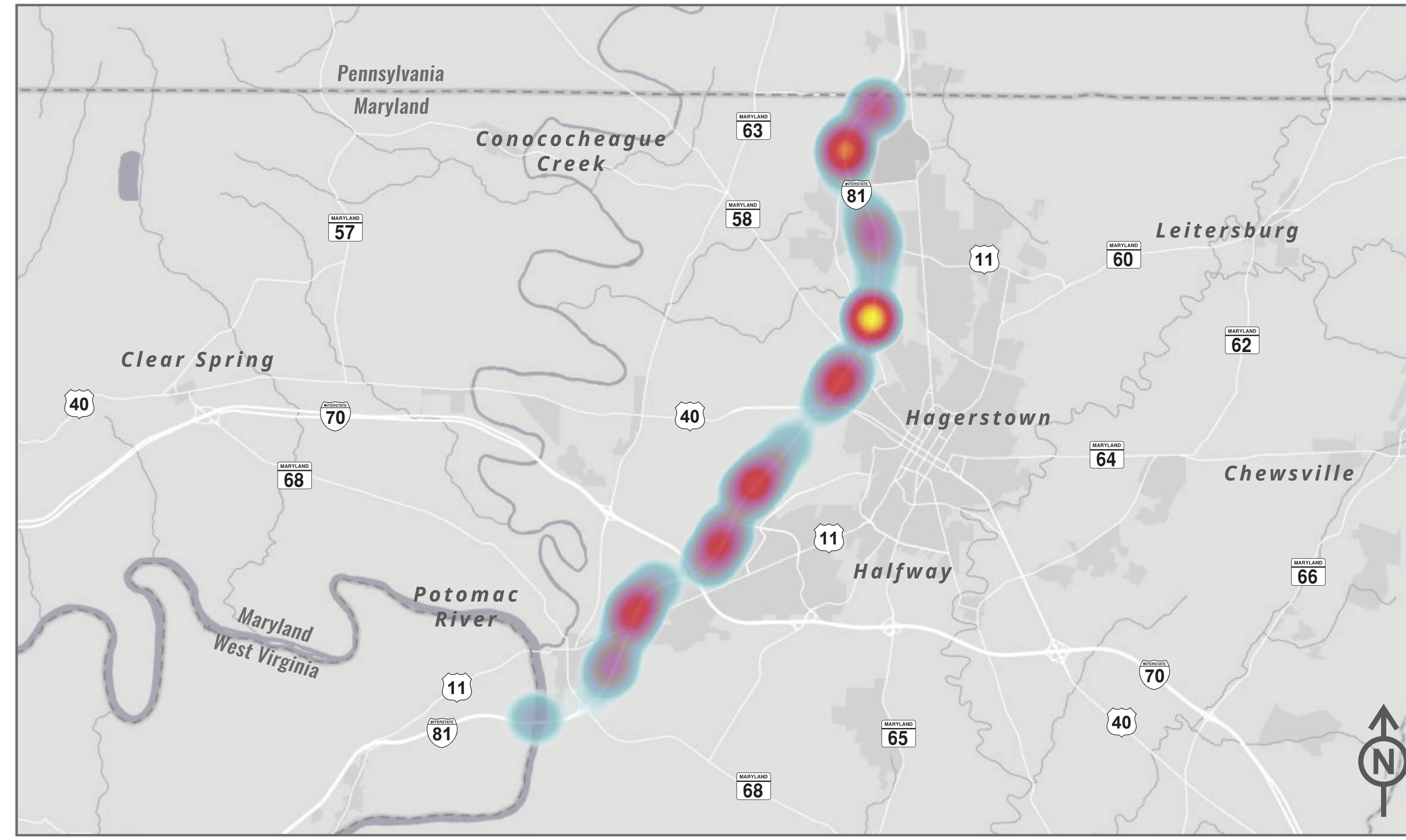
TSMO SYSTEM # 15



UNCONGESTED (**TTI < 1.15**) MODERATE CONGESTION (**1.15 < TTI < 1.3**) HEAVY CONGESTION (**1.3 < TTI < 2.0**) SEVERE CONGESTION (**TTI > 2.0**)

AM TTI (Freight) PM TTI (Freight)

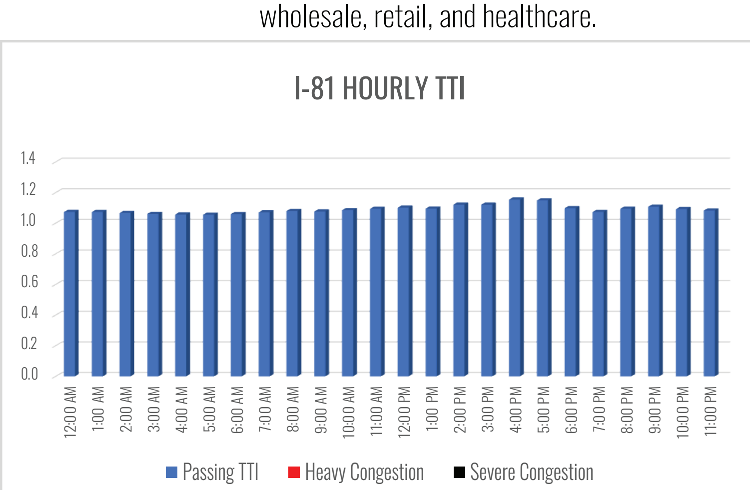
CRASH DENSITY

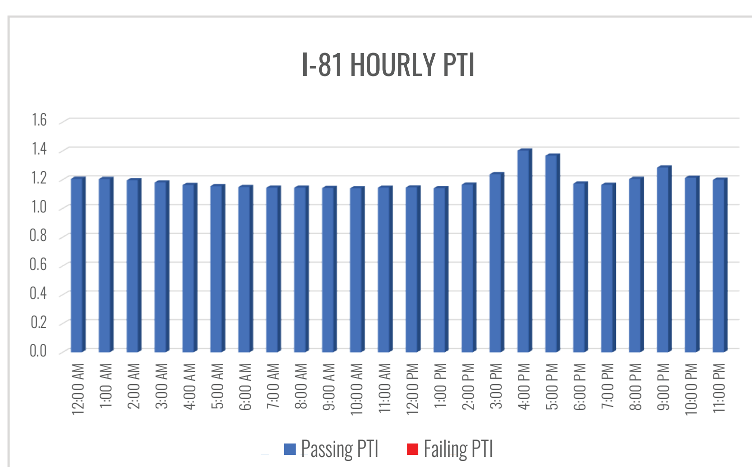


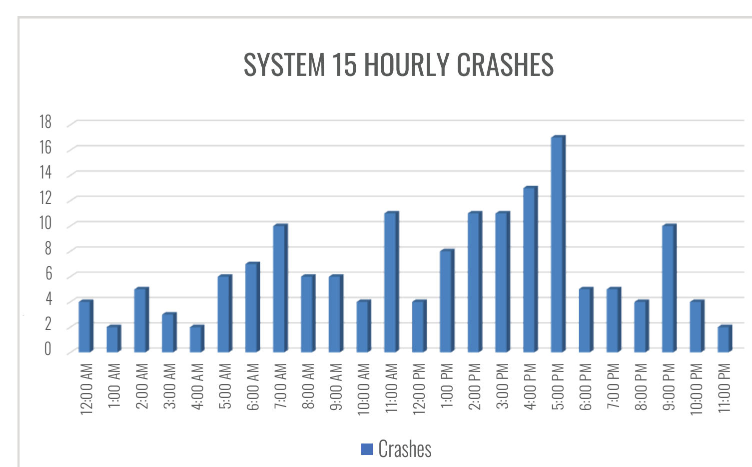
Crash Density: Sparse Dense

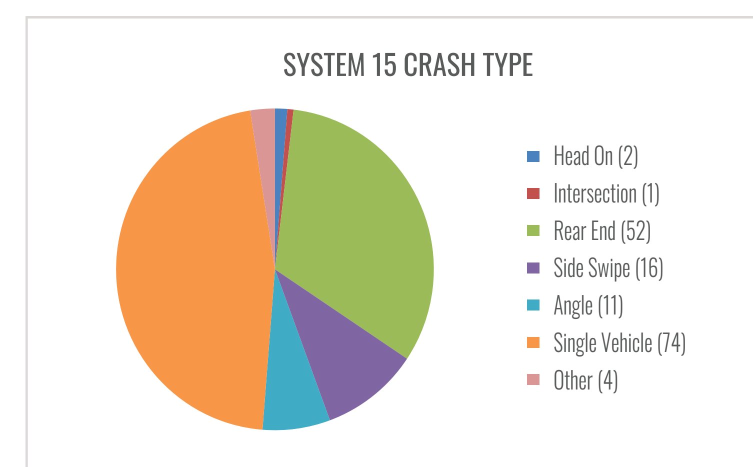
BACKGROUND: TSMO System # 15 is a critical truck thoroughfare and interstate crossroads linking northern and southern markets; the Baltimore-Washington area to northern U.S. and southern U.S. markets. I-81 is a Maryland Freight Corridor and is part of the National Highway Freight Network. The system also supports major railroad intermodal terminals, as well as one of Maryland's critical cargo bearing airports. Major markets supported include energy (solar/biomass), construction, utilities, manufacturing, wholesale, retail, and healthcare.

SAFETY OVERVIEW: The highest concentrations of crashes occur along I-81 north of MD 58 and between the PA line and Showarer Road. Crash data shows that the highest number of crashes occur between 4:00 PM and 5:00 PM and the most common crash type is single vehicle crashes. In 2018, there were 160 crashes reported within TSMO System # 15, with zero fatalities and 59 injuries.

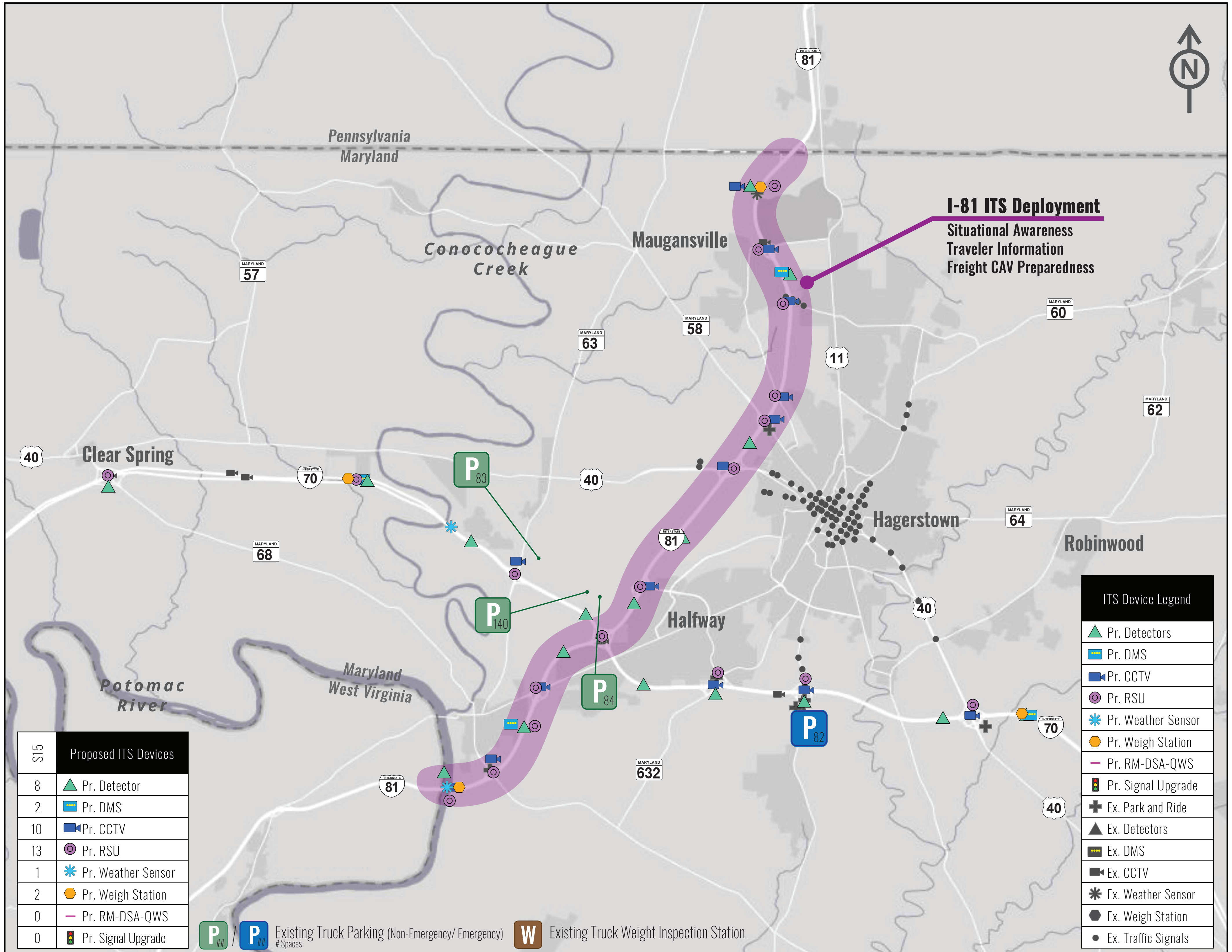








TSMO SYSTEM # 15: ITS OVERVIEW



S15	Proposed ITS Devices
8	Pr. Detector
2	Pr. DMS
10	Pr. CCTV
13	Pr. RSU
1	Pr. Weather Sensor
2	Pr. Weigh Station
0	Pr. RM-DSA-QWS
0	Pr. Signal Upgrade

COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	$N/A	<$1	$N/A
Construction	$9	$N/A	$3	$N/A
Total	$10	$N/A	$3	$N/A
Annual recurring costs: $95.5 K		Annual O&M costs: $1.5 M		

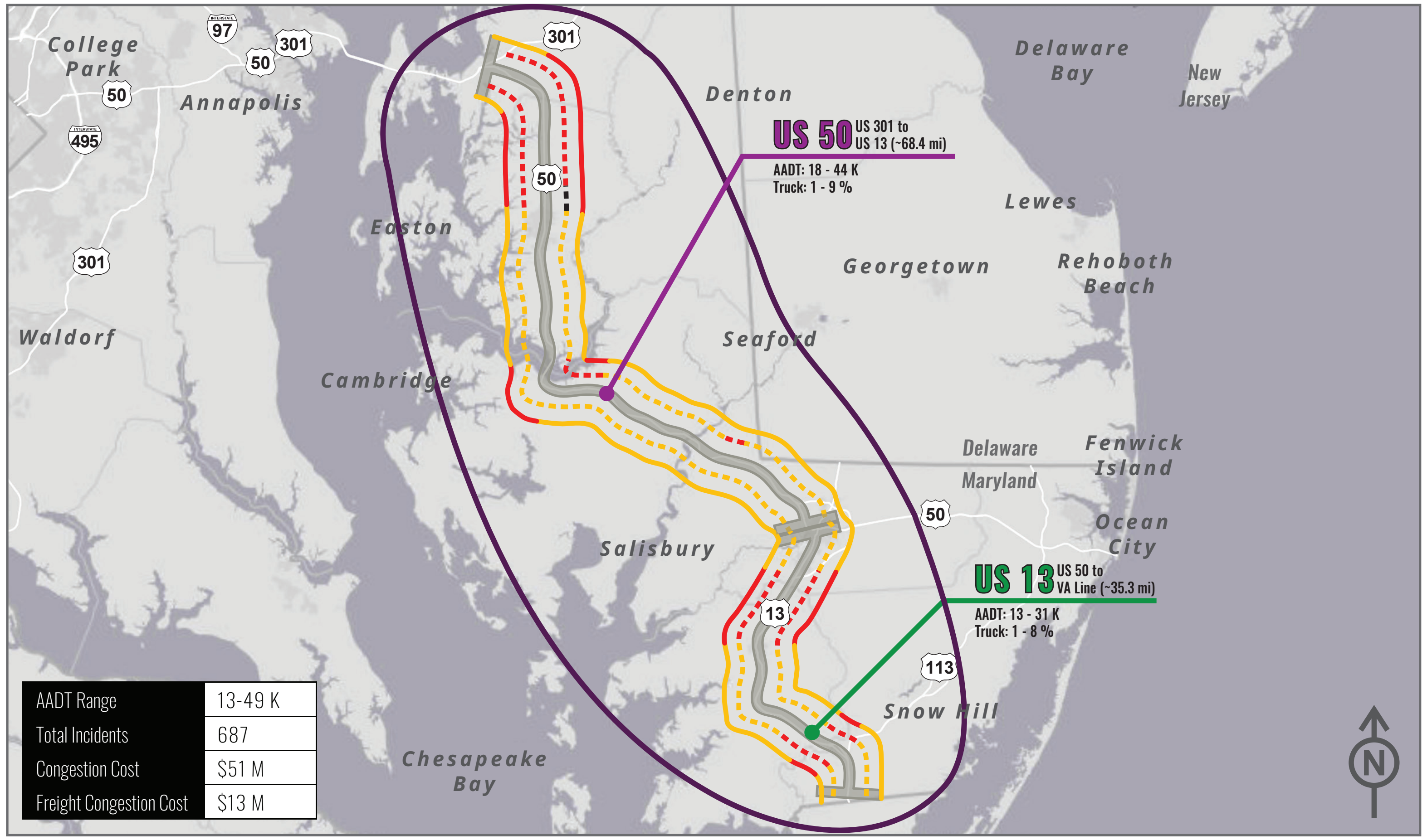
SUB-SYSTEM DEPLOYMENT:

System 15.1.1 (B/C: 3) Tier 1	I-81 ITS Deployment Deployment of In-Motion Weight Stations, Weather Stations, VMS signs, CCTV, traffic detectors, and RSU along I-81 between WVA State Line and PA State Line.	PE: $1.3 M CO: $8.9 M Recurring Cost: $95.5K Annual O&M: $1.3 M
System 15.3.1 Tier 1	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $0.4 M CO: $3.0 M Annual O&M: $0.1 M

PROGRESS STATUS:

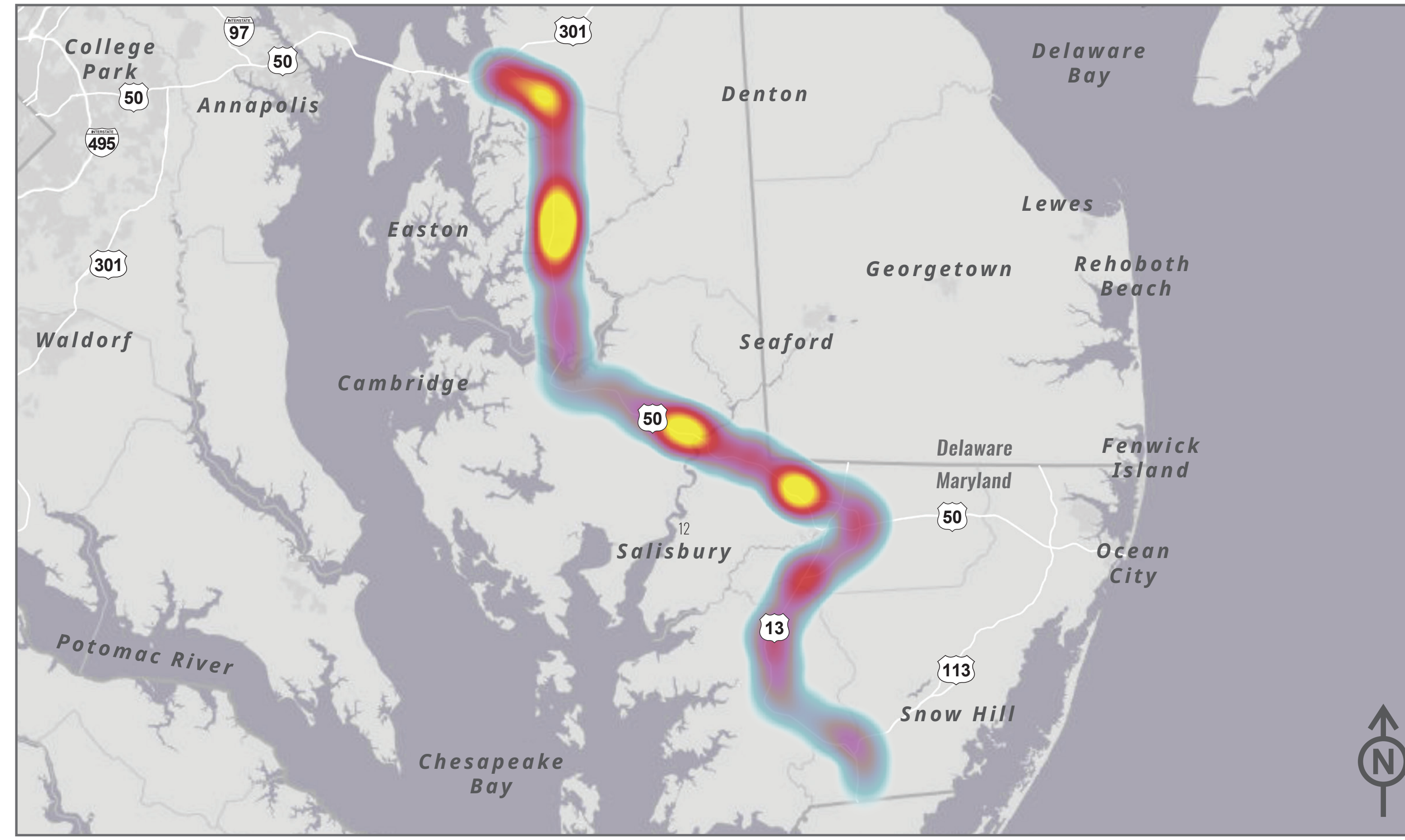
- Concept of Operations (TBD)

TSMO SYSTEM # 16



UNCONGESTED (TTI < 1.15) MODERATE CONGESTION (1.15 < TTI < 1.3) HEAVY CONGESTION (1.3 < TTI < 2.0) SEVERE CONGESTION (TTI > 2.0)
AM TTI (Freight) PM TTI (Freight)

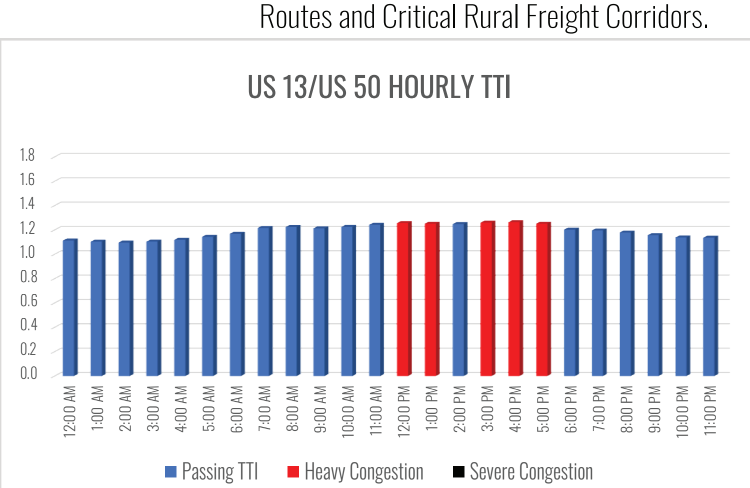
CRASH DENSITY

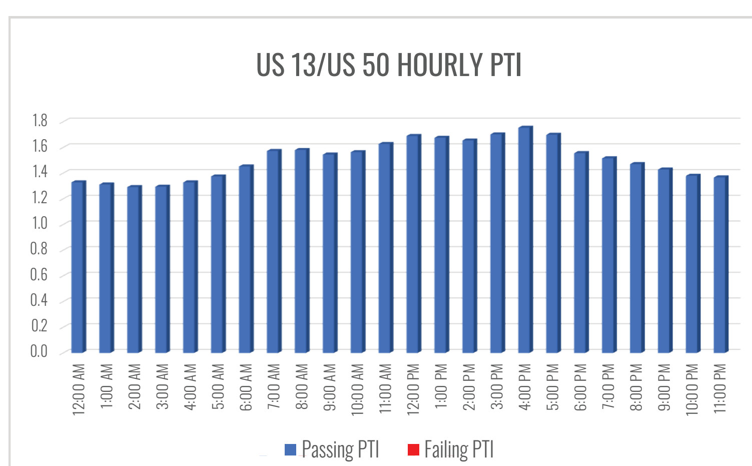


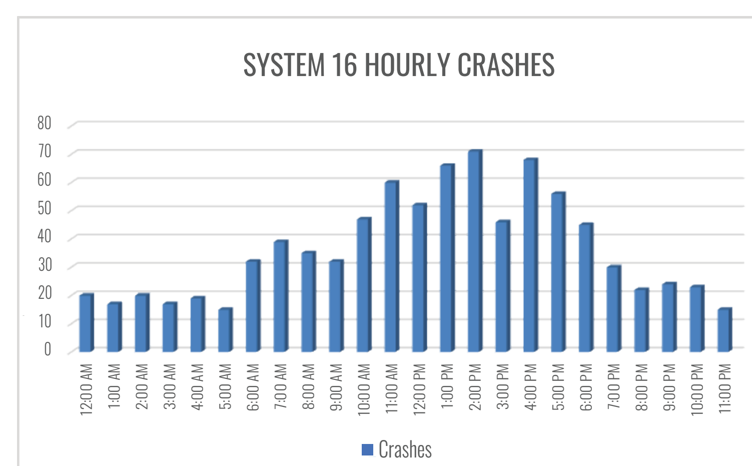
Crash Density: Sparse Dense

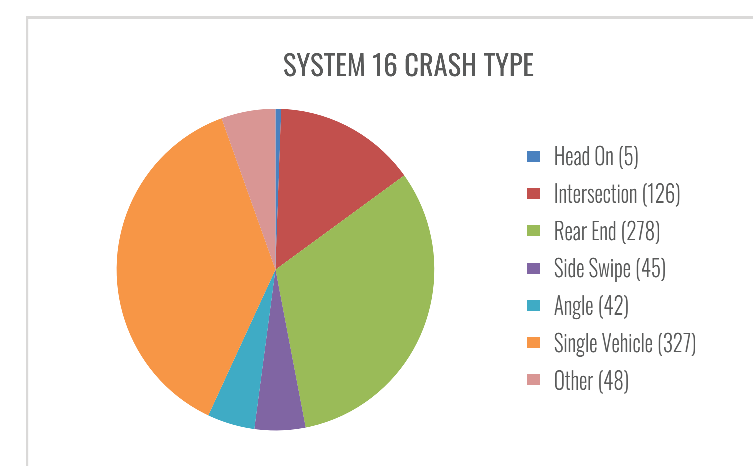
BACKGROUND: TSMO System # 16 provides alternate north-south freight route connecting US 301 with US 13, and provides access to the Eastern Shore and Washington DC This is a key corridor connecting the Baltimore Washington region to Eastern Shore markets and the Port of Virginia (Norfolk). The corridor is vital for poultry and agricultural production, supporting technology and defense industries and other freight flows between regions and major port areas. US 50 and US 13 are Maryland Freight Routes and Critical Rural Freight Corridors.

SAFETY OVERVIEW: The highest concentrations of crashes occur along US 50 east of the split with US 301, around Easton and Vienna, and near the interchange with US 13. Crash data shows that the highest number of crashes occur between 10:00 AM and 6:00 PM and the most common crash type is single vehicle crashes. In 2018, there were 871 crashes reported within TSMO System # 16, with seven fatalities and 572 injuries.

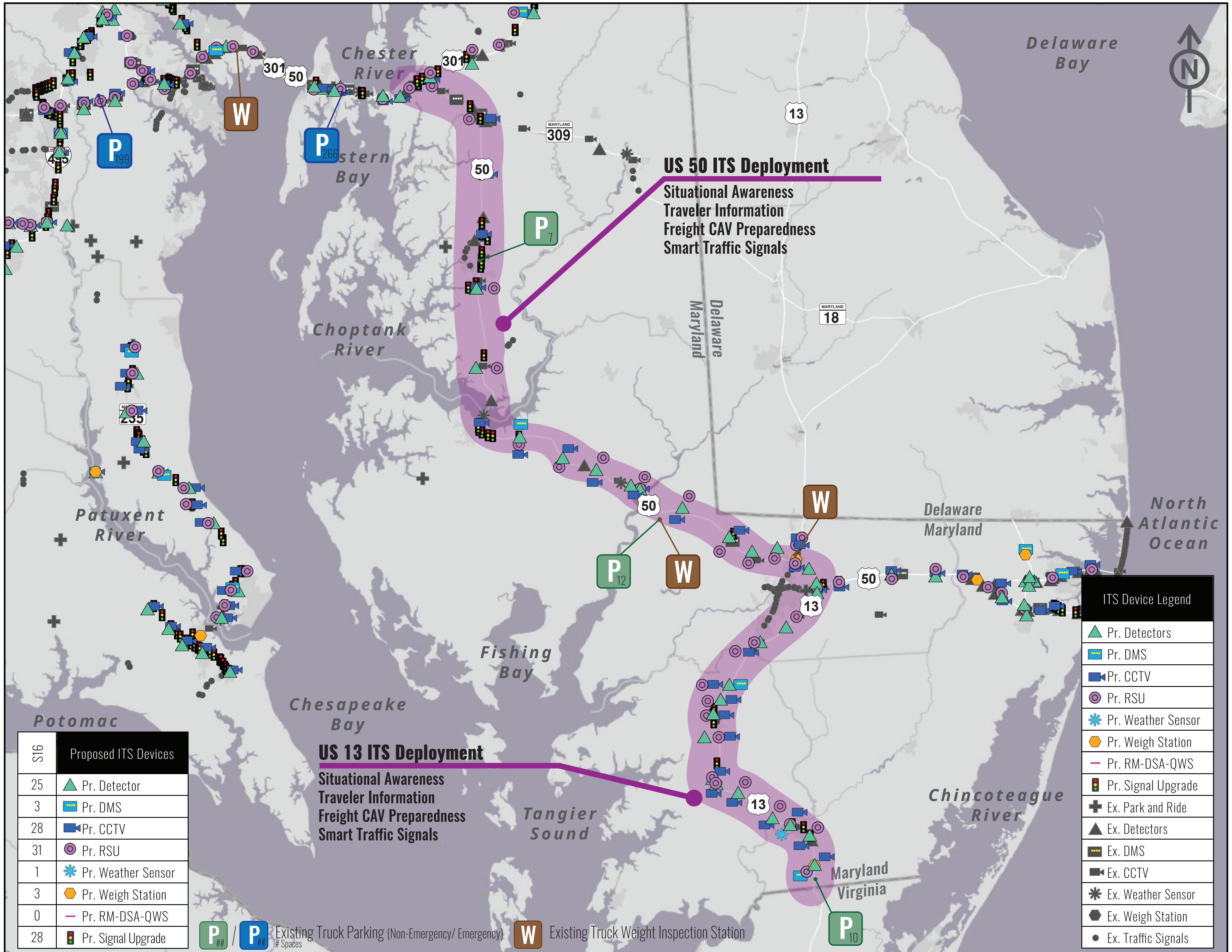








TSMO SYSTEM # 16: ITS OVERVIEW



COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$3	$1	$3	$N/A
Construction	$19	$5	$22	$N/A
Total	$21	$5	$25	$N/A
Annual recurring costs: $251.9 K		Annual O&M costs: $4.5 M		

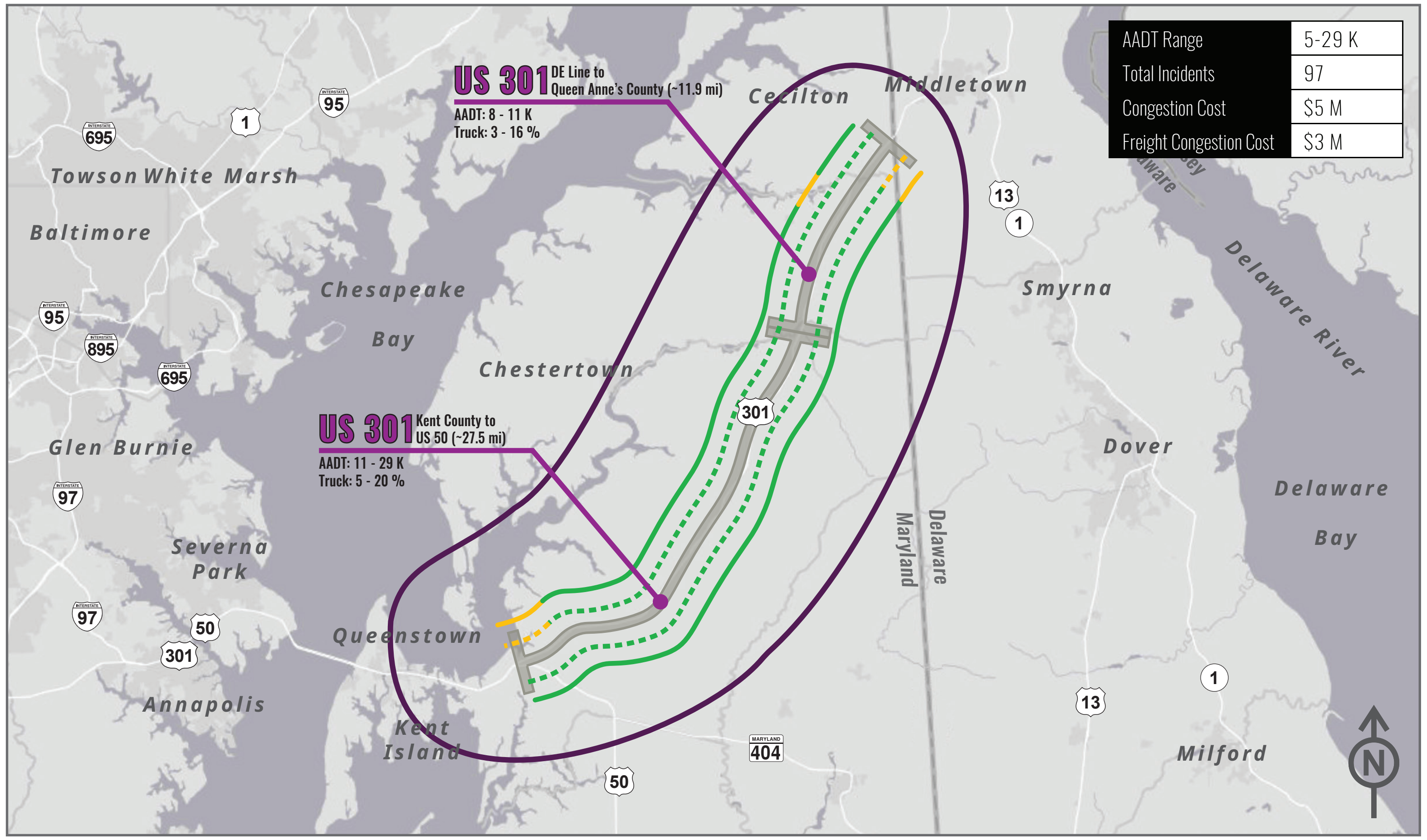
SUB-SYSTEM DEPLOYMENT:

System 16.1.1 (B/C: 43) Tier 1	US 50 ITS Deployment Deployment of an In-Motion Weight Station, VMS signs, CCTV, traffic detectors, and RSU along US 50 between US 301 and US 13.	PE: $1.3 M CO: $8.7 M Recurring Cost: $100.7 K Annual O&M: $1.3 M
System 16.1.2 (B/C: 10) Tier 2	US 13 ITS Deployment Deployment of In-Motion Weight Stations, a Weather Station, VMS signs, CCTV, traffic detectors, and RSU along US 13 between US 50 and VA State Line.	PE: $1.5 M CO: $9.9 M Recurring Cost: $131.0 K Annual O&M: $1.5 M
System 16.2.1 (B/C: 18) Tier 2	US 50 Traffic Signal Upgrade Upgrade existing traffic signals along US 50 between US 301 and US 13 to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, and ATMS enabled.	PE: $0.6 M CO: $3.7 M Recurring Cost: $15.1 K Annual O&M: $0.6 M
System 16.2.2 (B/C: 6) Tier 2	US 13 Traffic Signal Upgrade Upgrade existing traffic signals US 13 between US 50 and VA State Line to be fully-actuated, equipped with S-Cabinets, have Video Detection, have CAV Equipment, and ATMS enabled.	PE: $0.2 M CO: $1.0 M Recurring Cost: $5.0 K Annual O&M: $0.2 M
System 16.3.1 Tier 3	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $3.3 M CO: $21.9 M Annual O&M: $1.0 M

PROGRESS STATUS:

- Concept of Operations (TBD)

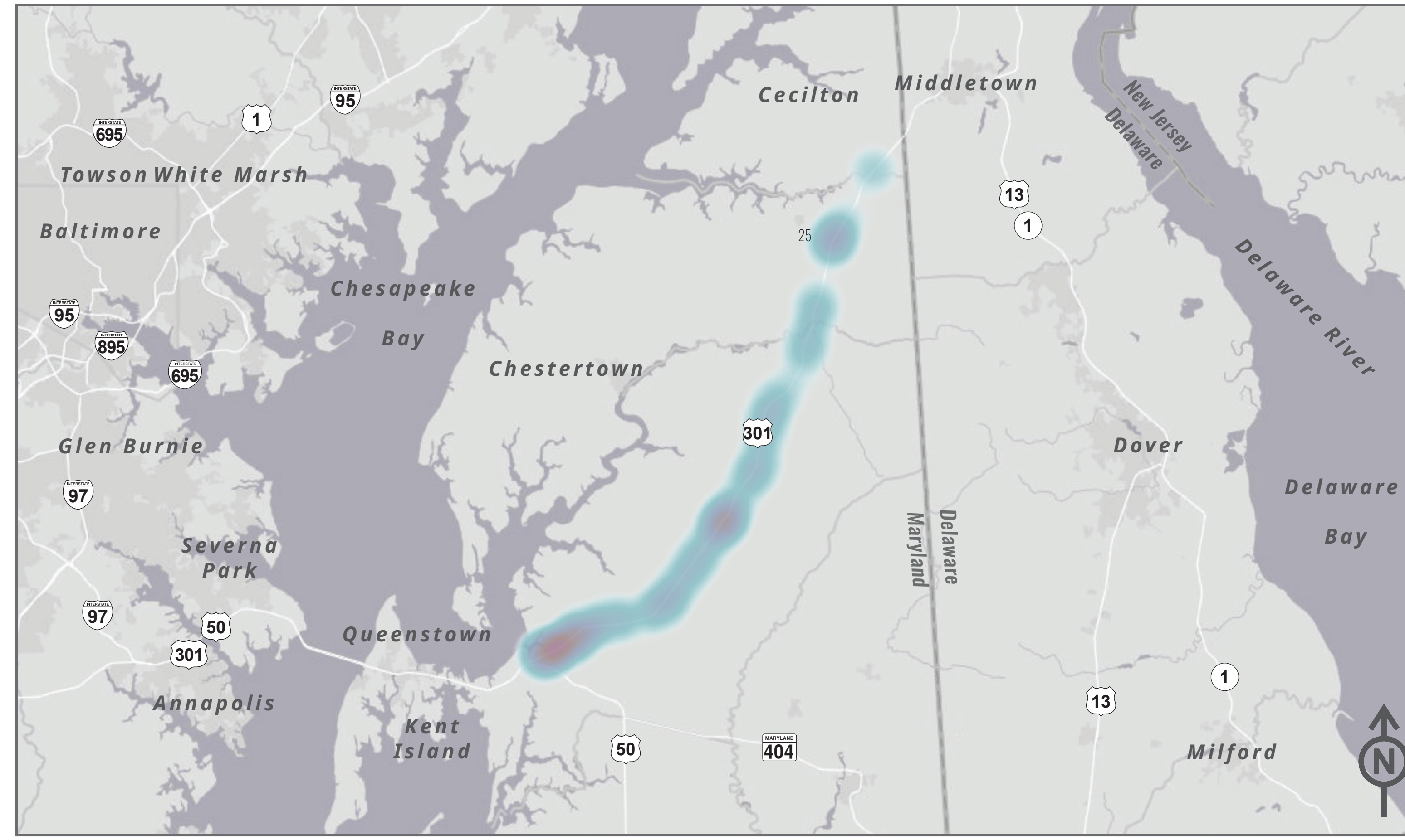
TSMO SYSTEM # 17



UNCONGESTED (**TTI < 1.15**) MODERATE CONGESTION (**1.15 < TTI < 1.3**) HEAVY CONGESTION (**1.3 < TTI < 2.0**) SEVERE CONGESTION (**TTI > 2.0**)

AM TTI (Freight) PM TTI (Freight)

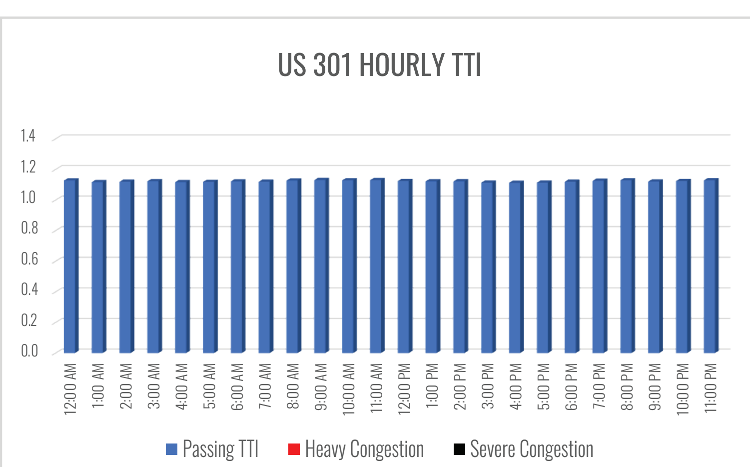
CRASH DENSITY

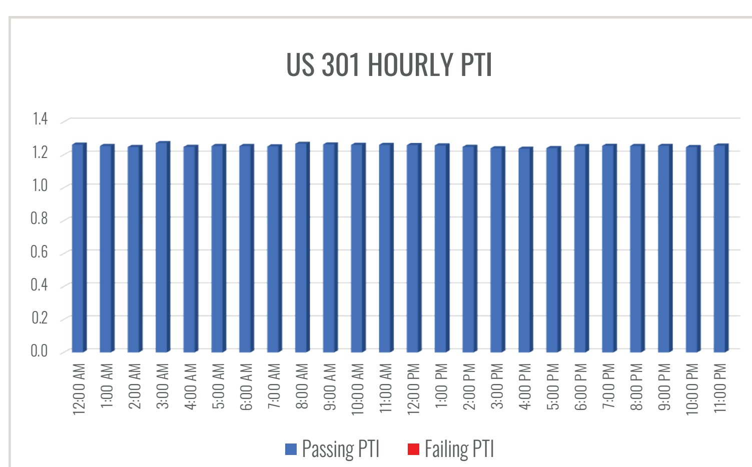


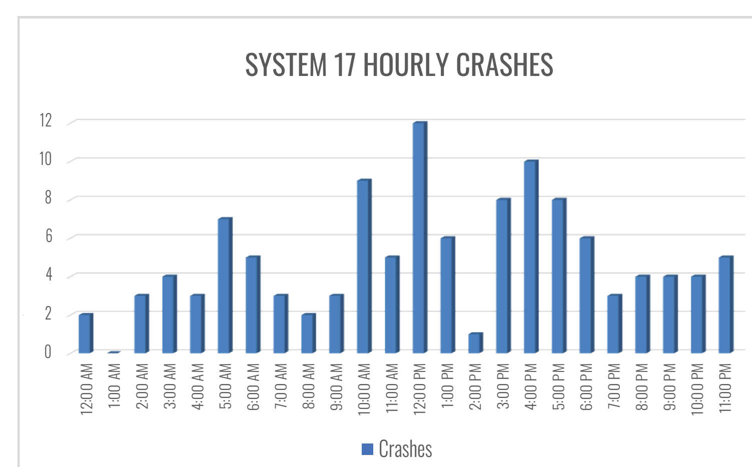
Crash Density: Sparse Dense

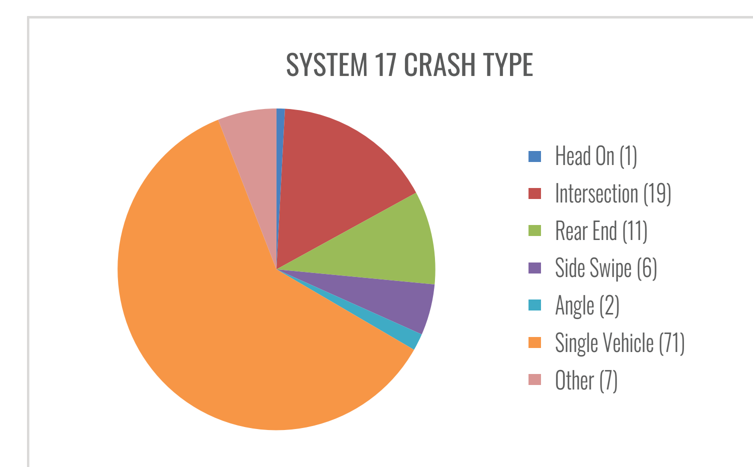
BACKGROUND: TSMO System # 17 provides alternative north-south freight route by connecting Delaware with US 50. This is a critical corridor for Maryland industries of agriculture, manufacturing, chemical production, and food/poultry production. This system provides a vital link between the Baltimore/Washington market and both northeastern U.S. and Eastern Shore markets. US 301 is a Maryland Freight Route and a Critical Rural Freight Corridor. Illegal truck parking is high on the corridor due to low availability.

SAFETY OVERVIEW: The highest concentrations of crashes occur along US 301 east of the split with US 50 and near the intersection with MD 405. Crash data shows that the highest numbers of crashes occur between 10:00 AM and 12:00 PM and between 3:00 PM and 5:00 PM and the most common crash type is single vehicle crashes. In 2018, there were 117 crashes reported within TSMO System # 17, with two fatalities and 60 injuries.

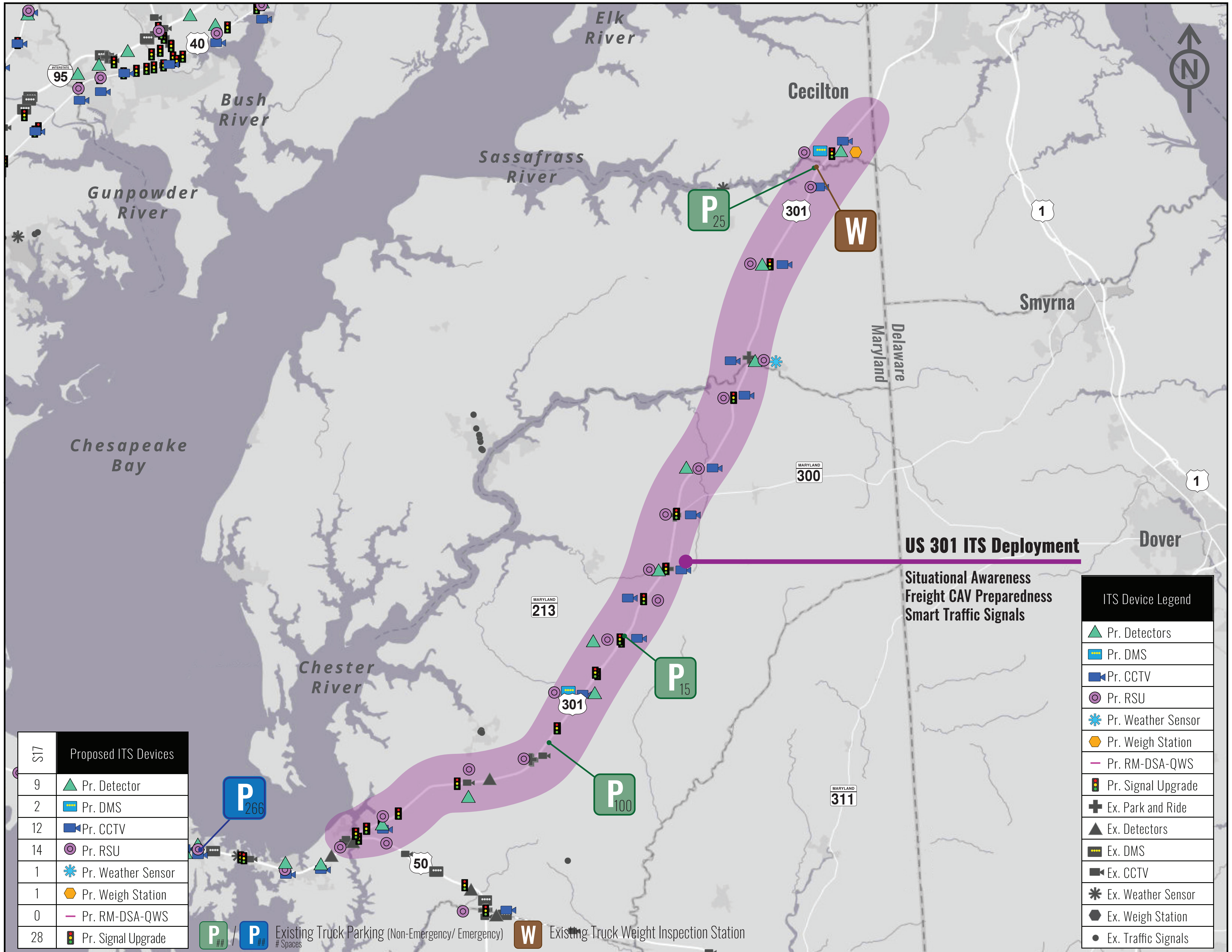








TSMO SYSTEM # 17: ITS OVERVIEW



COST SUMMARY:

Cost Summary ($ millions)	ITS	Signals	Telecomm.	Roadway
Preliminary Engineering	$1	$1	$3	$N/A
Construction	$10	$6	$19	$N/A
Total	$11	$6	$22	$N/A
Annual recurring costs: $146.8 K		Annual O&M costs: $3.2 M		

SUB-SYSTEM DEPLOYMENT:

System 17.1.1 (B/C: 2) Tier 2	US 301 ITS Deployment Deployment of an In-Motion Weight Station, a Weather Station, VMS signs, CCTV, traffic detectors, and RSU along US 301 between US 50 and DE State Line.	PE: $1.5 M CO: $9.7 M Recurring Cost: $126.6 K Annual O&M: $1.5 M
System 17.2.1 (B/C: <1) Tier 2	US 301 Traffic Signal Upgrade Upgrade existing traffic signals along US 301 between US 50 and DE State Line to be fully-actuated, equipped with S-Cabinets, and have Video Detection.	PE: $0.8 M CO: $5.5 M Recurring Cost: $20.2 K Annual O&M: $0.8 M
System 17.3.1 Tier 3	Telecommunications Fiber connections for ITS deployment in sub systems and to provide critical connections for the network	PE: $2.9 M CO: $19.5 M Annual O&M: $0.9 M

PROGRESS STATUS:

- Concept of Operations (TBD)

APPENDIX B

AREAWIDE ITS PROJECTS

PERSONNEL, EQUIPMENT, AND INFRASTRUCTURE PROJECTS

SOFTWARE DEVELOPMENT AND SYSTEM INTEGRATION PROJECTS

Areawide ITS Deployment Projects

Sub-System	Project Title	Project Description	Preliminary Engineering + Construction ($M)	Annual Recurring Cost ($K)	Annual O&M Cost ($K)
AW1.01	CCTV replacement (Phase I)	Replace all existing CCTV cameras at end of lifecycle with latest technology cameras to continue monitoring roadway conditions using the cutting-edge national communication protocol standards. Typically, CCTV cameras have a productive lifespan of approximately ten years due to exposure to extreme outdoor conditions, failures in PTZ motor assemblies, deterioration of the anti-glare lens coating, and other image quality related issues. Additionally, spare part availability from manufacturers is not guaranteed.	$0.5	$120	$60
AW1.02	CCTV replacement (Phase II)		$0.5	$120	$60
AW1.03	CCTV replacement (Phase III)		$0.5	$120	$60
AW1.04	Portable Trailer Cameras	Portable trailer-mounted cameras provide the functionality of any other CCTV camera, but with the flexibility to be mobile. These cameras may be used for semi-permanent (construction situation) or temporary (incident and emergency management) applications.	$0.4	$9	$50
AW1.05	Deploy permanent traffic monitoring equipment at work zones	Additional traffic monitoring devices will benefit construction zones in detecting and monitoring incidents, hazardous conditions, and congestion. This will improve incident response to dispatch the correct equipment for faster and more efficient incident removal; it will improve safety by detecting hazardous conditions to facilitate alerting motorists; and it will reduce delay by detecting and monitoring congestion to facilitate management of traffic flow.	$2.3	$4	$290
AW1.06	Purchase portable trailer mounted traffic detectors	Purchase portable side-fire traffic detectors mounted on trailers, with wireless communications to provide flexible monitoring capabilities at any location in the state. These detectors will provide the functionality of any other traffic detector, but with the flexibility of mobility. These detectors may be used for semi-permanent (construction situation) or temporary (incident and emergency management) applications.	$0.6	$14	$80
AW1.07	Deploy enhanced HAR at existing sites	Replace the existing HAR systems with leading edge synchronized HAR technology to assure superior service to broadcast live traveler information effectively. Synchronized HAR systems will be coordinated with MDTA to assure the messages and coverage areas are consistent among motorists traveling to/between MDOT SHA and MDTA-operated facilities.	$0.6	$6	$70
AW1.08	Replace portable DMS	Replace existing portable DMS trailers with the latest solar power technology and wireless communication medium.	$1.5	$24	$190
AW1.09	Roadside infrastructure for in-vehicle hazard alert	Install roadside detectors, and short-range radio transmitters and antennas to detect hazardous traveling conditions and alert traveling vehicles via radio. This infrastructure will provide motorists in-vehicle real-time information regarding immediate hazards and congestion in downstream lanes on highways, tailored to vehicles within the broadcast area. The service will reduce primary and secondary incidents and provide drivers the information to choose alternate routes at decision points prior to highway on-ramps.	$0.7	$5	$90
AW1.10	Replace roadside weather stations (Phase I)	Existing RWIS sensors are maintenance intensive. This project retrofits/ upgrades the existing Roadside Weather Information Stations with Remote Processing Units (RPU) technology. Replacing existing weather stations provides reliable information regarding current weather conditions, which will be passed along to travelers using CHART's website, DMS, HAR, and other available media. RPU technology will collect and transmit weather data to locations with existing traffic cabinets such as traffic signals or dynamic message signs.	$1.7	$18	$210
AW1.11	Replace roadside weather stations (Phase II)		$1.6	$18	$210
AW2.01	Install mile markers (Phase I)	Install mile marker signs at every 0.10-mile interval along all freeways and expressways within the state of Maryland. This improves CHART'S ability to locate and report incidents and hazardous conditions with greater precision for faster and more efficient incident removal to facilitate management of traffic flow.	$0.8	N/A	N/A
AW2.02	Install mile markers (Phase II)		$0.8	N/A	N/A

Personnel, Equipment, and Support Infrastructure Projects

Sub-System	Project Title	Project Description	Preliminary Engineering + Construction ($M)	Annual Recurring Cost ($K)	Annual O&M Cost ($K)
P1.01	Incident management field equipment for CHART (Phase I)	Purchase advanced field equipment to enhance incident management personnel's ability to respond and clear incidents and emergencies along state and interstate highways in all jurisdictions. State-of-the-art equipment for emergency traffic patrol and response operations, such as: vehicles, tow trucks, end loaders, street sweepers, roll-off dumpsters, portable hardened incident site lighting equipment, portable incident shelters, and portable devices (e.g., vehicle-mounted DMS and arrow panels, and static signs for incident management).	$2.0	$11	$300
P1.02	Incident management field equipment for CHART (Phase II)		$1.9	$11	$290
P1.03	Incident management field equipment for Agencies	Provide and transfer equipment to Maryland State Police (MSP) and other public safety agencies to improve coordination and joint activities with CHART. This project will provide additional equipment to public safety agencies to more effectively respond, log, investigate, report, clear, and restore traffic operations to normal conditions during incidents and emergency evacuation.	$1.3	$20	$200
P1.04	Deploy AVL technology in CHART vehicles	Install AVL equipment on future CHART vehicles. AVL technology in incident/emergency vehicles will give dispatchers greater knowledge about locations of vehicles and enable the nearest vehicle to be dispatched to an incident. This will provide faster response times, resulting in fewer secondary incidents and less delay for travelers.	$0.03	$4	$5
P1.05	Replace portable data sharing devices for personnel	Replace existing in-vehicle laptops with hand-held field computers for field operators to report quality real-time information on incidents and emergency events wirelessly to CHART remote incident management personnel to facilitate incident/emergency management field operations. These devices help make the reporting process less time-consuming by recording data electronically in the field and transmitting the captured images wirelessly to CHART centers and other CHART system users via VPN/APN path.	$0.3	$43	$40
P1.06	Deploy Trail Blaze signage for FITM (Phase I)	Furnish and store portable trail blaze signage systems for approximately 100 Freeway Incident Traffic Management (FITM) routes. This project includes approximately 20 mobile trailers at strategic locations within the various districts to facilitate the storage and mobilization of temporary devices for special events and incident management. Deployment will increase information dissemination to motorists along FITM routes during special events and non-recurring incidents. This will more efficiently manage traffic during detour and evacuation situations, resulting in reduced delay and occurrences of secondary incidents.	$0.7	N/A	$100
P1.07	Deploy Trail Blaze signage for FITM (Phase II)		$0.7	N/A	$100
P1.08	Deploy geo-location devices for equipment	Install GPS-based AVL equipment on MDOT SHA and other agencies' portable incident/emergency field equipment. This project provides additional capabilities for the Incident and Emergency Management Program and Operations and Maintenance personnel to monitor and manage field resources (including device trailers, tow trucks, incident management equipment and FITM trailers) during incidents and emergencies, to ensure the optimal placement for equipment.	$0.1	$108	$20
P1.09	Geo-location devices on portable work zone equipment	Install GPS location devices on MDOT SHA and contractors' portable work zone and event management equipment, including MDOT SHA construction vehicles. CHART personnel will be able to communicate with each device to identify its location within and outside the work zone/event limits. GPS capability provides management of field resources more efficiently by tracking of equipment usage, event management, vandalism management, and tracking of work zone locations.	$0.8	$720	$120

Personnel, Equipment, and Support Infrastructure Projects (continued)

Sub-System	Project Title	Project Description	Preliminary Engineering + Construction ($M)	Annual Recurring Cost ($K)	Annual O&M Cost ($K)
P2.01	Training for incident/emergency management (Phase I)	Train personnel, both within the MDOT SHA and from other agencies, to familiarize operational and technical staff with the underlying principles of incident management/emergency management, ITS applications, the impacts of congested roadways, and accident reconstruction areas. Trainings may result in certification of the personnel. This project will enhance the ability and expertise of operational and technical staff and other public safety agencies in the management of incidents and emergencies. The knowledge gained from training sessions will be used in incident and emergency management situations to expedite clearance and clean-up and to help reduce delay for travelers as well as minimize secondary incidents.	$0.7	$24	N/A
P2.02	Training for incident/emergency management (Phase II)		$0.7	$24	N/A
P2.03	Training for incident/emergency management (Phase III)		$0.7	$24	N/A
P2.04	Training for incident/emergency management (Phase IV)		$0.7	$24	N/A
P2.05	Training for incident/emergency management (Phase V)		$0.7	$24	N/A
P2.06	Extend CHART traffic patrol (Phase I)	Extend CHART's traffic patrol program to include 24/7 coverage of the entire State of Maryland. This project will include additional patrol operators, patrol and emergency response vehicles, and ancillary equipment. The additional resources will enhance response time to clear incidents and emergencies in the Annapolis, Eastern Shore, Cumberland, Hagerstown, and La Plata areas, thus improving safety to the motoring public and reducing traffic congestion and secondary incidents that may be caused by primary incidents and/or disabled vehicles.	$2.8	$823	$430
P2.07	Extend CHART traffic patrol (Phase II)		$2.9	$823	$430
P2.08	Extend CHART traffic patrol (Phase III)		$3.3	$823	$500
P2.09	Integrate Traffic Signal Operations with CHART (Phase I)	Integrate MDOT SHA's closed- loop traffic signal systems with CHART. The integration of these systems provides means to employ pre-programmed timing plans for special events and incident management, especially along Freeway Incident Traffic Management (FITM) routes. The system integration also provides the capability to monitor all system signals, collect system detector data, transmit data in real-time, etc. This integration provides the ability to adjust signal timing in response to unusual traffic conditions as well as emergency events and advise motorists accordingly via DMS and HAR to increase throughput and reduce delays, stops, and emissions statewide. The project will also improve management of traffic operations, consolidation of resources, coordination within OOTS and CHART, and visibility of system applications.	$2.9	$13	$440
P2.10	Integrate Traffic Signal Operations with CHART (Phase II)		$2.9	$13	$440
P3.01	Expand coverage of TOC to all Districts (Phase I)	Expand CHART's operational coverage in MDOT SHA Districts and include the deployment of new TOCs in the Eastern Shore/Northern Maryland Area, Southern Maryland Area, and Western Maryland Area to facilitate faster response to incidents, resulting clearance of incidents more efficiently.	$0.5	N/A	$60
P3.02	Expand coverage of TOC to all Districts (Phase II)		$0.5	N/A	$60

Personnel, Equipment, and Support Infrastructure Projects (continued)

Sub-System	Project Title	Project Description	Preliminary Engineering + Construction ($M)	Annual Recurring Cost ($K)	Annual O&M Cost ($K)
P3.03	Security improvements at CHART SOC	Install enhanced physical access control systems guarding entry into operations centers and critical network nodes connected to the CHART system. Deployment activities will include site preparation, security system equipment acquisition, and the subsequent equipment installation at each site. This project will reduce the network security risks attributable to unauthorized physical access to networking equipment including physical damage, power shutdowns, and reconfigurations via the equipment console ports to deny service or create network access "trapdoors."	$1.2	N/A	$150
P3.04	Security monitoring equipment at field locations (Phase I)	Install the components for enhancing physical access control and monitoring at CHART field device sites. Deployment activities will include acquiring and installing the security monitoring devices at equipment vaults and field device cabinets. This project will reduce the risk of unauthorized physical access to equipment vaults and field device cabinets, decreasing the risk of vandalism/sabotage and reducing response/repair time due to earlier detection of anomalies. This will also extend monitoring of environmental conditions to field cabinets.	$1.9	N/A	$240
P3.05	Security monitoring equipment at field locations (Phase II)		$1.9	N/A	$240
P3.06	Security monitoring equipment at critical locations (Phase I)	Install security monitoring equipment to protect- critical MDOT SHA-controlled transportation infrastructure, such as bridges and tunnels. Deployment activities will include site preparation, security system equipment acquisition, and the subsequent equipment installation at each site. Monitoring will reduce the risk of major destruction to structures by increasing the ability to detect irregular movements. Increasing safety will reduce the potential for large scale disasters in and on the structures. In addition, some of the cameras could also serve as traffic and incident monitoring devices.	$3.2	$24	$410
P3.07	Security monitoring equipment at critical locations (Phase II)		$3.2	$24	$410
P3.08	Security monitoring equipment at critical locations (Phase III)		$3.6	$27	$470

Software and System Integration Projects

Sub-System	Project Title	Project Description	Preliminary Engineering + Construction ($M)	Annual Recurring Cost ($K)	Annual O&M Cost ($K)
S1.01	Integrate CHART CCTV with other agencies	Integration to use video in the current standard format across existing network connections through the statewide government intranet. This project requires administrative configurations of new CCTVs in the system and will enable the exchange of video between CHART and other agencies. It also includes potential required modifications to the CHART video subsystem (if any) to support external agency CCTVs, which may include updates to Java, the operating system, etc. This will improve regional coordination between CHART Operations personnel and local traffic management operations personnel by providing local traffic management personnel access to CHART data and systems. This project will extend CHART and local CCTV coverage to previously unmonitored travel routes and will improve inter-agency response coordination, incident traffic management, and emergency/evacuation traffic management.	$0.5	N/A	$20
S1.02	Enhance for automatic incident/ congestion alerts (Phase I)	Enhance the CHART software to process Traffic Sensor Subsystem data for the system to automatically generate incident and congestion alerts. The traffic flow monitoring subsystem currently produces traffic flow information for both freeway and arterials, using data obtained from traffic detectors and traffic probe system inputs. The data received by the traffic flow monitoring subsystem comes from devices in CHART or data received from external sources (e.g., probe data). This enhancement to the Traffic Sensor Subsystem module will provide the capability to interpret the data feed to automatically generate incident and congestion alerts to the alert subsystem of the CHART system. Enhancement to the software to generate incident and congestion alerts will improve incident response time, incident traffic management, emergency traffic management, and traveler information.	$0.3	N/A	$10
S1.03	Enhance for automatic incident/ congestion alerts (Phase II)		$0.3	N/A	$20
S1.04	Develop weather and road condition monitoring software	Develop software enhancements to analyze the existing Weather Sensor Subsystem data and generate alerts for the CHART system based on rules defined by the administrator. The software will provide notifications using the alert subsystem of hazardous weather conditions to operations personnel and will improve weather incident response time and emergency traffic management.	$0.4	N/A	$20
S1.05	Enhance work zone/ evacuation monitoring system	Enhance the Work Zone/Evacuation Route Monitoring Software to receive and interpret data from external work zones in multiple formats to compute travel times and provide traveler information to portable and fixed equipment of internal and external organizations. Provides single point of management for work zones and evacuation routes for operations personnel and improves safety and emergency response in work zones.	$0.4	N/A	$20
S1.06	Develop security monitoring software (Phase I)	Develop software for Security Monitoring of the CHART system infrastructure to automatically generate alerts to the subsystem for unauthorized or unscheduled access (physical and communications) to monitored CHART devices.	$0.5	N/A	$20
S1.07	Develop security monitoring software (Phase II)		$0.5	N/A	$20
S1.08	CHART incident prediction report (Phase I)	Develop software to predict the probabilities of incidents. The Incident Prediction Module provides the capability to analyze information from the Traffic Sensor Subsystem (TSS), traffic probe data, Environment Sensor Subsystem, and Data Archive to identify stretches of highway where there is a high probability of incident occurrence and automatically generate incident watch alerts. This will improve incident response time, incident traffic management, and emergency traffic management.	$0.9	N/A	$40
S1.09	CHART incident prediction report (Phase II)		$0.9	N/A	$40

Software and System Integration Projects (continued)

Sub-System	Project Title	Project Description	Preliminary Engineering + Construction ($M)	Annual Recurring Cost ($K)	Annual O&M Cost ($K)
S1.10	Develop incident/ emergency exchange software for rail crossing	Develop software to exchange information with major and short-line railroad carriers. The Incident Management module provides the capability to send, receive, and interpret the data-exchange feeds from railroad operators and will automatically generate incident alerts for new incident information received or update current incidents with the additional data received. .	$0.5	N/A	$20
S1.11	Develop integrated parking management software	Develop software to send, receive, and interpret parking data-exchange feeds from parking operators. This project will provide access to parking information and provide operators with decision support, which is the automatic generation and posting of parking messages on DMS/HAR based on parking conditions. Parking information will allow travelers to better plan their travels and promote use of park-and-rides or multi-modal facilities.	$0.9	N/A	$40
S1.12	Develop electronic traveler information software (Phase I)	Develop software to provide traveler information to strategically located traveler information boards at major modal transfer points. The Traveler Information module will generate and display information on information boards, tailored to the location of the board. Device drivers will be added to the CHART system for specific models of information boards. This software will increase the available traveler information to help travelers make more informed route decisions.	$0.2	N/A	$10
S1.13	Develop electronic traveler information software (Phase II)		$0.2	N/A	$10
S1.14	Develop in-vehicle traveler information software	Develop software to send traveler information to in-vehicle traveler information systems. The Traveler Information Module will generate information for the in-vehicle traveler information system, tailored to the location of the vehicle. In-vehicle traveler information software will increase the available traveler information, provide more tailored information to each vehicle, and will help travelers make more informed route decisions.	$0.4	N/A	$20
S1.15	Develop arterial monitoring/ management software	Develop software to incorporate Arterial Traffic Monitoring and Management into CHART to monitor and retrieve information from traffic signal masters installed along arterials. It will enable CHART to query the status of traffic signals and allow preapproved signal cycles to be implemented based on anticipated traffic conditions. Incorporating arterial traffic monitoring into the freeway operations system will give CHART operators access to more information to provide a more complete awareness of the entire surface transportation network. This will enable better coordination between freeway and arterial traffic management.	$0.5	N/A	$20
S1.16	Develop ramp-metering software (Phase I)	Develop software to operate ramp-metering devices used to provide access to highways. The system will monitor and control the ramp-metering devices using defined business rules that control the flow of traffic and information provided to travelers based on the data collected from the ramp-metering devices to optimize system throughput. The ramp-metering module will automatically modify ramp-metering systems based on the current traffic conditions and alert operators depending on the extent of the change. Ramp-metering devices improve traffic flow on freeways during peak travel conditions, reducing congestion/delay for drivers.	$0.7	N/A	$30
S1.17	Develop ramp-metering software (Phase II		$0.7	N/A	$30
S1.18	Develop variable speed software (Phase I)	Develop software to operate Variable Speed Limit (VSL) Devices used for limiting the speed on highways. The system monitors and controls the VSL devices using defined business rules to control the flow of traffic and information provided to travelers based on the data collected from the traffic sensor subsystem (TSS) to optimize system throughput. When the TSS Module detects potential congestion, it will automatically change the speed limit for the given route based on predefined thresholds and sends an alert to the operators of the changes. VSL devices improve traffic flow on highways during times of congestion, reducing delay for drivers and potential for incidents due to congestion.	$0.5	N/A	$20
S1.19	Develop variable speed software (Phase II)		$0.5	N/A	$20

Software and System Integration Projects (continued)

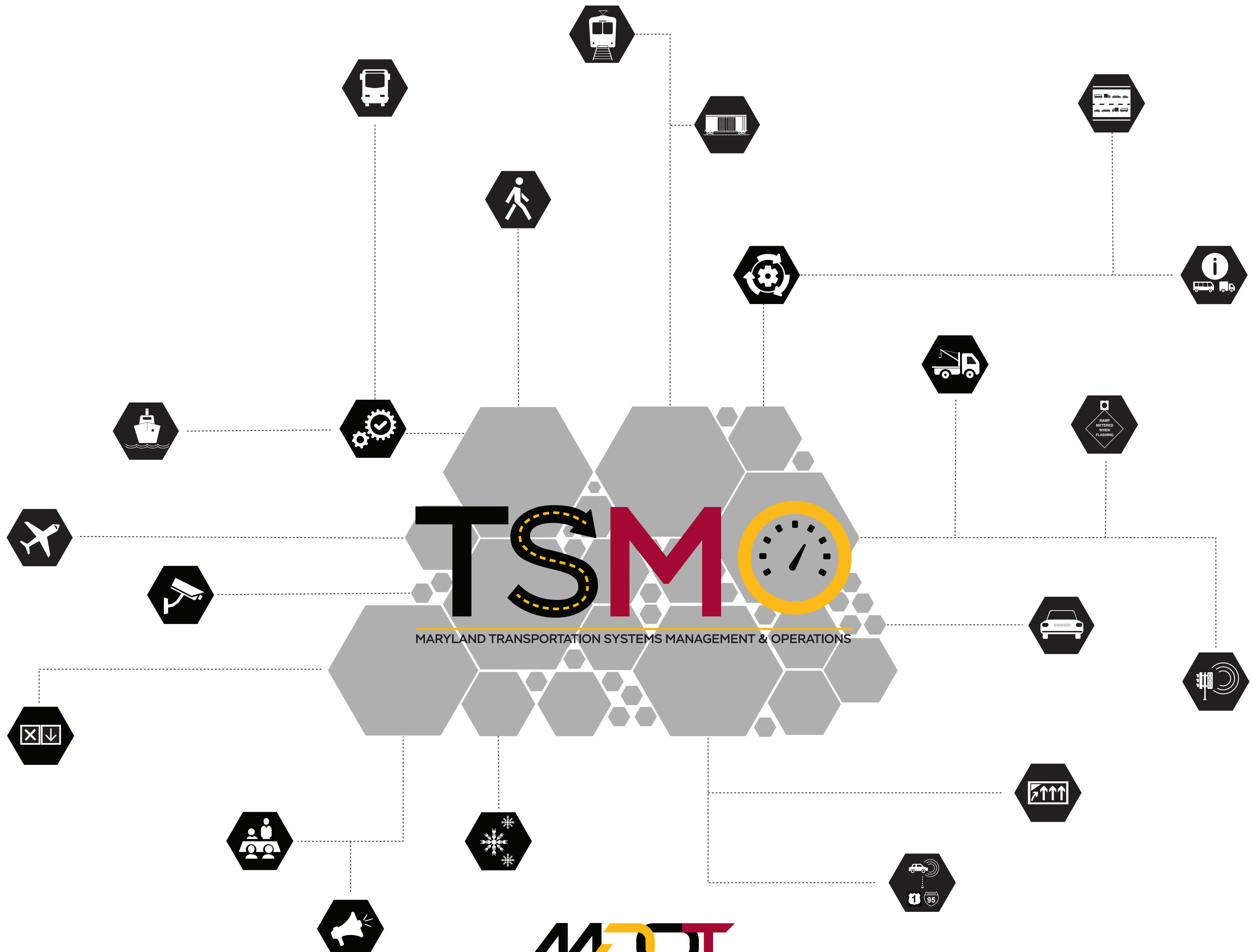
Sub-System	Project Title	Project Description	Preliminary Engineering + Construction ($M)	Annual Recurring Cost ($K)	Annual O&M Cost ($K)
S1.20	Develop lane control device software	Develop software to operate Lane Control Signal (LCS) Devices used for controlling traffic flow on highways. The system will monitor and control the LCS Devices using defined business rules to control the flow of traffic and information provided to travelers based on the data collected from the TSS to optimize system throughput. Upon detecting a potential congestion condition, the TSS Module will generate an alert for operators to respond and use the LCS devices to reduce congestion through the event. Under automated control, upon detecting a potential congestion condition, the TSS Module will automatically modify the lane control signals based on predefined rules. The software will enable operators to use lane control signal devices to improve traffic flow on highways during times of congestion, reducing delay for drivers.	$0.8	N/A	$40
S1.21	Develop queue detection/ warning alert software (Phase I)	Develop software to operate Queue Detection and Warning Devices and Highway Access Alert Systems, which is a combination of detector stations, DMS, HARs, and Hazard Identification Beacons (HIB) with dynamic flashers. These devices will be used for detection and reduction of traffic backups on highways. The system will monitor and control devices as an enhancement to the TSS using defined business rules to control the flow of traffic and information provided to travelers based on the data collected from the TSS to optimize system throughput. This project allows CHART to directly alert motorists of upcoming congestion or hazardous traffic conditions on freeways/expressways before reaching the decision points at arterial and freeway/expressway intersections and on-ramps to decrease congestion levels on freeways/expressways.	$0.8	N/A	$40
S1.22	Develop queue detection/ warning alert software (Phase II)	(same description as S1.21)	$0.8	N/A	$40
S1.23	Develop inter-modal transfer management software (Phase I)	Develop software to control Traffic Management Devices used at Inter-modal Transfer Points. The system will monitor and control the availability of routes and facilities that may be used at inter-modal transfer points based on current and historic usage data collected from the TSS and current conditions to optimize system throughput. The MD 511 Public Website can also be leveraged to publish messages. This will improve inter-agency response coordination by facilitating operators to divert traffic off congested freeways onto transit. It will also inform travelers about available travel options at decision points, and provide info on parking availability, transit travel times, and other transit-related information.	$0.6	N/A	$30
S1.24	Develop inter-modal transfer management software (Phase II)	(same description as S1.23)	$0.6	N/A	$30
S1.25	Develop advance technology traffic detector software (Phase I)	Develop software to accept and process data from new technology traffic detectors, such as side-fire vehicle detectors, in-pavement wireless detectors, magnetometers, radar, and microwave detection technologies. The system will collect, and process expanded data (including speed, volume, and occupancy data) obtained from the new detectors, as well as implement additional capabilities for status monitoring and control. The software provides additional roadway condition data to enhance traffic management for emergency operations, incident management, normal traffic condition monitoring, incident detection capabilities, and emergency/evacuation traffic management.	$0.1	N/A	N/A
S1.26	Develop advance technology traffic detector software (Phase II)	(same description as S1.25)	$0.1	N/A	N/A
S1.27	Develop real-time CHART simulation software (Phase I)	Develop software for real-time simulation of the effects of actions that may be taken in a response plan. The Simulation Module will use the data archive – a repository of CHART history, lessons-learned, performance metrics, and success stories – to simulate incident response plans prior to implementation. Using real-life situations in planning will improve inter-agency response coordination, incident traffic management, and emergency/evacuation traffic management.	$0.9	N/A	$40
S1.28	Develop real-time CHART simulation software (Phase II)	(same description as S1.27)	$0.9	N/A	$40
S1.29	Develop offline CHART simulation software (training)	Develop software to perform offline simulation of the effects of actions that may be taken in a response plan. It allows users to create various starting conditions for use in predicting the traffic impact of a response plan to train operators. It will also provide output for providing future network conditions to travelers via traveler information deployments. The Simulation Module will use the data archive - a repository of CHART history, lessons-learned, performance metrics, and success stories - for simulation data to simulate incident response plans in offline situations. It will also support pre-trip dissemination of suggested routes to travelers by simulating future travel conditions.	$1.2	N/A	$60

Software and System Integration Projects (continued)

Sub-System	Project Title	Project Description	Preliminary Engineering + Construction ($M)	Annual Recurring Cost ($K)	Annual O&M Cost ($K)
S1.30	Develop database modules/ protocol for probe data	Develop the database modules and protocol drivers necessary for the TSS to collect and process mobile traffic probe data obtained from MDOT vehicles. The project enhances CHART vehicle-detection coverage by supplementing fixed detectors with mobile traffic probes and adds the ability to collect and use traffic data such as travel time, delay, and location of bottlenecks especially on principal arterials and interstates. Adds flexibility to dispatch probe-equipped vehicles to incident sites to obtain more detailed information on conditions in the immediate vicinity.	$0.4	N/A	$20
S1.31	Develop CVO/ hazmat data interface software	Develop the software to allow the CHART System to access and exchange data with CVO and hazardous materials (HAZMAT) tracking databases maintained by various national and state-level monitoring agencies and commercial vehicle operators such as the Motor Carrier Division. Access to this information will provide the ability to monitor and track the transportation of hazardous materials through Maryland and will enhance emergency response in case of an incident by identifying the material(s) involved and the risks posed by their toxicity and volatility. The project will enhance clean-up efforts because HAZMAT teams can be dispatched with the proper equipment and cleaning compounds/agents and improve public safety as response, clean-up, and evacuation efforts will be more accurately matched to the risk presented by the materials involved.	$0.5	N/A	$30
S1.32	Enhance CHART status monitoring software	Enhance software to expand CHART's system health capabilities. Currently, this system monitoring software develops, detects, locates, and tracks failures/malfunctions within the CHART operating system components. Enhancements will improve regional coordination between CHART and other operations centers and improve system failure detection, which supports quicker restoration and CHART's ability to support its mission. It will also create a central location for all information on the status of CHART and its devices.	$1.0	N/A	$50
S1.33	Develop portable data-collection device software	Develop software that expands the database processing function to support the data formats utilized by the portable real-time data-acquisition and data-sharing devices. The software redesigns an aging algorithm to expire TSS data based on time, location, and quality. This project enables the use of new portable collection devices to increase operators' awareness of current roadway conditions, enabling them to disseminate current traveler information via permanent and portable devices.	$0.1	N/A	N/A
S2.01	Advanced Traveler Information Systems (ATIS Phase I)	Develop ATIS to improve mobility by providing travelers with multi-modal trip planning, route guidance services, and advisory functions. The system includes static and real-time information on traffic conditions and schedules, road and weather conditions, special events, and tourist information. ATIS is classified by how and when travelers receive their desired information (pre-trip or en route) and is divided by user service categories.	$0.9	$8	$140
S2.02	Advanced Traveler Information Systems (ATIS Phase II)		$0.9	$7	$140
S2.03	Machine Vision integration	Integrates video and traffic data obtained through video detection "machine vision" technology into the CHART system. Machine Vision technology provides automated detection of incidents, congestion, and hazardous conditions at signalized intersections and initiates automated notification through use of the alert subsystem to operations personnel. This project improves incident clearance time and safety by detecting hazardous conditions to alert motorists and reduces delay by detecting congestion to facilitate management of traffic flow.	$2.4	$450	$360
S2.04	Integrate MDOT probe data	Integrates mobile traffic probe data from MDOT resources (e.g., toll tag readers, probe-equipped MDOT vehicles such as MTA buses) into the CHART System. This integration enhances vehicle detection coverage by supplementing fixed detectors with mobile traffic probes and provides the ability to collect and use traffic data such as current traffic flow, travel time, delay, and locations of bottlenecks, especially on principal arterials and interstates. This allows MDOT to dispatch probe-equipped vehicles to incident sites to obtain information on nearby conditions.	$0.1	$120	$10

Software and System Integration Projects (continued)

Sub-System	Project Title	Project Description	Preliminary Engineering + Construction ($M)	Annual Recurring Cost ($K)	Annual O&M Cost ($K)
S2.05	Integrate external probe data	Integrates traffic data from external sources (e.g., subscription services or regional clearinghouses) into the CHART System. This integration enhances CHART vehicle/incident detection coverage by supplementing MDOT's internal resources with traffic data obtained from external sources to provide enhanced monitoring for traffic flow, travel time, delay, and locations of bottlenecks, especially on principal arterials and interstates. This adds enhanced data collection capabilities in existing coverage areas and extends the coverage area to places where there is no existing detection equipment.	$0.5	N/A	$80
S2.06	Purchase data services [private] (Phase I)	Purchase traffic data and services from private-sector traffic data/information providers on freeways and arterials. Data and/or services can be acquired through a recurring paid service fee or may be facilitated through a public-private partnership (PPP) agreement. Various available solutions can be used to collect, monitor and disseminate raw and/or processed traffic data (current traffic flow, travel time, delay, and locations of bottlenecks) to determine traffic flow conditions along freeways, expressways, and arterial roadways. This technology would be used as a more cost-effective alternative to collecting traffic data than continuing to deploy side-fire/in-pavement traffic detectors at 2-mile intervals along freeways and arterials.	$2.6	$114	$380
S2.07	Purchase data services [private] (Phase II)		$2.4	$114	$360
S2.08	Purchase data services [private] (Phase III)		$2.4	$114	$360
S2.09	Purchase data services [private] (Phase IV)		$2.4	$114	$360
S2.10	Purchase data services [private] (Phase V)		$2.4	$114	$360
S2.11	Purchase data services [private] (Phase VI)		$2.4	$114	$360
S2.12	Purchase data services [private] (Phase VII)		$1.6	$114	$240
S2.13	Integrated parking management systems	Integrate new communications infrastructure between CHART and smart parking management systems. This project will enhance the management of traffic in the area of the inter-modal transfer locations by enabling distribution of information to the public more effectively.	$0.3	$30	$40
S2.14	Integrate SOC sub-systems	Integrates the Statewide Operations Center (SOC) systems that support the ongoing development and expansion of CHART's network. This project installs and integrates the equipment and systems necessary to support an environment for the seamless communication of numerous SOC functions that will improve the efficiency of the operations capabilities, incident/emergency management, reduction in incident duration times, and the frequency of secondary accidents on highways throughout the coverage area.	$0.3	N/A	$50
S2.15	Integrate field equipment locations to CHART (Phase I)	Integrate wireless and other communications infrastructure into CHART. This project will reduce incidents along highways by improving the ability to monitor roadway conditions via CCTV and detectors and advise motorists accordingly via Dynamic Message Signs and HARs. Monitoring includes traffic incidents, congestion, construction activities, inclement weather conditions, and emergency evacuation.	$1.0	N/A	$160
S2.16	Integrate field equipment locations to CHART (Phase II)		$1.0	N/A	$150
S2.17	Integrate secure communications to CHART sites	Integrate secure communications between current and future operations sites on the CHART network, including physical access control systems that guard entry to CHART operations centers to decrease potential vulnerabilities. This project will lower network security risks attributable to unauthorized physical access to networking equipment including physical damage, power shutdowns, and reconfigurations via the equipment console ports.	$0.6	N/A	$100



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