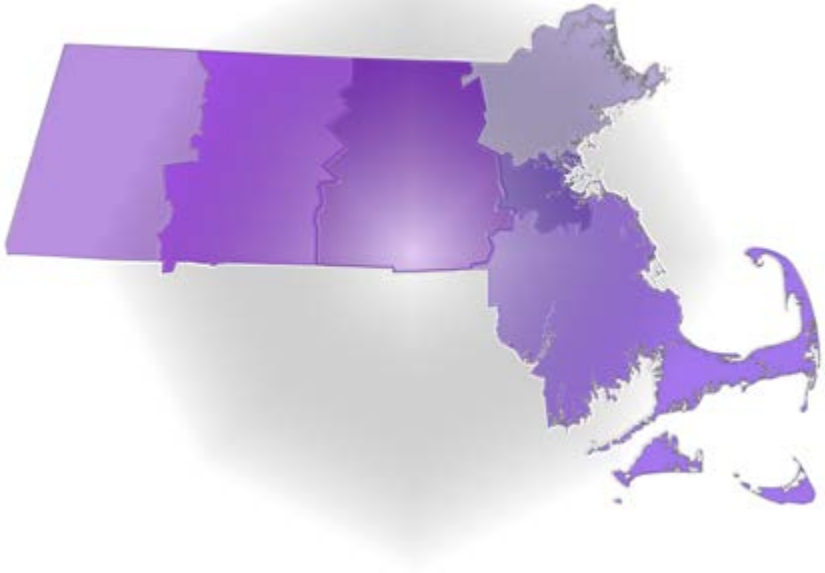
Massachusetts Department of Transportation

Highway Division

A 2014 Synthesis; the Status of Intelligent Transportation Systems Deployment

April 2014



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Acknowledgements

This document was prepared by the Massachusetts Department of Transportation- Highway Division, ITS Programs Unit and the Highway Operations Center to provide a status report for 2014 on Intelligent Transportation Systems (ITS) deployments throughout the Commonwealth. This report compiles information from a number of business units within the Highway Division to "paint a picture" of where it stands with respect to ITS planning, programming, procurement, deployment, use, maintenance, and replacement. This annual report or synthesis is a "living document" that captures the considerable progress that has been made in developing a comprehensive approach to ITS deployments, particularly through the systems engineering process. We wish to acknowledge the contributions of the following business units in ensuring an institutionalized and systematic approach to ITS deployments:

- Highway Operations Center
- ITS Programming
- Intelligent Transportation Systems (ITS) Planning
- Information Technology (IT) Systems Engineering
- Traffic Engineering
- Communications Engineering
- Legal
- Customer Service
- Statewide Operations
- Public Information
- Performance Management
- The 6 Highway Districts

The success of the ITS Program at MassDOT requires leadership and vision, and a set of deliberate management actions to improve agency capabilities. To that end, we also acknowledge the support **of Governor Deval Patrick**, **Secretary Richard Davey**, and Highway Division **Administrator Frank DePaola**; a leadership team that has embraced innovation and authorized the important initiatives outlined in this document.

1.0 Executive Summary

The purpose of this synthesis is to document the current status of Intelligent Transportation Systems (ITS) deployments in the Highway Division of the Massachusetts Department of Transportation. It is meant to provide a "snapshot" of our current standing and to identify the guiding ITS concepts and principles at the state and federal level that should advance the growth of our deployments. This annual report is also meant to identify challenges to overcome within the organization to ensure mature program development, and equally, to identify the structures, policies, and plans needed to address these gaps. The report also provides an overview of the processes that should be utilized to support program development, and to document how the organization is advancing ITS projects throughout the state. Finally, the report provides an overview of the funding processes and sources utilized for ITS deployment, and looks to the future of ITS deployments as technologies change and new resources are available to enhance the transportation experience within the constraints of current capacity.

1.1 MAP 21; A Renewed Emphasis on ITS

The Moving Ahead for Progress in the 21st Century Act (MAP-21) provides a platform that can significantly improve transportation within the Commonwealth of Massachusetts. Rather than making costly investments in the construction of new highway infrastructure, MAP-21 focuses on developing concepts and principles to guide the development of state-specific performance measures focused on 4 key areas: infrastructure condition, roadway safety, vehicle emission and congestion mitigation.

MAP-21 has encouraged states to take forward action through funding allocations of $400 million per year nationally for Intelligent Transportation Systems implementation[1]. With MAP-21 set to expire in 2014, it is expected that new transportation legislation at the federal level will build upon MAP-21 and reinforce, to an even greater degree, the need to utilize systems and technology in the support of daily operations, traffic incident management and congestion mitigation.

Massachusetts is unique among other states in that it has a centralized statewide transportation management center to both manage incidents and emergency situations and mitigate congestion on surface roadways, elaborate tunnel systems and bridges across the state. The Highway Operations Center is the end-user of all ITS devices deployed throughout the state, operating these devices to meet the public's expectations for efficient and safe roadway management.

At the center of ITS deployments needs to be an organization's capability to embrace the notion of integrating transportation systems management and operations, and developing ITS strategies that are based on operational needs, processes, and functions. Since building new superhighways is not on the immediate horizon, our transportation focus needs to be on narrowly tailored ITS solutions that enhance the transportation experience using adaptive technologies, integrated congestion mitigation strategies, and effective traffic incident management from detection to recovery.

This annual report or "synthesis" for 2014 documents the considerable progress made by MassDOT in advancing ITS deployments, consistent with the concepts and principles in MAP-21, and in accordance with the systems engineering process to ensure the integration of transportation systems with operations.

1.2 Transportation Systems Management and Operations (TSMO)

Transportation Systems Management and Operations (TSMO) brings together each distinct function of a transportation agency, including planning, construction, management and operations to optimize the performance of existing infrastructure. TSMO is an integrated concept to optimize the performance of multimodal infrastructure through the implementation of systems, services, and projects to preserve capacity and improve the security, safety and reliability of the transportation system. It treats infrastructure as a network rather than as separate entities. The goals and mission of TSMO is to invite a renewed and continual emphasis on Intelligent Transportation Systems (ITS).

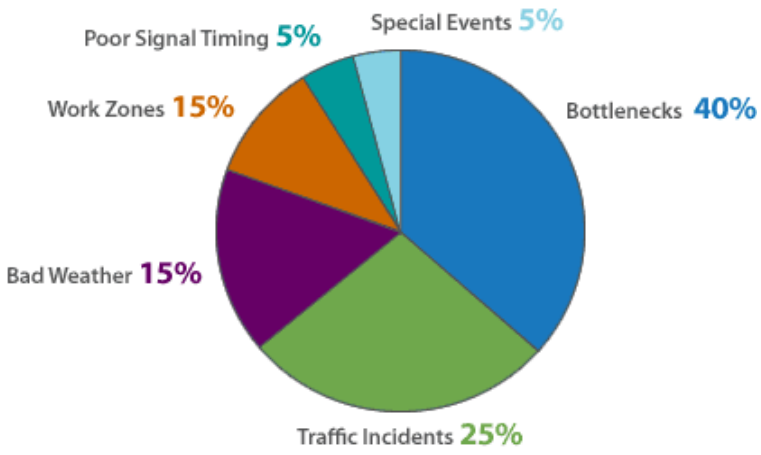
[1] http://www.fhwa.dot.gov/MAP21/summaryinfo.cfm

MassDOT has made significant progress in developing and deploying key ITS assets in support of TSMO activities. This report builds upon this progress made to "mainstream" ITS deployments as a core agency objective. Progress requires a set of deliberate management actions to improve agency capabilities in six specific dimensions; business processes, systems and technology, performance measurement, culture, organization and workforce, and collaboration. Assessing and enhancing these capabilities is essential to continuous improvement of TSMO and its performance impacts.

1.2.1 Sources of Congestion

Massachusetts recognizes that as congestion spreads and the level of incidents, delays and disruptions increase, the roadway network's level of service and reliability deteriorates. **Figure 1** shows the Federal Highway Administration's analysis of the estimated causes of congestion nationwide. Essential to successful congestion mitigation is an understanding of these sources and how each can be minimized.

Figure 1[2]



Over half of the total delay in large urban areas results from disruptions and incidents within the context of current and limited roadway capacity.

Without the ability to dramatically increase capacity, MassDOT will focus on strategies to operate its infrastructure at full potential. This requires strategies that seek to "retrieve" capacity lost to traffic incidents, construction, weather and poor signalization, and wherever possible, manage excess demand through better traveler information, multi-modal travel strategies and special event management.

Success will be determined by an organization's ability to implement and optimize proven strategies such as traffic incident management, work zone management, traveler information services and demand management, road weather information, freeway management and managed lanes, active traffic management, integrated corridor management, traffic signal operation, electronic payment/toll collection, emergency response, and freight management.

Organizations need to institute processes, operational and technical, for achieving the right integration of systems management with operations. This requires planning for standardization and documentation of systems and technology, training and performance measurement. Continuous improvement also requires putting the program on a stepwise path to improved effectiveness. ITS deployments of a high tech, real-time customer service nature need to be specifically accommodated with appropriate processes. MassDOT will continue to review its capabilities in this regard and develop ITS strategies from a process improvement standpoint.

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[2] FHWA Office of Operations, *Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation*

1.3 ITS Deployments;The Current Environment

MassDOT has been deploying and using Intelligent Transportation Systems (ITS) throughout the Commonwealth for over 20 years. ITS deployments have become an integral part of maintaining and operating critical roadways, providing travelers with valuable information, and enhancing the safety and security of the greater transportation network. ITS deployments have also played an important role in high profile construction projects within the Boston region and throughout the Commonwealth. One of the key components of a successful program is the need to ensure relevant stakeholders are included in all aspects of the ITS deployment schedule, starting with initial discussions regarding operational need to full deployment and system management at the Highway Operations Center.

The following projects, plans, and working groups have ensured that ITS technology has been deployed in a uniform and consistent manner, making use of all available stakeholder input and data.

1.3.1 Assessing Needs: UMASS Lowell ITS Assessment

In 2012 MassDOT commissioned a study conducted by the University of Massachusetts Lowell to develop a data-driven methodology that MassDOT can use in deploying new ITS devices on its roadways. The study identified principal criteria for the placement of Variable Message Signs (VMS) and Closed Circuit Television Cameras (CCTV), such as accident frequency and severity, available detours, capacity, and average volume. In addition to developing an initial methodology, the study made recommendations for the top 200 locations for device deployment. This study has proved invaluable and timely as MassDOT has recently made significant investments in this technology.

1.3.2 ITS Policy Group (ITSPG)

In 2012 the Highway Division formed the ITS Policy Group (ITSPG) to establish policy with respect to ITS project planning, programming, funding, strategy and deployment. The ITSPG is responsible for ensuring ITS deployments in the Highway Division are carried out in a uniform and consistent manner, and all relevant stakeholders are fully informed of short term and long term plans. In addition, the ITSPG ensures ITS projects advance through the systems engineering process, and that they have established standards, priorities and requirements. The ITSPG is the management structure to guide, streamline, approve and fund projects. The ITSPG is represented by: **Jerry Allen** and **Leonard Walsh** from MassDOT Statewide Operations, **Pete Sutton** from ITS Planning, **Russ Bond** from ITS Programming, **Tony Wade** from Communications Systems Engineering, **Celia Blue** from the Office of Performance Management and Innovation, and **Lorenzo Parra** from the Highway Operations Center (HOC).

In 2013 the ITS Policy Group convened the ITS "Road-Show," visiting each Highway District and providing an overview of the recent developments in ITS and related infrastructure across the state. In addition to reviewing the policy group's purpose and mission, each business unit made a presentation of projects relevant to each district. The presentation topics are included within this synthesis in Chapter 4, Report on Project Progress. The sessions were well received throughout the state and culminated in a presentation to the Secretary and senior staff in January 2014.

1.3.3 Traffic Management Working Group

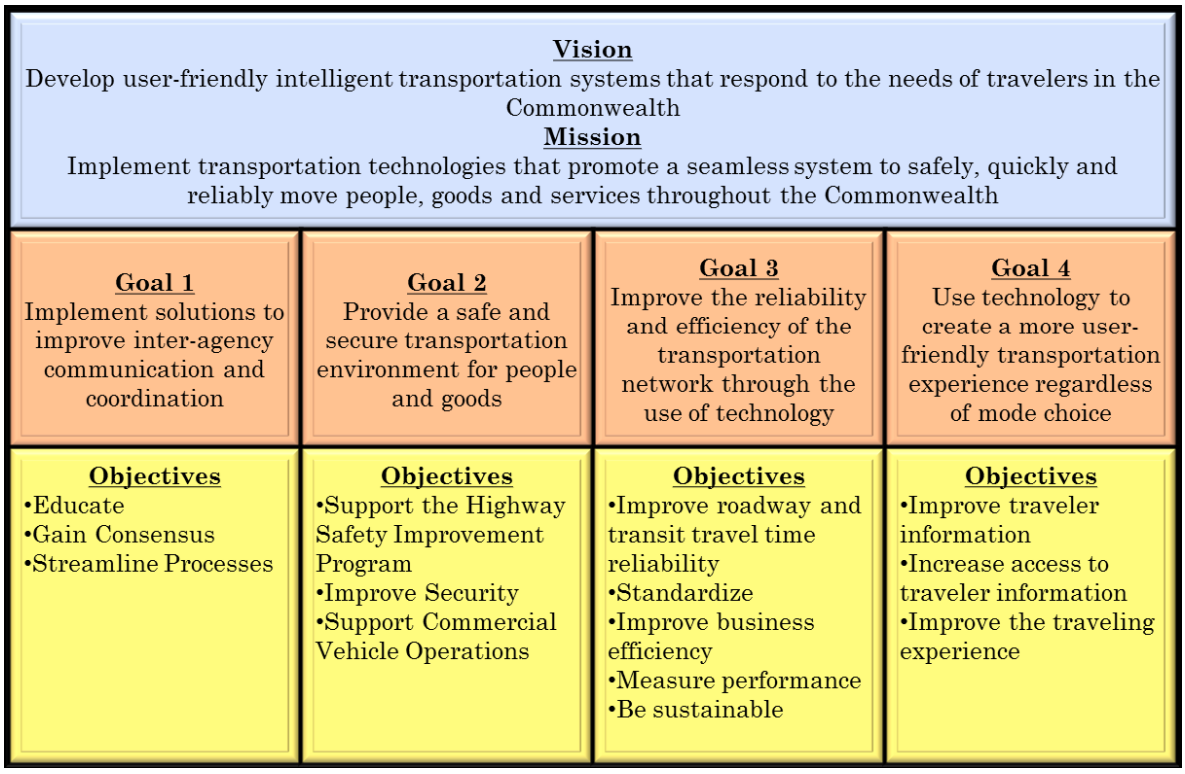
In 2012 the Highway Division also formed the Traffic Management Working Group that includes stakeholder representatives from the Highway Operations Center, Intelligent Transportation Systems (ITS) Planning, ITS Programming, Information Technology (IT) Systems Engineering, Traffic Engineering, Communications Engineering, Legal, Customer Service, Statewide Operations, Public Information, Performance Management and Innovation, and the 6 Highway Districts. The Working Group is meant to provide ITS project and other special project situational awareness to different business units within the MassDOT organization, and to solicit perspective and insights on those projects as they advance. A presentation is made at each meeting on a new technology deployment or strategy that would be of interest to the stakeholders.

1.3.4 ITS Strategic Plan

The 2013 ITS Strategic Plan produced by the Office of Transportation Planning at MassDOT identified challenges that need to be addressed to ensure MassDOT grows in line with the concepts and principles of

transportation systems management and operations. Those challenges included financial constraints, the lack of clear and consistent project parameters, technical deficiencies during implementation, the lack of data and resource sharing, and the need for greater end user education. To that end, the Strategic Plan shown in **Figure 2** identifies a new vision, mission statement, goals and objectives that should drive further ITS deployments.

Figure 2[3]



[3] ITS Strategic Plan, MassDOT Planning Department

2.0 ITS Deployments- Concept of Operations

MassDOT has taken great effort in the last two years to realign its ITS planning and programming processes to ensure they comply with the systems engineering process mandated by the Federal Highway Administration. The systems engineering process is now the core element of ITS Programming in the Highway Division and should be adopted by other business units for all system deployments. This chapter of the synthesis will provide a brief overview of the process, and identify reasons why it is the centerpiece of ITS Programming.

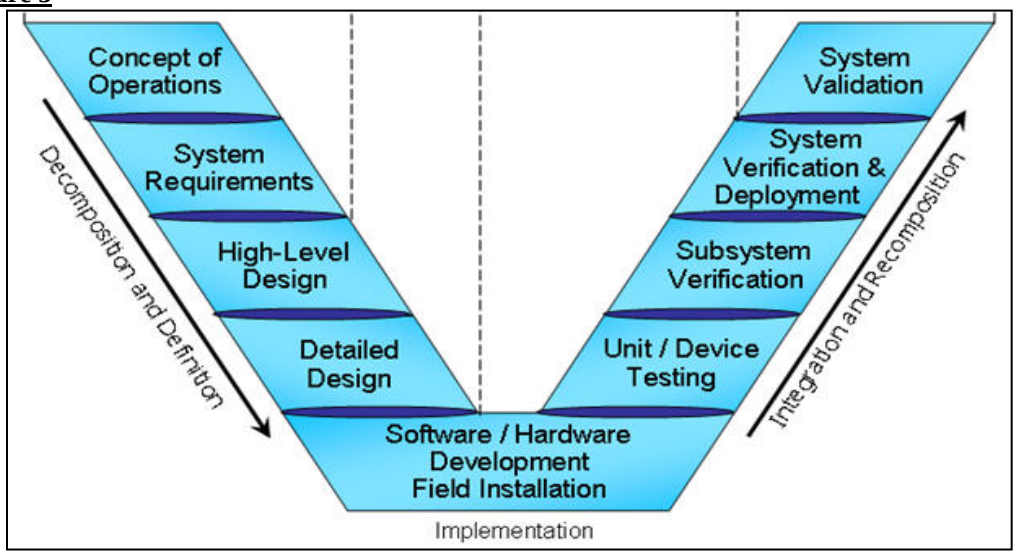
2.1 The Systems Engineering Process

The Systems Engineering Process is meant to be an interdisciplinary approach to ensure the realization of successful system deployment. It brings together multiple stakeholders prior to design to establish a uniform concept of operations for the project that reflects organizational needs. Once an operational concept is established, the development cycle can proceed to documenting requirements, and then advance with design synthesis and system validation while considering the problem in its complete context.

The beauty of the process is that it is inclusive by nature, and when done right, seeks to integrate all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. In doing so, it strives to ensure that the business and the technical needs of all customers have been considered, with the goal of providing a quality product that meets user need. The process can help an organization advance from need to deployment through a deliberative step by step method: the functions of the system are developed based on an operational need, system requirements and system design flow together in a seamless manner, and operational procedures and protocols are developed logically. In the same vein, testing, verification, and validation trace back to original needs and requirements. This process enhances the ability of the business unit to conduct performance reviews of the system, maintain and upgrade the system, or replace and retire the system.

Because the process lends itself to considerable scrutiny and contribution from multiple stakeholders, an organization can reduce the risk of schedule and cost overruns and acquire a system of higher integrity. Other benefits include better system documentation, higher level of stakeholder participation, system functionality that meets stakeholders' expectations, the potential for shorter project cycles, systems that can evolve with minimum redesign and associated costs, higher level of system reuse, and more predictable outcomes from projects. **Figure 3** shows the "V-model" adopted by Federal Highway to represent the systems engineering process.

Figure 3[4]



[4] http://www.fhwa.dot.gov/cadiv/segb/

3.0 Highway Operations Center Overview

The Massachusetts Department of Transportation has made significant investments in Intelligent Transportation Systems to help fulfill its mission to provide the nation's safest and most reliable transportation service. At the heart of these investments is the Highway Operations Center (HOC). The HOC is the central hub for statewide operations and is the primary location for roadway and tunnel management systems. These systems have various capabilities in data collection, fusion, and dissemination. The systems handle a wide variety of data types and control systems on the road network that allow HOC operators to effectively manage incidents.

3.1 The Center of ITS Deployment[5]

All ITS devices deployed at MassDOT report back to any number of control systems at the HOC. MassDOT has multiple central systems, stand-alone systems and tools used to support the management of planned and unplanned incidents that affect the public. Many of the devices deployed are linked to legacy traffic management systems inherited from the former Massachusetts Turnpike Authority and the former Massachusetts Highway Department at the HOC. Life safety systems in the Metropolitan Highway System are also controlled through the HOC. In addition, the HOC manages security systems, and a number of specialized stand-alone systems and tools to support the management of the road network. These systems and tools comprise a variety of functions, which include paging, video management, travel time dissemination, video wall control and weather websites, tunnel management, among others.

The systems are used to control and exchange data with a number of field devices situated throughout the state's roadway network. Some of these devices have traffic management-related functions and are used as part of traffic and incident management operations to survey the roadway network, detect incidents, disseminate information and warnings to the traveling public, or to collect roadway-related data and information. Other devices are employed for security, life safety, or facility management operations. Additionally, there are a number of external interfaces through which HOC systems connect in order to exchange data with other agencies or to disseminate information to the public. These interfaces include video sharing and information dissemination.

3.2 Mission Statement

The mission of the Highway Operations Center is to provide a reliable and sustained means of monitoring state roadways and facilities, ensuring workplace and public safety on a 24 hour basis. It is responsible for detecting roadway incidents, receiving reports of roadway incidents, responding to facility alarms, managing security systems, and coordinating traffic operations, maintenance and emergency response activities. The HOC uses a number of ITS deployments to achieve its core function to coordinate all elements of the incident management continuum; monitoring roadways, detecting incidents, making notifications, documenting the sequence of response, deploying resources, responding to the scene, recovering operations, learning lessons, and conducting after action reviews.

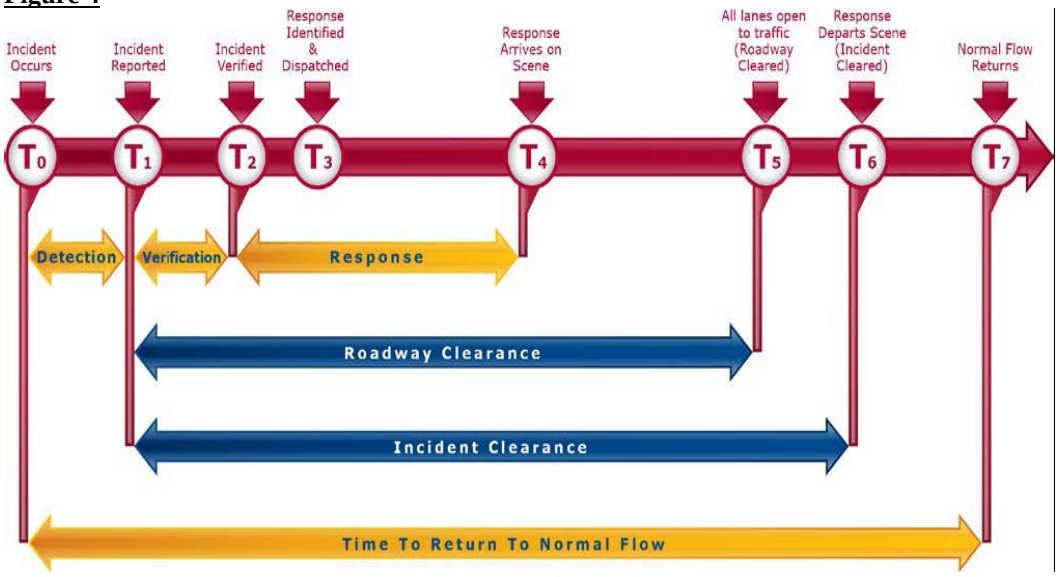
[5] ATMS Concept of Operations, Kanaan Consulting Inc.

3.3 Traffic Incident Management Continuum

ITS deployments support the conduct of numerous activities throughout the course of an incident. An incident is not only managed on scene; it is managed through the interplay of systems and human resources working together from remote locations, in the area of an incident, and at the incident scene itself. An incident is not over once debris has been cleared, but until the normal flow of operations has been restored.

The Traffic Incident Management Timeline shown in **Figure 4** lays out the sequence of activities from when an incident occurs until traffic conditions return to normal. Normal traffic conditions do not necessarily mean that traffic is traveling at the posted speed limit. During peak use periods, traffic volume may still result in congestion that is normal for that roadway at that time. Roadway Clearance Time is the interval defined as the time between the first recordable awareness of an incident (detection, notification, or verification) by a responding agency and first confirmation that all lanes are available for traffic flow. Incident Clearance Time is the interval defined as the time between the first recordable awareness of the incident and the time at which the last responder has left the scene.

Figure 4[6]

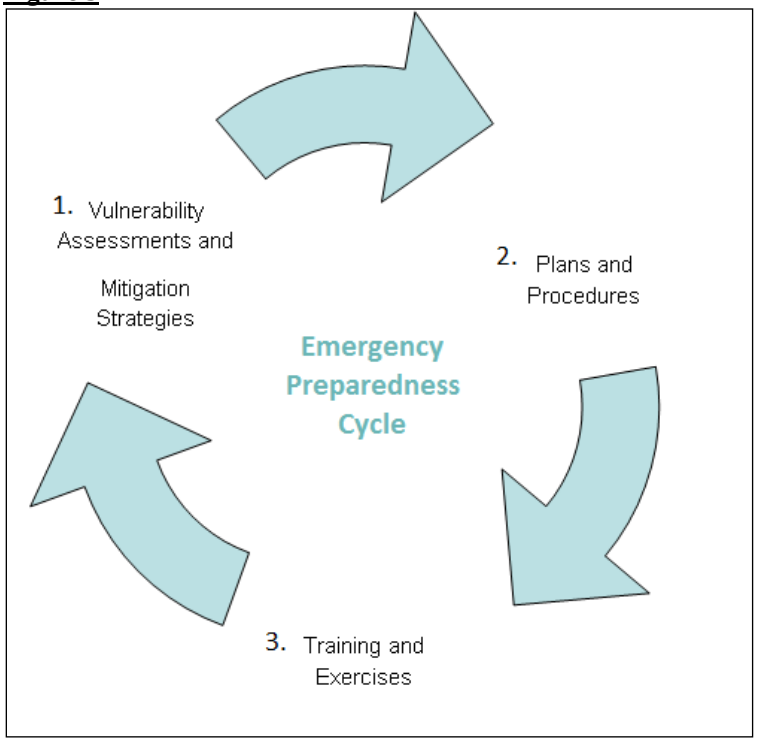


3.4 The Emergency Preparedness Cycle

The Highway Operations Center relies on the Emergency Preparedness Cycle, shown in **Figure 5**[7], to review performance and operations, and to ensure the organization is prepared to handle any number of threats or hazards to infrastructure, resources, or systems. The cycle is also a critical component of the process used to identify the need for new ITS devices and strategies. The first component of the cycle involves the conduct of vulnerability assessments of the critical functions, assets, networks and systems related to operations, and the development of mitigation strategies to protect those aspects of the organization. ITS devices are often identified to support these mitigation strategies. The second component of the cycle involves the development of emergency response plans and procedures that detail how we use various systems in support of operations, and the safety and security of the workforce and the public. Last but not least, the conduct of training and exercises provides an environment to assess how the systems operate in a simulated environment, and yield considerable information on how systems could be augmented in support of core functions, and identify new investments that should be considered.

[6] MassDOT Emergency Response Plan
[7] MassDOT Emergency Management Plan

Figure 5



4.0 Report on Project Progress

The Report on Project Progress provides a brief level of detail on the ITS platform that will inherit new and future ITS developments.

4.1 Traffic Incident Management

This section is intended to provide an overview of the progress MassDOT had made in recent years in developing and deploying systems and assets to support traffic incident management. The section highlights major projects currently under construction and development, and recaps significant investment projects that have taken place in recent years.

4.1.1 ATMS/ATIS

Since 2012 the Highway Division has been engaged in the systems engineering process to acquire and deploy an Advanced Traffic Management System/Advanced Traveler Information System (ATMS/ATIS) at the Highway Operations Center (HOC). As of this date, the Concept of Operations, System Requirements and High Level Design documentation has been completed. This new system will replace and/or integrate with existing systems to support a number of traffic incident management functions performed on statewide roadways and facilities. The new technology will allow the HOC to interface with device control systems and/or to manage all Intelligent Transportation System (ITS) devices directly from a single platform. Current systems in place are legacy systems used by former agencies prior to the MassDOT merger that do not interface, are reaching end of life, and do not lend themselves to accurate or efficient performance reporting.

4.1.2 IPCS Upgrade

The Highway Division is also exploring how it would include the upgrade of the Integrated Project Control System (IPCS) at the Highway Operations Center (HOC) in the overall ATMS/ATIS project. The IPCS provides the HOC with the tools needed to monitor roadways and facilities in the former "Central Artery Tunnel Project" footprint. The IPCS is responsible for facility and roadway management, incident response management, data reporting, and the detection of roadway incidents and facility/security alarms.

It is, in short, an advanced traffic management system with limited functionality customized to the unique characteristics of the Central Artery Tunnel Project. The core system is supported by proprietary DYNAC software and peripheral hardware procured and developed by Transdyn Inc. as part of the Central Artery Tunnel Project.

The system needs to be upgraded to improve operational efficiency, to take advantage of the latest advances in traffic management technology, and to retire legacy software and hardware. The systems engineering process has presumed interfacing with the IPCS as part of an overall ATMS/ATIS requirements document.

4.1.3 PVMS and CMB Deployment, Review and Maintenance

In 2012 MassDOT initiated a significant investment program in roadside Portable Variable Message Signs (PVMS) and Camera Message Boards (CMB) to provide more comprehensive traveler information to the public and operational awareness to first responders. The PVMS/CMB upgrade project is a $4 million investment over 2 fiscal years. This construction contract was re-bid in FY-2013, resulting in cost savings of over $15,000 per board; or over $1.24 million in a single fiscal year.

Since 2012, MassDOT has deployed 46 PVMS and 16 CMBs along the 123 mile stretch of I-90 west of I-95. On I-90 east of I-95, MassDOT has deployed 15 PVMS and 7 CMBs. In addition to these deployments on I-90, MassDOT installed or replaced 58 PVMS and 20 CMBs on various other roadways in the Commonwealth. Deployment locations were based on discussions with districts personnel and first-responders, and drew on recommendations from the UMASS Lowell ITS assessment (section 1.3.1).

The Statewide Communications Engineering Department will work with all 6 Highway Districts in 2014 to develop a PVMS Maintenance Program. This program will leverage local knowledge within each district, statewide resources and asset management expertise to ensure that the investments made in recent years continue to deliver on the mission of providing dependable traveler information and first responder operational awareness.

On a similar track, going forward the Highway Division must be diligent in identifying all ITS devices that are out of service and cannot be repaired, including new deployments, and an inventory of legacy overhead message boards and other systems. The HOC is working with all applicable partners to develop protocols to identify, remove and replace legacy devices that have fulfilled their life expectancy. This involves a constant process to review systems used at the HOC to ensure proper operations and maintenance, and to explore how other systems may be used to support operations currently or in the future in an interface environment. This might include enhancements to current systems until a new ATMS/ATIS is fully deployed. As part of any new deployment investment, equally important are the process flows to report, repair, replace, and verify the status of ITS devices used on all roadways, including the introduction of uniform and consistent naming conventions and nomenclature for all devices.

4.1.4 ITS Expansion by Corridor

The ITS Programs Unit has developed an aggressive plan to enhance ITS deployments throughout the Commonwealth in the coming year. This expansion of ITS deployments is meant to address gaps identified in previous assessments and to address local needs and requests as they are identified from engaging in the systems engineering process. These projects are shown in **Figure 6**.

4.1.4.1 I-90 ITS Construction on the western Turnpike between I-95 to Exit1. This project consists of 18 Closed Circuit Television (CCTV), one at each Interchange, and connects to the HOC using existing fiber-optic communications. This project is currently under construction.

4.1.4.2 I-95 between Route 2 and Route 3. This ITS project consists of the installation of buried conduit/fiber-optic communications along I-95 that will connect to existing conduit/fiber-optic communications on Route 3 and Route 2. Completion of this work will allow all ITS cameras to communicate directly with the HOC and also create more path redundancy to the existing statewide fiber-optic communications network. This project is nearing completion.

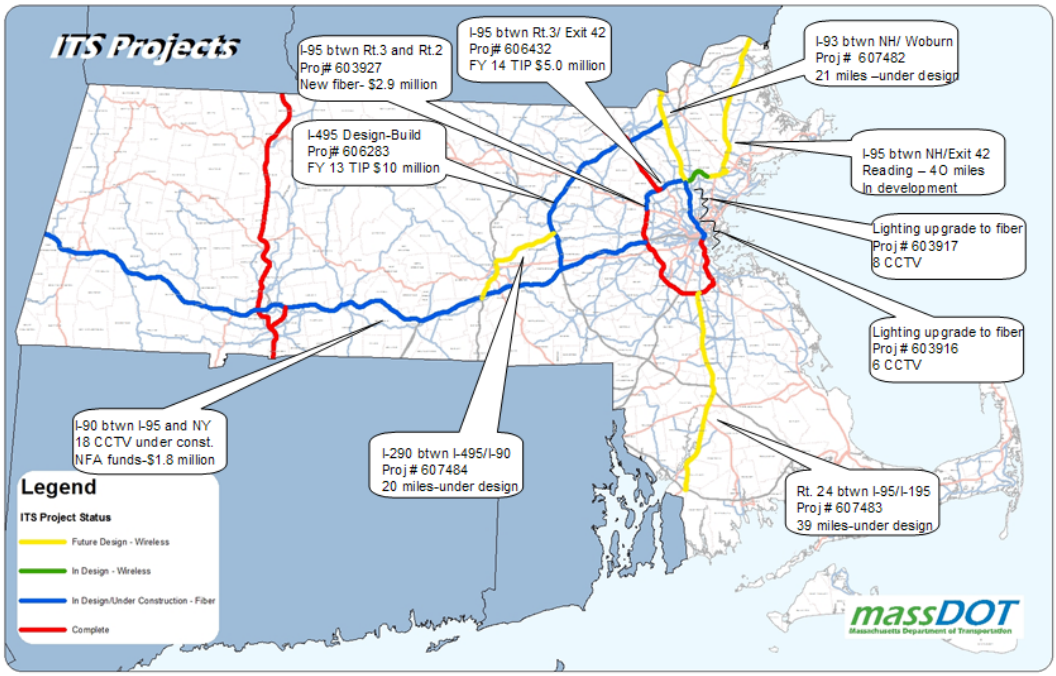
4.1.4.3 I-495 Design-Build Project will install 27 new cameras and 2 overhead Variable Message Signs (VMS) on I-495 between I-90 and I-93. This project will also light the existing fiber optics on I-495 and extend the network to I-90. Connections will also be made to Route 3 system to create a redundant communication path to the Mt Nebo Tower to alleviate bandwidth on the microwave system. The new fiber-optic system will connect all I-495 cameras to the HOC via existing fiber-optic communications. This $10 million dollar project will begin construction in early 2015.

4.1.4.4 I-95 ITS project between I-93 and Route 3 This project will extend the fiber-optic communications backbone on I-95 from Route 3 interchange to exit 42 (Salem Street). This project will also install 8 new CCTV cameras and connect ITS devices north of Route 2 to the fiber optic network to improve video quality and eliminate leased line communication costs. The new fiber-optic system will connect all I-95 cameras to the HOC via existing fiber-optic communications. Expected advertise date is August of 2014.

4.1.4.5 Route 24 ITS Project Design between I-95 and I-195. This project will consist of approximately 20 new CCTV and 4 overhead VMS that will be operated from the HOC using wireless communications. This project will be ready for advertisement this year.

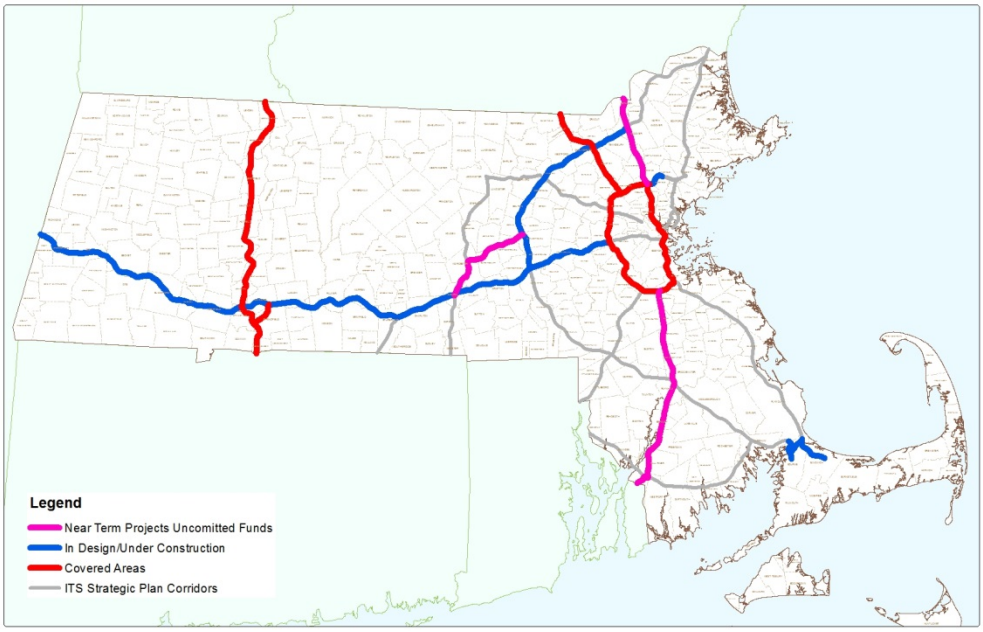
4.1.4.6 I-290 ITS Project Design between I-495 and I-90. This project that will include 16 CCTV and 4 overhead VMS operated from the HOC using wireless communications. This project will be ready for advertisement this year.

Figure 6



The implementation of programmed and planned ITS Corridor projects will expand the existing miles of highway coverage with ITS (primarily CCTV and overhead VMS) by 247 miles, a 174% increase over existing ITS coverage since 2012. This represents a significant commitment by MassDOT to expand ITS statewide. **Figure 7** below shows current and near term ITS construction project locations.

Figure 7



4.2 Traveler Information

MassDOT has made a commitment to implementing a number of strategies to ensure that commuters have access to timely and accurate traveler information. MassDOT is working closely with the Federal Highway Administration Operations Technical Service Team to initiate dialogue and the review process in assessing conformance with Title 23 Highways [23 CFR] Part 511 Real-Time System Management Information Program (RTSMIP). Transportation professionals from multiple disciplines are engaged in a collaborative effort to review, discuss and document how provisions are being met, by codifying the present level and future planned levels of compliance with the intent of the regulation (23 CFR Part 511) as it applies to the Commonwealth. This includes identifying existing policies & procedures that are effective in providing timely collection, quality assurance, and availability of RTSMIP information; and/or determining if revised or new policies and procedures are needed. In addition, the process is identifying and documenting any gaps that warrant corrective actions as determined by the review team.

The process is designed for persons engaged in any aspect of highway traveler information, construction activities, road weather management, maintenance, operations, traffic management, traffic incident management and highway safety; specifically those engaged in the implementation of solutions for roadway problems that are caused by weather, incidents, and construction work zones. The Rule is an outcome-based regulation with the goal to improve the day-to-day quality and performance of State's real-time transportation information systems and the objective of improving congestion management and operations. MassDOT plans to complete a compliance report for all Interstate roadways by November 2014, and other roadways deemed routes of significance by 2016.

4.2.1 Massachusetts 511 System

Currently MassDOT maintains a traditional phone-based 511 system through its partnership with IBI Group. This third-party vendor purchases private sector travel time data and operates the "back-office" for the system. The current 511 telephone system logs approximately 40,000 calls a week from new and current users. Commuters can also sign up for email and text alerts based on the roadways pertinent to their daily commute. A 511 website is also available to travelers, which includes a map with live-traffic conditions, planned construction events, and traffic incident updates. This information is updated as soon as incidents are detected and logged by the Highway Operations Center through a live-XML feed. Information is available for major highways within the Commonwealth, over 700 miles of roadway.

4.2.2 Real Time Traffic Management (RTTM)

Building on the 511 service and taking advantage of advances in new technology, MassDOT initiated an operational test of a Bluetooth based real time traveler information system in 2012 called the Real Time Traffic Management (RTTM) system. The system calculates travel time between two or more points along the roadway by using time stamps collected from anonymous wireless devices, and displays these live travel times in one minute updates on roadside portable variable message signs. RTTM uses new technology; a Bluetooth sensor, wireless communications, and solar powered sensors. **Figure 8** shows RTTM technology currently deployed.

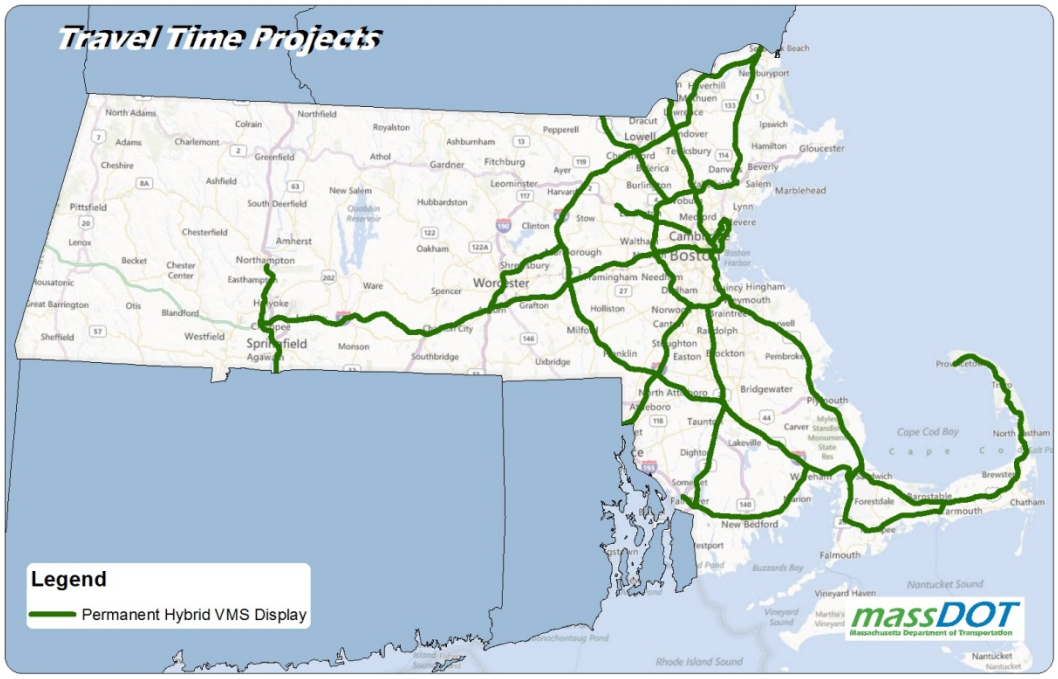
The purpose of the RTTM system is to inform drivers of the distance and number of minutes it will likely take to travel from the message sign they are reading to destinations 5 to 10 miles down the highway. This provides motorists with a sense of how long their commute will take, and an ability to plan ahead when traffic is worse than expected. These signs are placed at key interchanges or decision points across the highway network to facilitate a greater degree of route or mode diversion.

RTTM is multi-purpose. Real-time data can be used for Planning, Operations, and for real time performance measurement. The technology will form the centerpiece for compliance with new Federal Highway regulations requiring the collection and availability of real-time traffic information in metropolitan areas (23 CFR 511). RTTM will also support compliance with highway performance measurement requirements established in MAP-21. The RTTM system also enhances operations by displaying travel time data on a Graphical User Interface (GUI) posted to the RTTM website (93rttm.com). This provides a "snap-shot" of live traffic conditions across the entire roadway network. Operators in the Highway Operations Center use this GUI to proactively search for anomalies in roadway performance.

Figure 8

Based on the success of this test and positive customer feedback, MassDOT is expanding the system to Cape Cod (Rte. 6) in mid-April, with plans to cover all major highways throughout the Commonwealth. When completed, the RTTM will be the largest single deployment of a Bluetooth based travel time system, encompassing over 675 miles of State highway in a major metropolitan area. This represents a major commitment by MassDOT to use wireless technology to increase mobility, alleviate congestion, and improve overall highway safety. **Figure 9** shows anticipated coverage for the statewide deployment of RTTM. When fully deployed, it is estimated that over 2.2 million motorists will view the Travel Time Message Signs on a daily basis.

Figure 9



Going forward with the Rte. 6 expansion and all other expansions, MassDOT will be installing new static travel time signs approved by MUTCD. These signs, shown in **Figure 10**, will pose significant advantages over using PVMS to display travel times. The signs can accommodate up to 3 destinations and provide drivers with more information. The signs will represent a significant increase in customer service as the signs will be dedicated to travel time information and may reduce driver distraction. MassDOT can reassign currently deployed PVMS for other operational needs.

Figure 10

The statewide RTTM deployment will include a MassDOT owned "back office" that is scalable to expand to other highways or arterials. Unlike many other DOTs that buy their travel time data from third-party vendors, MassDOT will own and operate the statewide system. This business model will mean that travel time data is owned and archived by MassDOT, thus ensuring accuracy, accountability and reliability. This innovative strategy also allows MassDOT to make this data freely available in real time through the Internet to third party developers (http://www.massdot.state.ma.us/DevelopersData.aspx).

This open data strategy encourages the development of innovative third Smartphone applications by using data provided in a standard XML format open to anyone. Developers can also combine this data with other MassDOT data for transit, construction, and incidents, or third party data for parking, weather, and special

events to create customized information for users in real time. MassDOT has a forward thinking strategy; it leverages the developing trend of public-private partnerships along with the growth in ITS technology to deliver on the public's expectation for access to personalized and up to date travel information.

4.3 Road Weather Information

MassDOT has a multi-faceted approach to monitoring and disseminating road weather information that draws on a variety of ITS technologies. MassDOT operates 28 Roadway Weather Information Systems (RWIS) stations across the Commonwealth. This information is presented on a website to HOC operators, and informs operators of potentially hazardous roadway conditions. Some RWIS stations also include cameras that can be used to monitor weather conditions.

The Snow and Ice Operations Desk at the HOC is typically activated during serious weather events to monitor conditions and disseminate weather advisories. The HOC has developed a detailed Winter Storm Procedure Manual that outlines steps for notifying MassDOT personnel and providing the appropriate traveler information. MassDOT also coordinates with the National Weather Service to receive weather warnings both statewide and specific to the Boston Metro Region. MassDOT will receive text, email and phone notifications from regional agencies (eg: MEMA) regarding impending extreme weather situations. If roadway conditions are deemed hazardous, MassDOT can post an alert to any one of the over 450 VMS boards in the Commonwealth to alert drivers to potentially dangerous conditions. MassDOT is also currently reviewing its deployments of RWIS stations and is considering a new investment on critical roadways for the future.

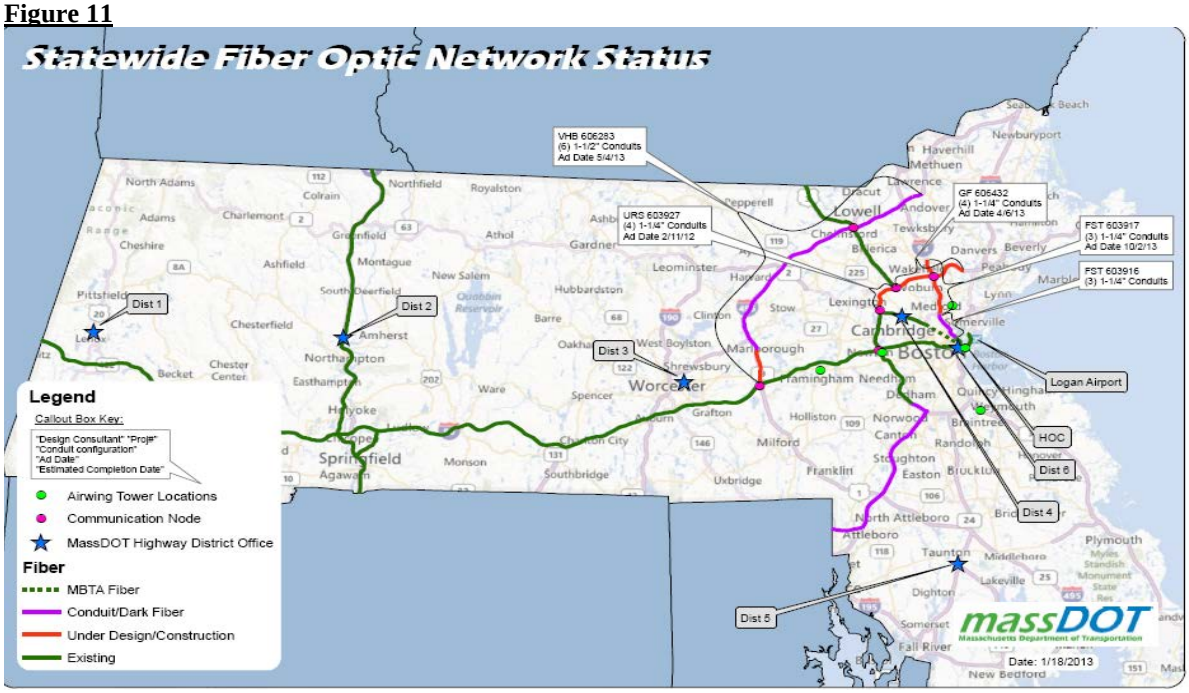
4.4 Fiber Optic Network Expansion

The backbone of ITS is a secure, buried fiber-optic communications network that enables high bandwidth communications between transportation and public safety operations centers in order to ensure information and video sharing capabilities during major events. Buried fiber-optic that connects to existing fiber-optic communication nodes brings data collected by ITS devices back to the HOC. Network management provides for path diversity (including digital microwave) and redundancy.

MassDOT Communications Engineering has made great efforts to identify existing fiber and determine the best locations for new fiber deployments that would maximize network coverage within the Commonwealth while minimizing cost. **Figure 11** below shows locations of existing fiber and proposed fiber expansions to connect the network. The following three projects are priority projects for MassDOT planned for advertisement in the next year, and are also included in section 4.14 as ITS Deployments by corridor:

- Expand fiber on I-95 from the Rte. 3 interchange to Exit 43, approximately 10 miles of roadway.
- Address the gap that would connect existing fiber along I-495 and I-90.
- Install buried conduit/fiber-optic communications along I-95 that will connect to existing conduit/fiber-optic communications on Route 3 and Route 2.

Figure 11



In addition to these priority projects for deploying new fiber, MassDOT has made efforts to maximize the potential of existing fiber infrastructure. In 2011, MassDOT was awarded a $7 Million Homeland Security Grant to establish the Massachusetts Emergency Transportation Fiber Optic Network (METFON). Through METFON, MassDOT has been able to deploy 12 Dense Wavelength Division Multiplexers across the state. These devices allow a single piece of fiber to carry up to 80 different channels of data simultaneously[8]. This technology "multiplexes" the capacity of existing fiber without the high costs of having to lay new fiber.

The Highway Division was also able to successfully leverage its relationship with the MBTA and other state and local agencies to obtain additional fiber capacity within the Commonwealth. The resource sharing partnership allowed MassDOT Highway to obtain 36 fiber strands within the Boston/Cambridge area, 2 fiber strands in Western Massachusetts, and 2 fiber strands along the South Shore to the Cape.

4.5 Smart Work Zone Management

MassDOT utilizes portable ITS devices to monitor, measure and evaluate traffic conditions so as to provide real-time information to the public and control operations within the work zone. These Smart Work Zones (SWZ) apply construction and traffic monitoring devices such as traffic and speed detectors that improve safety, measure performance, and calculate traffic delays through work zones to advise motorists of approaching delays. The sign pictured below in **Figure 12** uses Bluetooth to measure travel time through the work zone and follows the design of the new statewide RTTM signs. After construction, the signs will be removed or may become part of the permanent RTTM by changing the orange color to standard green.

MassDOT owns a fleet of 6 Radar Speed Feedback trailers with VMS boards that are used in work zone applications. The boards utilize GPS based tracking and allow for remote management and speed dependent messaging to motorists. The system also records and logs data for real-time access by password-protected end-users at DOT and within Massachusetts State Police to produce reports on work zone performance. Cameras and VMS are also deployed that enable MassDOT personnel to gauge the impact of construction on traffic and greatly enhance the safety and efficiency of the work zones. The use of SWZ technology is currently determined on a project-by-project basis.

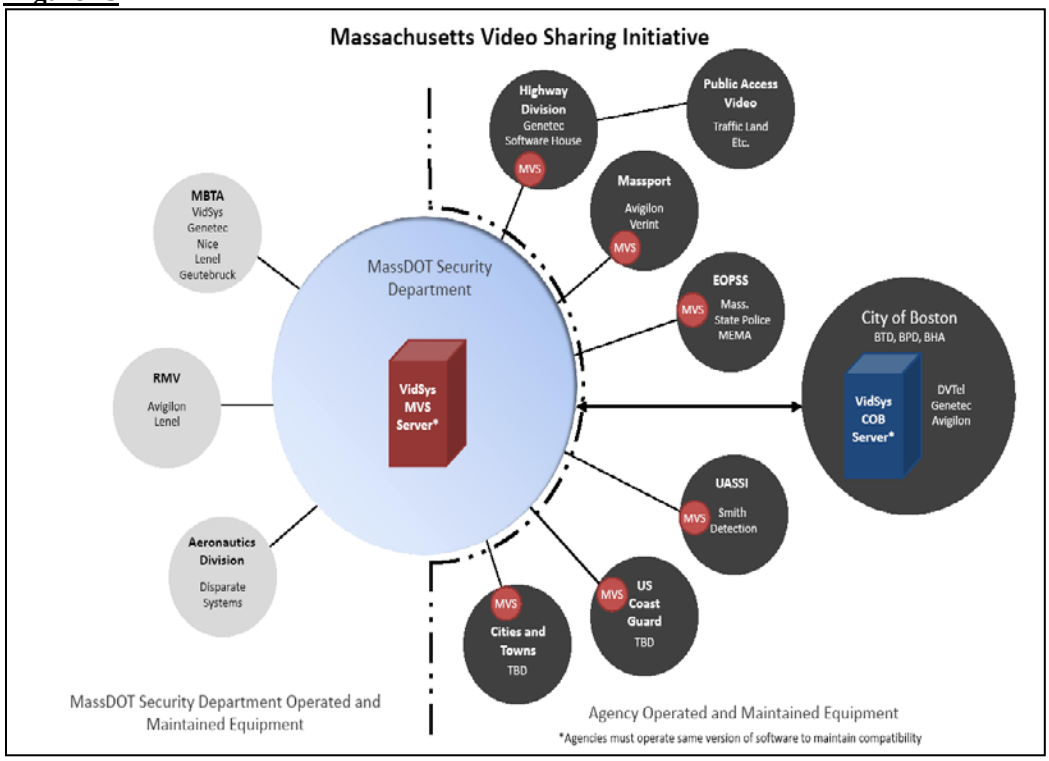
[8] International Engineering Consortium; iec.org

Figure 12

4.6 Enhancing Statewide Situational Awareness

Managing incidents and congestion requires that first responders and the public have access to roadway information that shows them the impact of recurring or non-recurring congestion. To that end, MassDOT has initiated a number of projects to enhance the level of information received by partners in public safety and the public who want to see the current status of roadways. The sharing of live video is yet another important tool that can be used to assess how incidents impact congestion, how travelers may want to change or augment their commute, or to ensure the security and safety of our roadways. The Third Party Video Distribution System detailed in **Figure 13** is a new initiative to be launched in 2014 that will address this demand.

Figure 13



4.6.1 Third Party Video Distribution

External stakeholders have clearly demonstrated that there is demand for access to live roadway traffic video. MassDOT currently provides live roadway camera feeds to the public through links on the Highway

Division and 511 web pages. These video feeds contain images updated approximately once every ten seconds, and includes 81 cameras only on the most highly travelled routes, I-90, I-93, I-95 and Rte. 3 and Rte. 6 near the Sagamore Bridge. An XML feed is also made available by MassDOT to third-party developers at no charge.

Separate from this public video service, MassDOT feeds many of its cameras into the Massachusetts Interagency Video Information System (MIVIS) to provide situational and operational awareness to agency partners, first responders and emergency personnel. This system currently supports 73 live traffic cameras, but requires a significant upgrade to improve video distribution ability.

MassDOT has procured a video distribution solution to allow a greater number of cameras to be shared with the public, media, and emergency responders with enhanced video quality. The Third Party Solution through TrafficLand will enable MassDOT to both improve roadway video provided to both the public and internal stakeholders. Using TrafficLand, traffic cameras on the MassDOT website will increase to 350 and will update one frame every 2 seconds. This represents a significant increase in quality and quantity of video distribution. The TrafficLand solution will allow MassDOT to share over 650 of its traffic cameras with agency partners such as State and local Police, Fire and other emergency personnel. The TrafficLand solution will also allow the retrieval of live video on a mobile device, representing an enormous increase in situational awareness for first responders within the Commonwealth.

This project, working in concert with other video sharing initiatives, will ensure that first responders inside and outside of the MassDOT fiber optic network will have access to streaming live video for congestion and incident situational awareness.

4.7 Other Projects

MassDOT has initiated plans to implement All Electronic Tolling (AET) on the Tobin Bridge and other MassDOT toll roads. AET will improve roadway performance and air quality by eliminating the need for drivers to stop or slow down to pay their toll. How this initiative fits into the broader ITS “picture” will be determined as deployment gets under way. In the interim, MassDOT has planned for a future interface between the ATMS/ATIS software platform and this software platform so as to ensure data sets can be fused together to measure performance of our systems.

The Highway Division is also working with the Department of Security and Emergency Management on a Security Concept of Operations whereby all MassDOT cameras, security alarms, and video can be accessed on a single platform within a single business for the sole purposes of ensuring security and emergency preparedness.

MassDOT is also working with the Communications Department to upgrade its current radio system. This will include the deployment of equipment and services necessary to improve the Highway Operation Center Radio Dispatch and Inter Agency Operations. A total of 20 Motorola MCC7500 Operator Workstation Clients will be installed in the HOC as well as necessary networking hardware and required software upgrades at core locations. The procurement also includes Motorola Engineering support for software installation, optimization, and system start up. The new hardware shall be distributed over two system networks.

5.0 The Cost of Deployment

Planning, programming, deployment and maintenance for ITS is a process that is constantly being reviewed as new technologies are developed and as new needs are identified on our roadways. The cost of ITS is also rapidly evolving as technologies advance. To that end, MassDOT ITS Programs is fully engaged in a process to identify multiple funding sources for these technologies that improve operations, ensure the safety and security of our roadway users, and assist in managing recurring and non-recurring congestion. In short, the costs are significant, but the investments are worthwhile as we use technology to enhance the transportation experience, short of building new roadways to enhance current capacity.

5.1 The Development Process

ITS Programs works closely with the MassDOT HOC, Communications Group, Planning, IT, District Offices, and FHWA to provide technical support for every aspect of ITS: systems engineering documentation, equipment specification, design, procurement, shop drawing review, acceptance testing, construction, operations and maintenance. ITS deployments follow a comprehensive systems engineering process manner as part of the Secretary's initiative to enhance customer service, promote public safety and workplace safety, provide traveler information, improve transportation performance and the develop tools to measure performance.

5.2 Sources of Funding

All Federally funded projects are required to be programmed in the State Transportation Improvement Program (STIP) or Regional TIP over a five year time horizon. ITS Programs submits an annual list of projects eligible for Federal funding to MassDOT Planning. This list is based on Highway Operations/ITS priorities given the fixed budget that is available for ITS projects. The table in **Figure 14** below shows the current list of federally funded ITS projects. ITS programs also supports a variety of non-federally funded ITS projects on the Massachusetts Turnpike, MBTA, RMV, and MAC. The ITS Program's budget is on average $15,000,000 annually and supports a variety of ITS projects and ITS related programs such as the Highway Assistance Patrols.

Figure 14

Amended FFY 2014 THROUGH 2017 PROJECT LISTING

TARGET PROJECTS — **ITS and HOV Capital (CMAQ)**

FFY	RANK	PROJ. NO.	DESCRIPTION	TFPCC
14	1	607422	Statewide Real Time Traffic Monitoring (RTTM) System	$7,000,000
14	2	607424	Advanced Transportation Management System (ATMS) software	$3,250,000
		606914	ITS Design Consultant Services	$750,000
		606927	VMS Replacement (enhancement)	$1,000,000
			Total CMAQ	$12,000,000
			ITS and HOV Operations (STP-Flex)	
14		606916	HOC Operating and Maintenance Expenses	$520,000
14		606427	Highway Assistance Patrols - area 2 - year 3	$1,328,535
14		606428	Highway Assistance Patrols - area 3 - year 3	$1,328,535
			Total STP-Flex	$3,177,070
			Total CMAQ+STP	**$15,177,070**

CONTINGENCY PROJECTS

FFY		PROJ. NO.	DESCRIPTION	TFPCC
14	3	606432	I-95 ITS and Fiber-Optic expansion - Burlington to Woburn	$5,000,000
14	2	607482	I-93 ITS - Woburn to New Hampshire border (21 miles)	$2,400,000
15	3	607483	Route 24 ITS - Randolph to Fall River (39 miles)	$3,000,000
15	4	607484	I-290 ITS - I-495 to I-90 (40 miles)	$3,000,000
			TOTAL	$13,400,000

5.3 Current Budget

The ITS Program construction is supported by FHWA 80% and State 20% matching funds. This budget averages $15,000,000 annually and supports a variety of ITS projects and ITS related programs such as the Highway Assistance Patrols. Other available funds include toll revenue and state transportation revenue bonds that fund such projects as the AET.

6.0 The Future of ITS Deployments

Current trends in wireless communication (phone apps) and the capability to collect real-time location aware data (Bluetooth, Wi-Fi, social networking) have created unprecedented opportunities to dynamically and proactively provide incentives to increase the mobility of commuters across transportation modes and across agency jurisdictions.

6.1 Integrated Corridor Management

Looking for solutions to the issues facing transportation in the 21st century, MassDOT will seek ways to use ITS technology to support a number of initiatives, including an Integrated Corridor Management (ICM) strategy. This initiative will capitalize on the high availability of ITS information (through real time collection of speed, volume, incident, and weather data), the ability to fuse this data into meaningful information, and the transformation of this data into "actionable intelligence" through public dissemination (via VMS, open data initiatives, connected vehicles and smartphone applications).

MassDOT took its initial steps toward developing an Integrated Corridor Management strategy in early 2014, submitting an application to FHWA for a grant to conduct a feasibility assessment and develop a concept of operations.

The ICM vision for MassDOT is in its earliest stages. It would target the Rte. 3 corridor from the Sagamore Bridge to I-93 at the "Braintree Split", over 40 miles of roadway. The strategy would make use of the large number of transportation assets along or near the corridor, including 3 commuter rail lines, Red line stations, underutilized parking capacity at transit stations, and 5 park and ride lots.

The ICM strategy would be two-fold. The first part of the strategy would make use of the power of traveler information, allowing the availability of real-time travel conditions help commuters find the most efficient usage of existing transportation assets. MassDOT would support the development of a multi-modal travel "app" that would allow drivers to easily compare travel times to their destination based on either transit or highway travel. The multi-modal app would leverage existing sources of real-time and historical traveler information including: RTTM travel times, MBCR and MBTA "next arrival times", expected transit travel times, live traffic cameras, incident data, and construction data.

The second part of the ICM strategy would be to provide a number of incentives to impact traveler behavior and increase overall throughput. Based on historical congestion, transit usage, and parking capacity data, MassDOT would provide short-term incentives to encourage transit use. This may include, but is not limited to, providing discounted commuter rail fares and discounted parking. The goal is to make transit more appealing to the typical driver based on potential time savings and cost savings.

6.2 The Connected Vehicle[9]

The connected vehicle, at least before Google's Autonomous Vehicle Program, has been a government funded research initiative that is divided into two sub-programs: Vehicle to Vehicle (V2V) applications and Vehicle to Infrastructure (V2I) applications. According the USDOT, "Connected vehicles have the potential to transform the way Americans travel through the creation of a safe, interoperable wireless communications network that includes cars, buses, trucks, trains, traffic signals, cell phones, and other devices. Like the Internet, which provides information connectivity, connected vehicle technology provides a starting point for transportation connectivity that will potentially enable countless applications and spawn new industries."

The use of in vehicle radar to detect and prevent accidents is a primary example of the connected V2V application. According to a U.S. Department of Transportation (DOT) report, combined V2V and V2I systems potentially address about 81 percent of all-vehicle target crashes, 83 percent of all light-vehicle target crashes, and 72 percent of all heavy-truck target crashes annually. In the past, the U.S. DOT has

[9] http://www.its.dot.gov/factsheets/pdf/JPO_PublicOfficials_v6.pdf

focused on helping people survive crashes. Connected vehicle technology will change the paradigm by helping people avoid crashes[10].
V2I applications also hold great promise for transforming the average commute. Annually drivers spend a total of 4.2 billion hours and 2.8 billion gallons of fuel sitting in traffic. V2I capabilities and other wireless transmission media, such as anonymous wireless device communications, have the potential to provide transportation agencies with dramatically improved real-time traffic, transit, and parking data, making it easier to maximize the efficiency of transportation systems and minimize congestion. Travelers could also use information collected and supplied by connected vehicles to dynamically change their route and travel time or mode based on up-to-the-minute conditions to avoid traffic jams. While significant advances in V2V applications are within years of being implemented, there is currently no ITS architecture for V2I applications.

6.3 Open Data and Big Data Initiatives
ITS technology collects a wealth of data about the transportation network's performance, including information about asset performance, incidents, construction, congestion delay, volume, weather, etc. Within MassDOT there is a need to share this data efficiently with other states, agencies, systems and subsystems, and also to fuse this data to tell an insightful story about the network's performance.

In 2013, as part of the Open Data Initiative, MassDOT partnered with the MIT Technology Collaborative. The goal was to leverage the data management expertise within the Collaborative to provide meaningful reports and visualizations of transportation patterns and performance in order to enhance operations.

On a similar track, in partnership with the Mass Big Data Initiative, MassDOT organized a "hackathon" in December 2013. This event invited in numerous groups with experience in data analysis. MassDOT made available many of its transportation data sources, including RTTM data, volume counts and transit data. Hackers worked through the night, and presented their findings to MassDOT employees the next morning. Cash prizes were awarded for the most compelling and insightful visualizations. The event produced many insightful data visualizations. Building on this success, additional MassDOT sponsored "hackathons" are planned for the future.

The growth of ITS technology, and the move towards integrating multi-modal performance data for enhanced operations, points to need for a MassDOT-wide data warehouse to send, store, manage, share and fuse this information. In the next few years MassDOT will be deploying numerous systems for asset management, traffic incident management, weather data collection, and electronic tolling. These systems will collect massive amounts of data that can be used for gaining insights into operations and continuously monitoring performance. A MassDOT owned or third party managed data warehouse will allow for the perpetual storage of this data, and an improved capacity to fuse, layer and connect this data in new and meaningful ways.

This need for a MassDOT-wide data warehouse is consistent with the goals and strategies developed by MassDOT Planning in the 2013 ITS Strategic Plan, and was cited as a priority project by MassDOT Planning.

[10] http://www.its.dot.gov/safety_pilot/

7.0 Conclusion

The current status of Intelligent Transportation Systems (ITS) deployments in the Highway Division of the Massachusetts Department of Transportation is a vibrant one, revitalized by legislative priorities, and by a new understanding within the organization as to how ITS can meet the goals of the Department and the needs of the roadway user. As this synthesis identifies, significant investments and deployments have been made and are planned in the near future, and it is critical that the guiding concepts and principles developed at the state and federal level continue to advance the growth of these deployments.

This report highlights achievements, but also identifies the need to be diligent in the way MassDOT will measure performance of these investments, and maintain them to ensure performance. This document should be updated on an annual basis to provide a "snapshot" of our current environment, and ensure transparency within the Department. The scope of the report may well be expanded to include other areas that are either impacted by ITS investments or can impact current or future ITS priorities.

Processes that should be utilized to support program development are well in place, and greater awareness and adherence to these processes will ensure successful implementation of a comprehensive ITS program. The funding process for these endeavors is indeed complex, and involves multiple players internal and external to the MassDOT organization. It is for that reason that collaborative engagements be further institutionalized within the entire process from planning, programming, deployment, maintenance, and retirement. Next year, this report will undoubtedly look and feel different as technologies change and new resources have become available to enhance the transportation experience.

MassDOT has transformed its vision for the future with ITS infrastructure at the forefront of transportation planning. **Governor Deval Patrick**, **Secretary Richard Davey**, and Highway Division **Administrator Frank DePaola** have put in place important initiatives that will enhance the transportation experience for many years to come. With continued leadership and vision, MassDOT will indeed lead the nation in transportation excellence.