Impacts of Technology Advancements on Transportation Management Center Operations

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16. Abstract This report provides guidance to TMCs and transportation management agencies on how to better position themselves operationally in anticipation of future technology changes and advancements. Eight top trends of TMC operations are identified, including those that come from both within and outside the transportation community. Individual strategies – 80 in total – are presented to assist TMC managers with addressing the trends. The strategy descriptions include successful practice examples and key references as applicable. Recognizing the potential difficulties in successfully implementing individual strategies, the report also presents tools for building a framework for the technology and mindset developments.			
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Preface/Acknowledgements

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Executive Summary

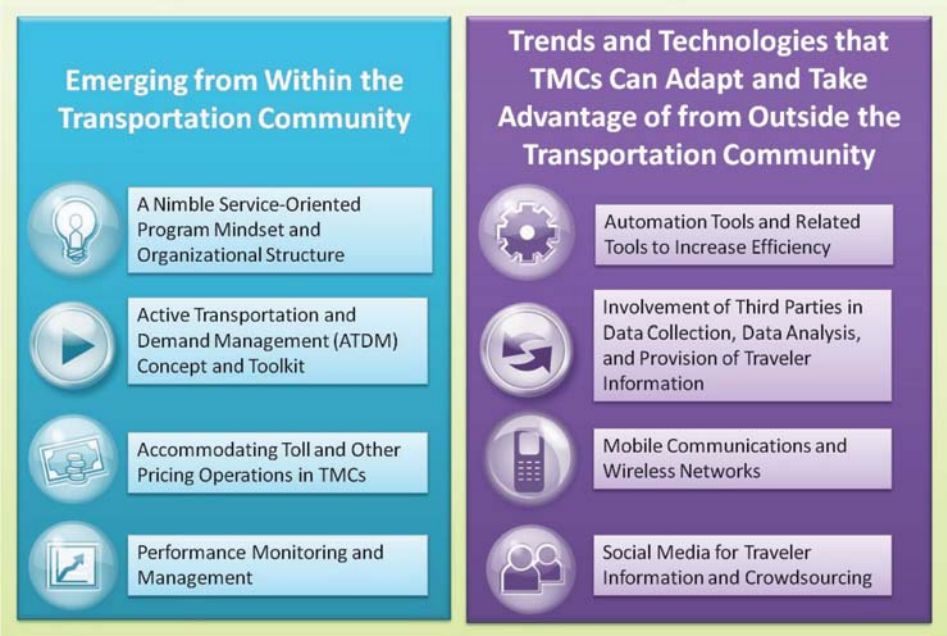
Transportation Management Centers (TMCs) have historically been at the forefront of leveraging technology to manage transportation. However, as need for innovative solutions grows, the technology options multiply, and funding streams diminish, TMC managers are under increasing pressure to rapidly adapt to the impacts of changing technologies and expectations. The purpose of this report is first to identify and analyze the potential impacts on TMC operations due to technology advancements in the next 10 years. It will then present successful practices and strategies for TMC managers to best position themselves for maximum benefit. Finally, it will offer tools that TMC managers can use to build the internal, technological, and broader agency framework that supports successful utilization of emerging technologies and related trends.

Through preparing a literature review and consulting with experts, big picture influences on potential TMC technologies were identified. The most transforming implications for TMC operations are based on the proliferation of wireless communication, the rise of social media, and the involvement of third parties. Together, they create massive two-way data and communication streams throughout the transportation network. New classes of real-time holistic data become available to TMC operations, often through third parties. This enables unprecedented real-time understanding of the transportation network that can be leveraged into increasingly sophisticated control strategies. As travelers access personalized and user-friendly commercial information through their mobile device apps, their expectations for transportation system information increase.

The convergence of big picture influences with rapidly evolving Intelligent Transportation System (ITS) technology reveals an opportunity to meet growing needs with careful application of technologies within progressive agency structures. In order to adapt to rapidly changing technology, financial pressures, and increased accountability, TMCs will need to be nimble and flexible. This will be a challenge for many agencies, but a likely necessity over the next decade if not already.

Fortunately, TMCs are also gaining more abilities thanks to new technology and processes. With the more detailed, varied, and geographic coverage of data, TMCs will have a much greater understanding of needs and conditions to draw upon. By integrating with regional partners and developing new ways of utilizing data, they can improve multi-modal options, trip reliability, network reliability, and safety with processes and systems that are much more automated than in the past. Third parties can be important partners in providing data to TMCs as well as developing innovative transportation analysis tools and providing the resulting traveler information to the public. That may allow TMCs to focus on transportation management and providing the information that the private industry is not able to provide. Again, flexibility will be very important for agencies so they can adapt to changing roles and take advantage of new opportunities.

Eight TMC operations top trends and issues emerged as the focus of this project, both for explaining the trends and for organizing strategies that TMC managers can use for addressing them. The top trends described in Chapter 3 are:



(Source: Parsons Brinckerhoff)

For each of the top trends, there are many specific strategies and technologies that TMC managers can consider to position themselves to address operational changes. These strategies are presented in the following table.

Trend and Description	Strategy	Related Trends
A Nimble Service-Oriented Program Mindset and Organizational Structure *Represents the framework of being positioned to successfully select and rapidly adopt changing technologies and processes to address growing and changing expectations from travelers for efficiency and communication*	Foster an Agency Culture of Embracing Technological Change	
	Create a TMC Operator Training Program	
	Enhance Operational Communication, Which Will Promote a Culture of Open Communications Among Staff.	
	Develop Memoranda of Understanding (MOUs) and Inter-Agency Agreements Facilitating Multi-Agency (sometimes Multi-State) Cooperation & Operations	
	Create New Technology Piloting and Testing Program	
	Develop Skill sets of TMC Managers in Areas of Contracting, Privacy, Security, and Intellectual Property	
	Adopt Standards on TMC Related Equipment and Processes	
	Use Open-Source or Non-Proprietary Software when Possible	
	Require Application Programming Interfaces (APIs) and Document for Future Development	
	Require Documentation on All Systems and Software - include Search Capabilities and Provide Remote Accessibility	
	Follow the Systems Engineering Processes	
Active Transportation and Demand Management (ATDM) Concept and Toolkit *Using a variety of tools at one's disposal to proactively make operations more efficient, including through staff and technology*	Implement a Suite of Emerging Transportation Concepts, Coordinating as Necessary	
	Integrated Corridor Management (ICM)	
	Active Traffic Management (ATM) Which May Include Lane Use Control, Variable Speed Limits (VSL), and Hard Shoulder Running	
	High Occupancy Toll (HOT) Lanes	
	Portable Work Zone ITS Systems	
	Regional or Multi-State Coordination of Detours and Traveler Information	
	Provide Real-Time Travel Time Estimates on Full Range of Devices and Systems Available	
	Display Transit Info on Parallel Route DMS (Possibly with Comparative Travel Time and/or Parking Availability)	
	Parking Management Including Dissemination of Real-time Garage Space on DMS and through Apps	
	Arterial Management with ITS Devices such as Closed Circuit Television Cameras (CCTV), Dynamic Message Signs (DMS), and Remote Access to Traffic Signal Controllers	
	Integrate Ramp Metering Schemes with Adjacent Arterial Signal Timing to Minimize Conflicts with Ramp Queues	

Trend and Description	Strategy	Related Trends
	Adaptive Signal Control Technologies (ASCT)	
	Transit Signal Priority (TSP)	
	Road Weather Integration	
	Weather-Responsive Signal and Ramp Meter Timing Plans	
	Develop Protocols and Maintenance Program to Address Increased Number and Complexity of ITS Field Devices	
	Co-locate Freeway & Arterial Transportation Management	
	Promote Coordination with Arterial Management Agencies	
	Look for Opportunities to Share Resources with other Agencies (e.g., communication networks, cameras)	
Accommodating Toll and other Pricing Operations in TMCs *Integrating pricing in operations encourages obtaining revenue through tolling and financing infrastructure expansion*	Develop Protocols for Operations (Such as Pricing and Ops for Diversions to HOT Lanes During Major Main Lane Incidents) during Early Feasibility Planning	
	Develop Protocols for Joint Operation of Freeways & Toll Roads during Early Feasibility Planning	
	Develop Protocols for Operations and Implementation of HOT Lanes with Variable Pricing During Early Feasibility Planning	
	Develop Protocols for Operations for Cordon Pricing for Congested Areas during Early Feasibility Planning	
	Consider Increased Network Reliability and Data Security Needs	
Performance Monitoring and Management *Increasing data collection and analysis can lead to improved operations, enhanced customer service, and documented effectiveness of TMC actions*	Use Results of Performance Monitoring Related to Agency Goals to Support Funding Requests	
	Proactively Develop Performance Metrics Based on Staff Priorities as well as Agency Goals	
	Use Multiple Data Sources to Monitor System Congestion, Including to Support Travel Time Estimation	
	Consolidate Efforts to Develop Data Management Tools Across Agencies	
	Frequently Process and Distribute Measures of Effectiveness (MOE's), Including to Operators, to Improve Operational Effectiveness	
	Utilize Features in Software to Track and Report Performance	
	Utilize On-Board Device data from Agency Vehicles to Monitor Pavement Condition	
	Train TMC Operators How to Use Performance Monitoring and How to Populate the Data Needed for Performance Monitoring	

Trend and Description	Strategy	Related Trends
Automation Tools and Related Tools to Increase Efficiency *New technologies that improve system management and cost-effectiveness thus resulting in greater productivity*	Use Advanced Graphical User Interfaces to Increase Operator Efficiency	
	Develop Decision Support Systems	
	Install Remote Power Cycling of Field Devices	
	Install Automatic Power Cycling of Field Devices	
	Specify Automation Features in Software Contracts	
	Consolidate Interfaces to or Consolidate Alert Systems across Agencies	
	Develop Default Sets of Traveler Information Messages across Devices (such as DMS) and Media for Quick Implementation during Recurrent Special Events or Incident Types/Sites	
	Utilize Low-Cost Low-Infrastructure Devices, such as Solar-Powered Pole-Mounted Traffic Sensors with Wireless Communications	
	Utilize Predictive Analysis and Forecasting for Anticipating Congestion	
	Because the Private Sector Often Develops the Automation Tools, Support Strong Participation to Provide Better Tailored Tools	
	Include Options for Manual Verification and Override to be used as Operators Fine Tune and Gain Confidence in New Applications	
	Develop a Data Fusion Engine to Merge Data from Multiple Sources, such as Travel Time Information Coming from Toll Tag Readers, Bluetooth Sensors, and/or Third-Party Providers	
Involvement of Third Parties in Data and Traveler Information *Utilizing data services that third-party vendors provide to manage roadway traffic and deliver traveler information to the public*	Develop Pre-qualifications or Standards Regarding Data Accuracy and Validation (Potentially Both for Data Received and Data Provided)	
	Provide Real-Time Data to Third Party App Developers	
	Share Data Among Agencies	
	Develop Protocols for Data Privacy and Confidentiality, including for Media and other Agencies Co-located in the TMC Observing otherwise Restricted Material	
	Utilize Private Sector Meteorological Services or In-House Meteorological Resources	
	Research Solutions that Others have used to Solve Similar Problems	

Trend and Description	Strategy	Related Trends
	Use Multi-Agency Procurement for Economies of Scale	
	Train TMC Operators on How to Interpret Alternate Data Sources to Support Operations Decision Making	
	Consider Use of Applicable Standards to Simplify Data Exchange, such as XML	
Mobile Communications and Wireless Networks *Advances in wireless technology provide options when it comes to modernizing their field equipment and increasing data coverage*	Coordinate with Information Technology (IT) Staff to Develop Firewalls and Other Security Protocols that are Effective without Limiting Functionality	
	Efficiently Expand Field Device Coverage and Operations Cost Using Wireless Networks	
	Allow Appropriate Remote Access into TMC Software or Devices (primarily for Maintenance Staff and Appropriate Coordinating Staff from Partner Agencies)	
	Utilize Commercial Mobile Devices and Apps to Support Collaboration between Freeway Service Patrol and Other Emergency Responders, TMC Operations Staff, and Field Maintenance Staff for Improved Communication and Enhanced Field Collaboration	
	Operate Mobile Command Centers or Satellite Centers with TMC Software Access	
Social Media for Traveler Information and Crowd sourcing *Using social networking tools to receive and distribute information among agencies, travelers, and third parties*	Develop Procedures and Protocols for Use of Social Media	
	Foster Relationship among Agency Public Relations Groups	
	Co-Locate Traveler Information Provider Staff with TMC Staff and Agency Public Relations Staff	
	Support Two-Way Information Exchange Via Social Media	
	Designate a Larger or Statewide TMC to Take Responsibility for Social Media Alerts on Behalf of Multiple Agencies in a Region	
	Provide Information through Social Media and Mobile Apps Focused on Pre-trip Planning to Minimize Driver Distraction (Near Term)	
	Utilize En-route Social Media (including Crowd sourcing) as Voice Activation Becomes More Common (Longer Term)	
	Utilize Crowd sourcing for traffic information, incident information, feedback on department performance, pavement roughness	
	Provide Incentive for Drivers to Participate in Crowd sourcing	
	Partner with the Private Sector to Facilitate Social Media Outlets and Realize Cost Efficiencies	
	As More Traveler Information Content is Available to Travelers through Third-Party Apps, TMCs Can Focus on Providing Content on Core Mission (Such as Upcoming Construction and Estimated Time to Reopen Lanes)	

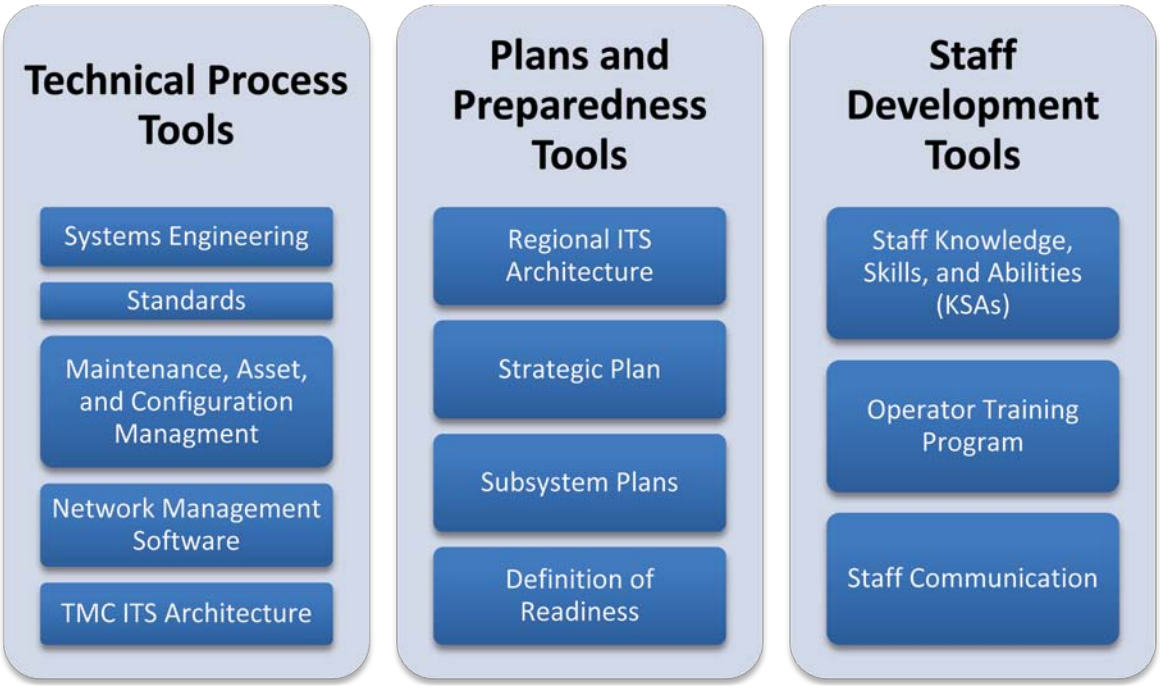
TMC managers are encouraged to consider the 80 strategies presented to help them address the trends that are expected to impact them over the next decade. The strategy descriptions in Chapter 4 include successful practice examples and key references as applicable. A table cross-listing the trends and strategies while also identifying trend/strategy pairs that have high potential to be feasible on limited budgets and even reduce TMC expenditures is also included in Chapter 4.

Adopting identified strategies, as part of a program of progressive TMC operations over the coming decade is a major undertaking. Program-level implementation and integration tools help to establish a climate conducive to successful implementation, operations, and funding

Recognizing the potential difficulties in successfully implementing individual strategies, let alone the integrated sets that provide the most benefit, Chapter 5 of the report also presents tools for building a conducive framework for implementing strategies. The tools and their associated checklists for TMC managers cover internal TMC processes and technologies. They also cover cultivating a strong position for the TMC within the broader organizational context.

The tools for technological and internal processes that can typically be applied directly by the TMC manager are:

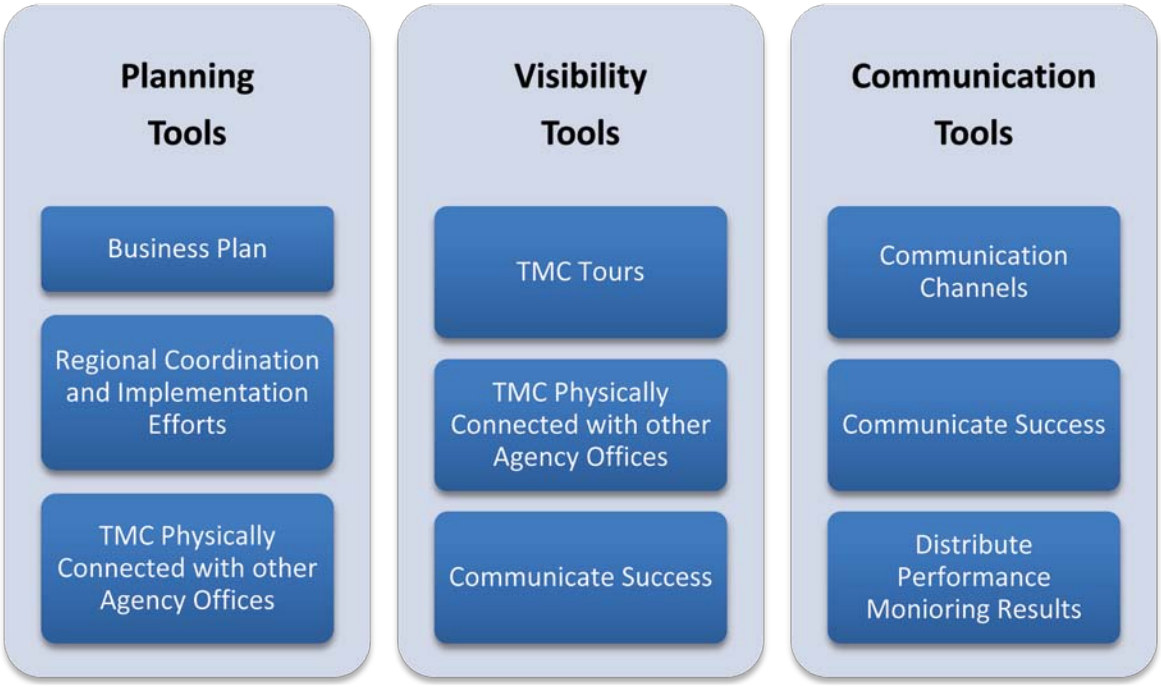
- Technical Process Tools: Systems Engineering, Standards, Maintenance, Asset, and Configuration Management, Network Management Software, and TMC ITS Architecture;
- Plans and Preparedness Tools: Regional ITS Architecture, Strategic Plan, System Plans, and Definition of Readiness; and
- Staff Development Tools: Staff Knowledge, Skills, and Abilities (KSAs), Operator Training Program, and Staff Communication.



(Source: Parsons Brinckerhoff)

The second set of tools is for coordination of TMC processes with the broader organizational context in order to increase support for the TMC's programs, systems, and staff. They are:

- Planning Tools: Business Plan, Regional Coordination and Implementation Efforts;
- Visibility Tools: TMC Tours, Keeping the TMC Physically Connected with Other Agency Offices; and
- Communication Tools: Communication Channels, Communicate Success, Distribute Performance Monitoring Results.



(Source: Parsons Brinckerhoff)

Implementing these tools builds a framework for successful deployments of the strategies that allow TMC operators to take advantage of trends and technology in fulfilling their missions.

Taken collectively, the material in Chapters 3, 4, 5, and 6 present strategic options for TMC managers that will enable them to take advantage of technological change. It is our expectation that readers of this report will be able to better recognize trends and associated strategies that align with their agency program goals and budgets, while also benefitting the transportation community as a whole. A final checklist is provided to TMC managers in Chapter 6 with recommended actions for using the report materials.

Chapter 1
Introduction

1.1 Background

(Source: Parsons Brinckerhoff)

The rapid advancement and proliferation of technology continues to present TMC operators with both great challenges and great opportunities. Already, most TMCs have developed from primarily having a monitoring role into one requiring much more decision-making and proactive control, often involving multiple agencies and jurisdictions. While this has yielded significant benefits, the expectations of the public and of the funding agencies are only expected to increase while at the same time vehicle miles traveled will increase without significant physical capacity increases and funding for transportation will stagnate or decline. Intelligent Transportation Systems (ITS) are increasingly being tapped as cost-effective strategies. Diminishing resources will be monitored carefully so performance measurement will be a critical component in justifying effective TMC operations programs.

The context of this report is the many larger societal and technological trends that have implications to TMC operations, oftentimes driving the ITS trends and strategies described in Chapters 3 and 4, respectively. These big picture influencers are described in Chapter 2.

1.2 Report Objectives

This report stems from a need recognized by the Pooled Fund Study (PFS) members to better understand the trends and opportunities that will affect them, especially in the area of rapidly evolving technology. The objective of the report is, therefore, to identify and analyze potential impacts on TMC operations due to technology advancements in the next 10 years, and to suggest successful practices and strategies for TMC managers to best position themselves for maximum benefit.

To cover that objective over the 10-year technology horizon of the report, this report includes:

- Cutting edge practices already showing success for early adopters that can be spread;
- Insights into emerging technologies; and
- Ways that TMC operators can position themselves now to handle advances that we cannot yet predict.

This report, and future accompanying resources, will also be the basis for an outreach webinar.

1.3 Report Organization

This report covers a broad range of interconnected material. The structure below has been designed to present it logically if reading cover to cover and also if looking for specific information.

1.3.1 Chapter 1: Introduction

Chapter 1 provides the background, focusing on big picture influencers, as well as objectives and report organization.

1.3.2 Chapter 2: Literature Review

Chapter 2 provides a brief synopsis of the literature review.

1.3.3 Chapter 3: Top Trends and Issues of TMC Operation

Chapter 3 describes each of the top trends and issues of TMC operations that were developed in accordance with the report's objectives based on the literature review and expert input, including the direction of the PFS members. They are listed in Figure 1.

Figure 1: Top Trends and Issues of TMC Operations

(Source: Parsons Brinckerhoff)

1.3.4 Chapter 4: Successful Practices and Strategies for TMC Managers

Chapter 4 presents 80 strategies that TMC managers can consider using to help them address the top 8 trends identified in Chapter 3. Many of the strategies address more than one of the top trends, but they are presented in groups by the trend they most directly address. For each strategy, a description, considerations, successful practices, key resources, and related trends are presented as applicable.

1.3.5 Chapter 5: Program-Level Implementation and Integration

Chapter 5 provides information that TMC managers can use to implement program-level changes that will enable them to take advantage of changing technologies to improve their operations. The

recommendations, in the form of discussion, tools, and checklists, are categorized by:

- Technological and internal processes that can typically be influenced directly by the TMC manager, and
- Coordination of TMC processes within the broader organizational context.

1.3.6 Chapter 6: Summary and Conclusions

Chapter 6 provides a summary and conclusion for this work. It includes the TMC Manager Programmatic Checklist of Recommended Actions. It is designed to guide managers in using the content of the report.

1.3.7 Chapter 7: References

Chapter 7 serves as a bibliography for the report and a listing of useful references.

Chapter 2
Literature Review

The basis of knowledge and understanding of what ITS technologies are emerging and their associated influencers came from a review of published literature from ITS industry publications, association websites, governmental websites, technology journals and various reports.

Additional information gathering from external sources included brainstorming discussions with the subject matter experts on our consultant team, talking with TMC managers and input received from a project-related webinar with PFS members and at the TMC PFS Annual Meeting. Talking with the TMC managers was most helpful in getting their views and perspectives on current issues and technologies that could provide opportunities or that they are positioning themselves for implementation, along with any techniques they have used in the past for successful implementation.

The significant amount of related literature found during the review period led to identifying numerous issues and implications. Many of the concepts raised during the preparation of this report are interrelated.

2.1 Big Picture Influencers

(Source: FHWA)

Many larger societal and technological trends have implications to TMC operations, oftentimes driving the ITS trends. At the most overarching level, the proliferation of **mobile communications** is revolutionizing many aspects of our lives. Mobile communications can generate large volumes of data used by TMCs, transmit that data almost instantaneously, allow travelers to access TMC-generated information almost continuously, and even provide more convenient platforms to monitor, test, and maintain field devices and other TMC equipment. The advances in mobile communication are based on the technology advances in mobile communications networks, advancing from third generation (3G/GSM) to fourth generation (4G) technologies in 2011. The bandwidth and speed enhancements of each new generation of the mobile network are significant. The next generation (5G) will provide another increase in capabilities, likely geared toward intelligent networks that can handle billions of connected devices and remain stable and reliable. A closely related influence is the rise of **social media**. The public is beginning to expect personalized two-way communication that they can interact with, not only from commercial enterprises, but from their

governments as well. Overall, **computing** continues to advance, such as sophistication in analysis and prediction for decision support systems and **automation tools**, ability to process massive amounts of data from varied sources extremely quickly, and potential to function and store information in a distributed cloud environment.

Another general influence is changes to funding opportunities. As capital budgets shrink, there will be increasing emphasis on **systems management and operations** over traditional construction projects. While this generally favors operations, it may be increasingly difficult to fund ITS system expansion, especially in areas where ITS infrastructure construction has been integrated with major roadway work. Funding is also increasingly being tied to **performance monitoring and management**. While there are established measures for things such as pavement roughness, TMC systems may need to identify appropriate measures of effectiveness for such amorphous things as driver satisfaction over "tweeted" construction updates. Also, even when data is collected on output measures (such as number of service patrol stops) and outcomes (such as travel time reliability and incident duration), those performance measures are not always used to report system performance or to manage the operations of agencies.

New funding sources will also be necessary to replace shrinking gas tax revenues. Not only are vehicles becoming more efficient, but also alternatively fueled vehicles reduce the correlation between vehicle miles traveled and gas consumption. Raising gas taxes is also politically unpalatable in most locations. One potential method of generating revenue is **pricing**, which includes both traditional fixed rate **tolling** and other applications such as congestion pricing zones. TMC systems may be integrated with the payment systems and variable toll displays, increasing requirements for system reliability and security.

Vehicle-based systems are also on the horizon for influencing TMC operations. Car manufacturers, governments, and research institutions are collaborating on a range of **connected vehicle technologies**. The vehicle-to-infrastructure initiatives, such as Road Weather Management, are most likely to just begin to influence TMC operations within the next 10 years. Factory-installed vehicle sensors that continuously collect data on vehicle conditions such as headlights and windshield wipers, along with measurements on ambient temperature, pressure, and humidity, will provide accurate and real-time information to help TMCs reduce the number and severity of weather-related traffic incidents. The manner in which drivers and vehicles interact with the roadways could begin to change near the end of the 10 year window, as various levels of **autonomous vehicle technologies** begin to get introduced and "super cruise control systems" and other robotic technologies gain market penetration. Finally, the proliferation of technology resident and carried into the vehicle has set up a scenario where **distracted driving** will likely continue to be a concern.

Primary groupings of the technology trends (in no particular order) are as follows:

- Data and Communications;
- Connected Vehicle;
- Agency Processes;
- Control Technologies; and
- Traveler Information.

Highlights of each category are described in the sections below.

2.2 Data and Communications Category

Within the data category, a major trend is the rise of third-party involvement in ITS data. Third parties not only provide a wide and varied stream of data to TMC operators, they also consume data provided by TMCs for their own applications and distribution channels. This requires defining institutional responsibilities for the public and private sectors, such as requirements for quality control of data. In the longer term, the involvement of third parties in the traditional TMC roles of collecting and distributing data may lead to a shift in focus of TMC operations to a more exclusive traffic management role. However, TMCs will need to continue collecting data that is not of commercial interest, such as vehicle volume and weight data used in pavement and bridge management. A common theme in ITS data is the need to process, manage, analyze, validate, display, share, and store the increasing diversity, content, and coverage of data streams, including those representing the driver perspective. As multi-sourced data is made available and shared across agencies, the need arises for increased data storage and archiving capability. A potential solution is to rely on cloud servers for data management. Eventually, high-capacity, low latency, mesh or wide-area networks will provide virtually ubiquitous coverage that could be leveraged by TMC operators and others to collect and distribute data. With the development of next- generation wireless networks comes the opportunity for efficient data transfer and increased geographic coverage of rural freeways and arterials.

2.2.1 Key Development: Increasing involvement of private third-parties in ITS data

As third-party vendors continue to provide traffic data and distribute more traveler information, the TMC role may be focusing more on traffic management and less on travel information distribution directly to the public. More consideration of the relationship between the public and private sectors will be necessary, such as if the public sector has responsibility to review or vouch for data provided to third parties.

2.2.2 Key Development: Increasing diversity of sources, coverage, types, and quantity of data (including from third-party sources)

Implications include the need to process, manage, analyze, validate, display, share, and store data. Developments in communications, both ubiquitous private sector low-latency mesh coverage and connected vehicle, should lead to virtually inexhaustible data supplies. Advances in solar power and battery technology coupled with wireless communication enable much less expensive installation of roadside devices; Power over Ethernet (PoE) also simplifies wiring. Many of the new data sources will be from the traveler perspective. TMCs will need to manage the incoming raw data to provide operators with enough, but not too much, useful intelligence to complete tasks.

2.2.3 Key Development: Developments in next-generation wireless communications

Leased wireless service, including 4G/LTE and beyond to 5G, will provide increasing data rates, geographic coverage, and network control features. 5G networks will likely focus on intelligent networks, which will make communicating with a large number of field devices and mobile devices more stable and reliable. TMCs should be aware of spectrum allocation and increasing interference in some bands.

2.2.4 Key Development: Increasing coverage of rural freeways and arterials

Implications to TMC operations include opportunities for additional operations coverage with additional operator responsibilities, including traffic signal system management and more interfaces with local agencies. This could also provide an opportunity for TMCs to access private sector data on rural corridors. There is not a need for information as precise as in the urban areas for urban applications. However, there is a need to know any major slowdowns or impacts, or be able to align congestion/queues on rural corridors with incident information will help organizations react appropriately.

2.3 Connected Vehicle Category

Trends in connected vehicle technologies that specifically affect TMC operations are more likely to be seen in Vehicle-to-Infrastructure (V2I) communication (and not as much with vehicle-to-vehicle communication). With the rapidly increasing ability of next-generation wireless networks, satellite radio, and Dedicated Short Range Communication (DSRC), the way in which drivers, vehicles, and the roadway each interact is changing rapidly. During the next 10 years an increasing number of vehicles will be able to serve as moving data probes that provide real-time information on instrument diagnostics, traffic conditions, and changing weather patterns. This more robust

collected data will be valuable to TMCs for managing roadway incidents as well as in providing more accurate travel-time information. As automakers become increasingly aware of drivers desires to stay continuously connected to the world and their social environment, they are designing flexible built-in interfaces that will support a variety of external mobile devices that are brought into the vehicle. The ability for seamless integration between the vehicle and personal mobile communication devices will open the door for third-party application developers to create new innovative traffic applications that will communicate important traffic safety information and traveler updates directly to the interior vehicle display.

In late 2013, the National Highway Traffic Safety Administration (NHTSA) is expected to make a "recommendation" on the future of connected vehicle technologies, which could result in federal regulations imposing a timeline for automakers to install connected vehicle communications technology in vehicles. However, until such a decision takes place, the future of connected vehicle technology implementation rests largely on market forces and whether or not a significant "pull" emerges from consumers. During the next 10 years, there is anticipation that something will change from what we have today, and most likely it will begin with applications being developed that consumers perceive as beneficial either from a safety, information, convenience, or entertainment perspective. Those applications could come from automakers, mobile device providers, and/or third-party vendors. However, the rapid advancement of the "App" isn't going to end with the current state-of-the-practice, which leads to deducing that additional applications will become available.

While the uncertainty surrounding vehicle-to-vehicle communication and hand-held device communications continues to percolate, so too does uncertainty surrounding vehicle-to-infrastructure communication with no current regulatory or legislative demands on the horizon. Left to their own schedule, will road management agencies (state, county, municipal) perceive enough benefit to warrant the installation and operations/maintenance of road side communication devices compatible with in-vehicle communication devices? Will the roll-out confine itself to urban applications predominantly? Will the many questions surrounding data ownership, consumer privacy, and legal/ liability be answered during the next 10 years?

For the purposes of this project, assume that during the next 10 years agencies will begin to see implementation of connected vehicle communications and applications, but not on a widespread or nationwide basis during the 10-year window.

2.3.1 Key Development: Seamless integration between vehicle and personal Smartphone and other mobile communication devices

Although widespread adoption is expected to be at least 10 years in the future, implications to TMC operations from seamless integration between vehicle and personal communication devices include a change in operations dealing with the resulting new and expanded data sources. TMCs will need to incorporate capabilities that allow them to utilize new concepts for third-party traffic-related application development that relays information through in-vehicle displays or through in-vehicle or mobile device applications. As mobile communication devices shift mode to mode with the traveler, the amount of data collected and aggregated will lead to an increased focus on integrated multi-modal operations.

2.4 Agency Processes Category

Good agency processes will facilitate the ability to leverage opportunities, whereas shortsighted or shackling processes will allow external influences to hamper the ability for agencies to operate effectively. Funding, and the ability to get funding, is a key way to allow agencies to leverage opportunities. Performance measurement is an important process that allows TMC managers to know how they are performing so they can improve their performance. It also sheds light on the beneficial things TMC managers do so they can more effectively position themselves for funding. The proliferation of data described above is a resource for measuring many aspects of operations performance.

In general, governmental budgets are expected to be stable or shrink over the next decade. As new decision makers, such as investors, bonding agencies, and private sector operators and providers, are added to the picture, TMC managers will need to understand and manage occasional competing priorities, which may include revenue versus traffic management. TMC managers may also be directed to implement innovative funding mechanisms such as tolling and pricing as well as public-private partnerships. Public-private partnerships can include outsourcing TMC operations for operators and maintenance staff as a way to reduce cost and enhance existing services like remote-access capabilities. Private partners can be responsible for the technical and organizational issues that go with inter-agency data sharing while TMCs can assist with the quality assurance aspect.

Another way to potentially increase effectiveness while reducing costs is joint operations of TMCs. This trend is an approach to resolving technical challenges including developing and integrating systems to implementing industry standard products, services, and processes.

2.4.1 Key Development: Toll and other Pricing operations in TMCs

Implications to TMC operations because of pricing programs include increased demands on travel time forecasting to support congestion-based pricing and the need for higher communications reliability to support fee collection. The philosophy on setting and managing toll rates is more proactive-predictive than with fixed or static rates. If rates are set or managed at the TMC, operators will need special training in the philosophy behind rate setting and in using the software.

2.4.2 Key Development: Accelerating ITS system design and implementation cycles

Design and implementation should aim to be service-oriented, quick, and nimble. Strategies for avoiding installation of obsolete equipment under traditional design-bid-build contracts include a "best value" procurement method, ITS-specific contracts, open and flexible specifications, use of interoperability standards, flexible ITS architectures, and adaptable software. It would be beneficial for TMCs to establish a system to define data for exchange and have a method for compensating for differences in data coding.

2.4.3 Key Development: TMC Operator and Manager Responsibilities Not Being Aligned with Civil Service Classifications

While there may be only so much influence that the TMC manager can have on agency job classifications and descriptions, the difference between the skills needed in TMC personnel and traditional agency positions is becoming a serious issue in many agencies. Part of the challenge is aligning pay scales with the actual skills and technical qualifications. There is a need to repeatedly involve agency human resources departments that are usually disconnected from TMCs and operations.

2.5 Control Technologies Category

The heart of trends in control technologies is expanding the capabilities of the TMC (operator and automated) to manage traffic. The term Active Transportation and Demand Management (ATDM) covers a mindset of being responsive to demands and conditions as much as possible, using all the tools available. As the type and coverage of data expands into unprecedented realms, equally innovative analysis and resulting control strategies will revolutionize the scope and effectiveness of TMC operations. New holistic algorithms will drive those applications.

One more emerging tool already being used in some areas is Integrated Corridor Management (ICM); multiple agencies collaborate across modes and facilities in a related network, such as parallel

freeways and arterials or a major freeway across state lines. The collaboration can take many forms including joint operations of TMCs. As communications costs fall and the range of data coverage increases, arterial management is expected to be a growth area for TMC operations. The number of Adaptive Signal Control Technology (ASCT) systems in the United States has grown exponentially in the past few years. Additional emerging trends in control technologies include Active Traffic Management (ATM) and Weather Related Transportation Management (WRTM). WRTM has recently proven useful not just in northern states subject to snow, but extreme weather such as hurricanes, wildfires, and tornadoes that unfortunately are expected to become more common as the climate changes.

Decision support systems and increased automation of TMC functions can increase the efficiency of TMC operations staff in analyzing and responding appropriately. Advanced algorithms, decision-support systems, advanced computing, and secure, high-bandwidth networking, cloud computing, and voice communications allow for the increased development of remote operator interfaces and virtual TMCs. As pressure mounts to reduce costs, technology may allow operators to be located anywhere – in a TMC, in an agency office, or at home – and still be a fully functional operator of the agency's transportation management system.

2.5.1 Key Development: Active Transportation and Demand Management (ATDM) – a mindset using a set of tools to be responsive to demands and conditions

ATDM is a philosophy of proactively managing the transportation network in real-time. A key feature is that it includes managing both the transportation infrastructure functions and the demand created by travelers. It uses real-time and archived data, with the help of predictive tools, to achieve or maintain system performance as illustrated in Figure 2. As envisioned by FHWA, it entails a cycle of implementing dynamic actions, monitoring the system, assessing the system performance, and evaluating and recommending dynamic actions.

The ATDM tools that can be integrated into this process include traditional TMC capabilities as well as emerging programs such as managed lane use, speed harmonization, and dynamic parking pricing. The ATDM mindset and its associated tools work together to advance agency goals such as efficiency and safety.

Until in-vehicle messaging is ubiquitous, which is beyond the 10-year horizon of this project, agencies will need to build, operate, and maintain significant amounts of field infrastructure to implement many of the ATDM tools.

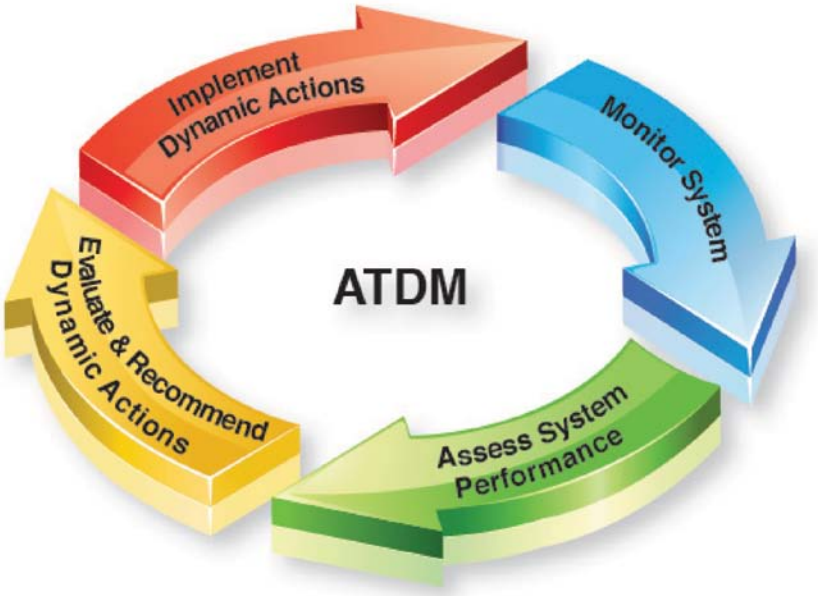


Figure 2: ATDM Approach

(Source: FHWA-HOP, 2012)

2.5.2 Key Development: Launch of Integrated Corridor Management (ICM) initiatives

ICM strategies coordinate and integrate a range of independent traffic management systems for improved monitoring and optimization of all corridor operations within a network, across regions, and state lines.

2.5.3 Key Development: Arterial management, including adaptive signal control

As software and communication costs have come down, many smaller agencies have been able to implement central software with capabilities once reserved for cities and state Departments of Transportation (DOTs) mostly on freeways. Arterial management systems rely heavily on properly trained operators. Increased coverage areas will give TMCs increased responsibilities with a greater potential for positive impact. Along with this comes an increased responsibility for managing driver expectations on arterial travel time estimates.

2.5.4 Key Development: Emergence of decision-support systems

TMCs are beginning to integrate traffic conditions, weather, and emergency information into decision support tools that aid TMC operators in determining the most effective traffic management plan. This includes an increased efficiency and accuracy when managing traffic conditions and traveler delays.

2.5.5 Automation of TMC functions

Implications to TMC operations include the possibility of a reduced need for low-skilled operator staff and improved efficiency of automated weather systems that can facilitate traveler safety when responding to special weather events.

2.6 Traveler Information Category

The single most profound technological trend in traveler information may be the explosion of social media. The individualized two-way communication presents a greatly enhanced user experience, but requires changes in the way that agencies and other information providers have traditionally operated. For example, some agencies have strict procedures involving public information officers and communications staff that would apply to social media, but not to dynamic message signs.

TMCs will need to focus on providing information that can't be collected directly by third parties such as construction, emergency response, special event, and disaster recovery information.

Another fundamental consideration for TMC operators over the next decade is their evolving role in providing traveler information. As third parties produce and distribute information, TMC operators may shift focus to areas that are not commercially viable, but still demonstrate the value provided by their agencies. TMCs will need to focus on providing information that can't be collected directly by third parties such as construction, emergency response, special event, and disaster recovery information. TMC operators will be central in providing this information to third parties for broad distribution or continuing to provide it through agency sponsored channels, such as Smartphone applications, where the information is not commercially viable or commercial interests do not distribute the information to enough populations.

TMCs will also have the opportunity to receive and integrate new user-generated data types, made available from crowd-sourced mobile data, to provide enhanced traveler information. TMC operators can also leverage technologies being developed for traveler information, such as predictive analysis and forecasting, to enable higher quality proactive management. A critically important trend is integration between handheld devices and vehicles. This integration allows rapidly changing handheld device technology to become the core communications and application platform for the vehicle. TMCs, with or without third-party collaboration, could potentially obtain vehicle probe data (not only

location, but environmental conditions output from the vehicle's own computer). TMCs could also communicate more directly with vehicles, from providing dynamic route guidance to active traffic management lane controls and speed recommendations or limits.

2.6.1 Key Development: In the future, in-vehicle applications will be provided through handheld devices that interface with the car rather than built-in systems that become outdated over the lifespan of the vehicle.

A wide variety of constantly changing third party and agency apps have the potential to reach drivers in a convenient and safe manor not constrained by the lifespan of the average vehicle. The new interfaces could include screens larger than Smartphones, heads-up displays projected on the windshield, and voice integration.

Eventually, active traffic management currently conveyed through expensive roadway infrastructure could be distributed directly to drivers, thus increasing coverage and reducing costs.

2.6.2 Key Development: Predictive analysis and forecasting

This includes the ability for TMC operations to become less reactive and more proactive and increasing the overall performance of the traffic network. Using an Advanced Traveler Information System (ATIS) allows motorists to make better travel decisions in the pre-trip or en-route stage through real-time and predictive information. This is especially useful for weather-related traveler forecasts.

Chapter 3
Top Trends and Issues of TMC Operations

The top trends and issues of state-of-the-art TMC operations were identified as the result of the expert analysis of the multitude of trends and technologies gathered in light of the big picture, impacts, and successful practices as well as feedback from the PFS members. These eight high level trends represent the key developments as well as important influences and impacts. Additional factors that influenced development of the top trends from the myriad of possibilities included the magnitude of potential impact, the frequency of citation in literature and by practicing TMC operators, and the likelihood of the issue to be widely influential to TMCs within the 10 year project horizon. Some of the trends are emerging from within the transportation community and can be spread further within it as they continue to develop. Other trends, and their related technologies, originated outside the transportation community, but which TMC operators should be aware of as they can be adapted and utilized to help meet their needs.

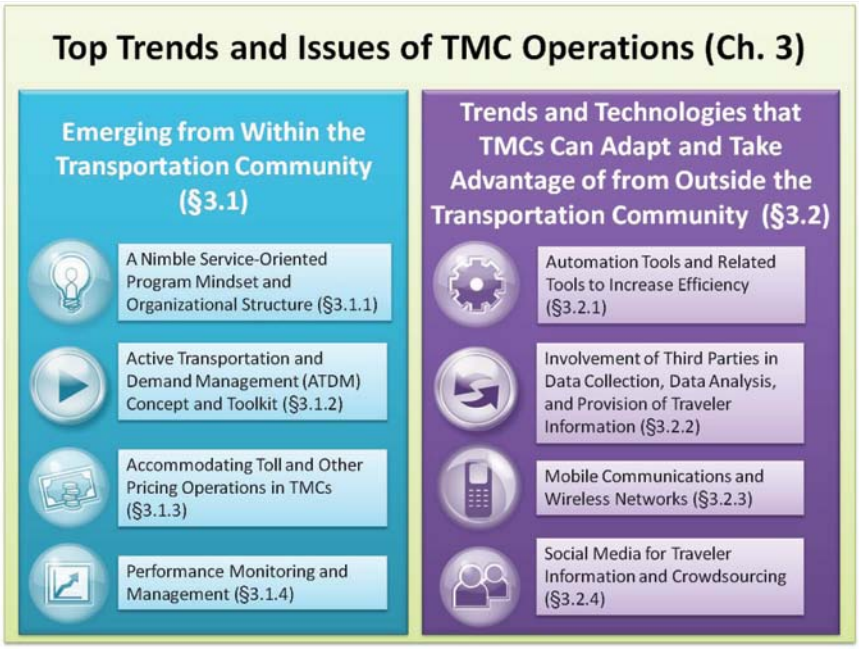


Figure 3: Top Trends and Issues of TMC Operations with Section References

(Source: Parsons Brinckerhoff)

The trends are described in Chapter 3. Chapter 4 is also organized according to trend and it provides strategies and successful practices for addressing each of the trends.

3.1 Trends Emerging from Within the Transportation Community

While there is some overlap between trends emerging within and outside of the transportation community, the four identified in this section are firmly rooted in transportation. The first trend, a nimble service-oriented mindset and organizational structure, reflects the dynamic nature of ITS within a modern transportation system. The second trend, active transportation and demand management (ATDM), includes a set of tools developed by transportation engineers, operators, and companies to support proactive transportation system management, often using emerging technology. The third trend, accommodating toll and other pricing operations in TMCs, recognizes that TMC operators need to be positioned to accommodate such a change given the increasing frequency of tolling which is expected to continue over the next decade. The fourth trend, performance monitoring and management, reflects both the increased effectiveness possible through performance management and the requirements for performance management being imposed on TMC operators by their transportation funding agencies.

3.1.1 A Nimble Service-Oriented Program Mindset and Organizational Structure

This trend is a **mindset** of being positioned to successfully select and adopt rapidly changing technologies and strategies. From literature and experience, being nimble, constantly looking for ways to improve, and embracing change are hallmarks of successful TMC operations (as well as businesses and other organizations.) This trend focuses on how TMCs can position themselves to **be able to** effectively change. Some of the other trends are examples of changes that could be facilitated by having a nimble service-oriented program.

The need for this mindset is driven by three main influences:

- Rising expectations from the public (through elected officials) for greater customer service;
- Rapidly changing ITS technology and processes; and
- Lack of funding.

The first factor manifests as a pressure placed on the TMC operators. The second represents both a pressure and a critical opportunity. Some of the new technology allows for cost-saving alternatives to traditional ways of accomplishing transportation management system goals. This can help agencies deal with the third factor.

This mindset and organizational structure will also help agencies deal with specific changes in technology that are not yet able to be forecasted.

The principles in the trend Nimble Service-Oriented Program Mindset and Organization Structure are aligned with FHWA's statement that, "Effectively addressing the congestion problem will hinge on the ability to reshape traditional transportation organizations into 21st century operations agencies using 21st century technologies." (FHWA) Facets are shown in Figure 4.

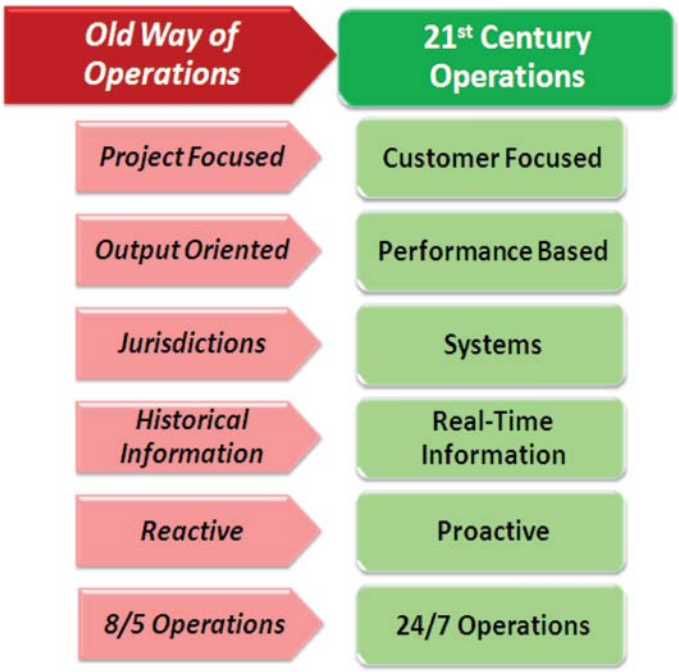


Figure 4: Changing Elements of Transportation Agency Operations

(Source: Adapted from FHWA)

The trend also includes related systems and technical approaches that agencies can include that will help them adapt to new technologies and give them the flexibility to add new technologies as they develop. For example, in the area of multi-state cooperation and operation, a nimble service-oriented program provides a platform for multiple agencies to share experiences and develop joint solutions to problems.

Specific strategies related to the trend of a Nimble Service-Oriented Program Mindset and Organizational Structure are included in Section 4.1.1.

3.1.2 Active Transportation and Demand Management (ATDM) Concept and Toolkit

ATDM is the major **outcome** of a nimble mindset and organizational structure. It uses all of the tools at one's disposal to proactively make operations more efficient, including through staff and technology.

ATDM includes a suite of concepts and tools based on a wide variety of new data types and data sources with widespread coverage using new holistic algorithms. Examples of ATDM include Integrated Corridor Management (ICM) and managed lanes. Decision support systems are part of ATDM, but in this report they are covered under the "Automation Tools" trend.

One of the underlying influences leading to ATDM is the inability to expand capacity. It leads to developing and implementing better tools to manage the system in a coordinated fashion.

The FHWA groups ATDM approaches into demand-side, traffic, and parking areas. Some example approaches for each approach are shown in Figure 5.

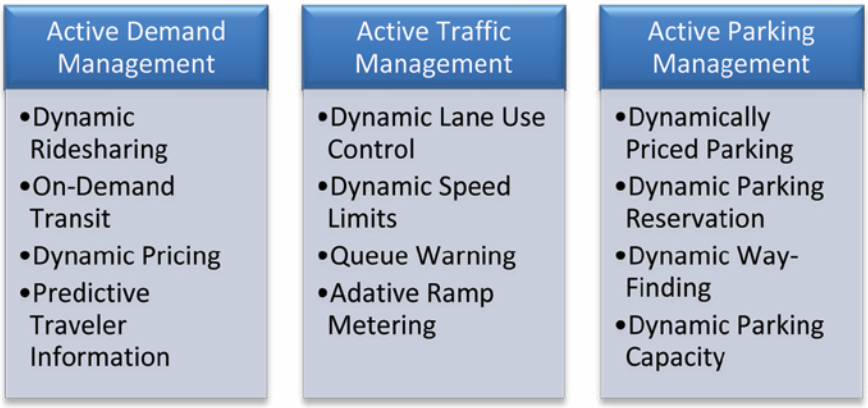


Figure 5: ATDM Areas with Example Approaches

(Source: Adapted from FHWA, 2012)

As the report focuses on approaches that are directly related to TMC operations, many of them are under the Active Traffic Management category. See individual ATDM strategies in section 4.1.2.

3.1.3 Accommodating Toll and Other Pricing Operations in TMCs

While TMC operators will have little, if any, influence on the policy decisions required to implement toll and other pricing operations, it is extremely likely that they will be affected when decisions are made to add tolling to facilities or to integrate operations with agencies that already toll.

Infrastructure pricing, including traditional tolling, high occupancy toll (HOT) lanes, and congestion zone pricing will also grow and may be managed from TMCs, either by agency staff, in public-private partnerships, or through outsourcing.

One influence driving the trend of accommodating toll and other pricing operations in TMCs is the limited funding from traditional sources. This encourages obtaining revenue through tolling, including financing infrastructure expansion based on the expected toll revenue stream. Another influence driving this trend is the infeasibility of physically expanding capacity in some places. Tolling can promote better management of the existing capacity, including strategically pricing it to alter behavior and funding maintenance.

The strategies for addressing the trend, accommodating toll and other pricing operations in TMCs, are in section 4.1.3.

3.1.4 Performance Monitoring and Management

Over the next 10 years, it is expected that there will be an increasing need to both monitor performance through data collection and analysis as well as to apply the knowledge to promote more efficient operations. Performance management is also becoming critical to obtaining funding.

One specific part of the trend, and general good performance management practice, is measuring ***outcomes*** instead of ***outputs*** when possible. Challenges include isolating impact of the TMC operations from other factors, especially for the performance measures that are proxies for outcomes such as safety. Some measures are more geared to tracking and improving internal performance, while others help demonstrate value to other parts of the agency, especially those who allocate funding. A key challenge is the need to identify performance measures that are strong proxies for agency goals that may not be able to be measured directly.

Two factors that have influenced this trend are the reduction in funding pressuring greater accountability and the increase in emphasis on customer service.

A promising part of the trend is that regional data sharing can provide common performance measure and enhance planning activities. Also, private sector data can support performance measures. There could also be valuable information from third-party/private sector systems that could support better TMC operations (such as user responses to operational strategies). TMCs can look for ways to be able to obtain that kind of data to support performance management objectives.

3.2 Trends and Technologies that TMCs Can Adapt and Take Advantage of from Outside the Transportation Community

The four trends identified in this section originated outside of the transportation community, but have traits applicable to traffic management and operations. The first trend, automation tools, uses new technology to assist operators in many of their daily TMC processes. The second trend, involvement of third parties in data collection, data analysis, and the provision of traveler information, includes ways that agencies can benefit from working with rapidly growing third-party providers to increase and manage data resources. The third trend, mobile communications and wireless networks, recognizes the social dependence on mobile devices and suggests ways that incorporate updated wireless technology into TMC functions. The fourth trend, social media for traveler information and crowdsourcing, suggests ways that TMCs can use popular social media tools as a means to gather and disseminate traveler information.

3.2.1 Automation Tools

Advanced computing and communications technologies will allow more automation in TMC systems. With the reduction in traditional revenues, TMCs may need to rely on automation and technology efficiencies in order to function at current levels of productivity with reduced staffing.

New technologies are continually being made available to improve system management and improve cost-effectiveness and greater productivity. Advanced software programs and better traffic data from a wider set of integrated devices allow for many of the TMC operations to become automated, thus eliminating many of the tedious and time-consuming tasks normally performed by the operator. Machines are now handling some tasks such as monitoring and processing large quantities of data from different sources to make decisions on which traffic control methods to use.

Nimble and service-oriented decision support systems provide a knowledge base and options for making decisions on how best to utilize new communications technologies and improve existing tasks.

Automation tools can also improve the quality of decision support systems. Traffic device software can allow direct communication to a mobile device or traffic management tool that can archive, manage, and compare historical and real-time data for use by decision support systems. This allows for a broader range of alternatives to be added to the decision matrix for a more optimized response to both recurring and non-recurring situations that would otherwise negatively affect traffic flow. The TMC operator would have access to all the quantitative inputs in one tool upon which to make their decision.

Nimble and service-oriented decision support systems provide a knowledge base and options for making decisions on how best to utilize new communications technologies and improve existing tasks. They are designed to support operators and decision makers by taking into account a multitude of interrelated systems and providing

pre-determined responses for commonly occurring roadway scenarios, while simultaneously encouraging thought processes outside their own experience. Decision support systems are also being designed with predictive aspects, which help the TMC operator identify when certain thresholds are being crossed and thus helping operators anticipate at which times certain strategies will be most effective.

The strategies for addressing the trend Automation Tools are in section 4.2.1.

3.2.2 Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information

A third party is defined as any organization outside the agency itself that indirectly provides a service to the agency. Third parties for traffic data and traveler information can include commercial traveler information vendors, the media, other agencies, and even connected vehicles as a potential source of data.

Third-party vendors sell and provide nationwide coverage of traffic data to agencies, under the Data-as-a-Service (DaaS) model. Agencies use this data to manage traffic on their roadway network and deliver traveler information to the public. Data is mapped to a GIS reference system, with speeds and travel times being the most common forms of data provided. Third parties utilize a variety of data sources such as agency-owned roadway sensors and Closed Circuit Television (CCTV) cameras; Global Positioning System (GPS) and Bluetooth systems installed in commercial devices, Smartphones, and fleet vehicles; and historical traffic counts obtained from agencies. Third-party providers collect and process large amounts of real-time data as discrete, individual sets from specific sources which can then be sold as discrete or aggregate data packages to individuals or other organizations, including agencies. It is often the responsibility of the agency to validate the quality and accuracy of the data.

TMCs rely on a variety of data types for traffic management and traveler information. Some of the data collected from agency-owned devices and computer algorithms include real-time speed, volume, and occupancy data; travel time estimations; and live CCTV video feeds. There is a little overlap in the types of data that third parties generally provide, including real-time speed and travel time data, but they can also provide greater coverage and historical data from their own stored data sets. TMC managers will need to assess the agency's data needs, look to what third-party providers are offering to supplement or replace the agency's resources, and devise a plan for collecting data not offered by third parties but that is still a necessity for TMC operations. This may include devices installed and owned by the agency or a combination of third-party owned and agency owned devices. These devices may also collect other data.

Although the amount and types of data provided by third parties is vast and comprehensive, there may still be other types of data that may be uniquely developed by or needed by TMCs that will become significant to traveler information over the next 10 years. Construction events such as emergency closures and on-going or future construction closures that affect travelers come directly from the TMC. Third parties many not factor delays associated construction impacts in their travel time estimations. Axle loading data will be an important data set for agencies to receive as they budget for future roadway improvement and pavement preservation projects.

In order for agencies to remain nimble, they must plan for contingencies with third-party providers in case operations budgets don't allow for third-party data or third-party providers stops providing needed data.

Third-party data providers that use primarily vehicle probe-based data include INRIX, NAVTEQ (product of Nokia), and AirSage. Third-party providers that use infrastructure, field-based equipment include BlueTOAD (product of TrafficCast), Digital Traffic Systems (DTS), and SpeedInfo (Athey Creek, 2012). Agencies need an efficient way of storing and managing all of this new data and are turning to cloud service providers (CSPs). A few of the top CSPs include Microsoft Windows Azure, Cisco, GoGrid, and Rackspace, to name a few (Athey Creek, 2012).

There are a few important factors to consider regarding the use of third-party data, which is often stored on a cloud server, and third-party developed mobile applications, including data coverage, formats, validation, intellectual property, security, and storage. Third parties often fill the gap in areas where agencies are lacking data coverage, and have capabilities for regional or national coverage. The diversity in data formats may require further processing on the agency side before it is in an open, useable format. Data validation techniques of third party data become the responsibility of the agency to perform through cross-data matching with other technologies, such as GPS or AVI. Data from third-party vendors remains the property of the vendor and an agreement on data sharing outside of designated traveler information purposes is recommended if the agency plans on coordinating this information with other agencies. Third party applications use encrypted data stored on their server and authentication tokens for data access from the server to the mobile device, guaranteeing that everyone viewing the data is authorized and data remains secure.

Cloud computing is a new business model that offers the flexibility and cost efficiency agencies need, through leased power, storage, and bandwidth, to supplement their data center, expand their resources, and deliver quality performance under tighter operating budgets. CSPs are effective at offering agencies high-availability architecture that makes the cloud server available 100% of the time from anywhere there is an internet connection. Resource needs are scalable which eliminate the need for increasing size of hard drives. Organizations such as the Cloud

Security Alliance (CSA) offers certification to cloud service providers that are in compliance with their management and configuration practices. Concerns over data security and ownership are addressed in (Jansen & Grance, 2011) and (NIST, 2009) that agencies can refer to when considering using the cloud.

Agencies must plan for contingencies if cloud storage is used to make certain that data archiving will meet the long term needs of the TMC. Some CSPs, such as Amazon Glacier, offer an archival service that is low-cost, long-term, complete with data encryption, multisite redundancy, and regular data integrity checks. Data retrieval isn't as instantaneous as if the information was stored in an on-site server room and agencies should be cautious of the cost and frequency of retrieval requests.

The availability of private sector resources that were previously available only on the public side, such as displayed travel times on DMSs, leads to a competition between third parties to provide the same service at a potentially lower cost and at a higher quality.

The strategies for addressing the trend Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information are in section 4.2.2.

3.2.3 Mobile Communications and Wireless Networks

Mobile communications can generate data used by TMCs, transmit that data almost instantaneously, allow travelers to access information almost continuously, and provide more convenient platforms to monitor, test, and maintain field devices and other TMC equipment. Specific wireless technologies that will influence TMC operations include:

- Continued deployment of 4G networks,
- Development of the next generation (5G) in wireless communication (based on historic trends there is a 10 year cycle of developing and implementing new generations of mobile communications to 5G would not be expected to be prevalent until 2020),
- Increases in coverage areas, particularly in rural areas, and
- Overall system capacity increases in bandwidth.

Agency-owned wireless communication in the past has been transmitted over relatively low radio frequencies. Advances in technology are giving agencies options when it comes to modernizing their field equipment and increasing their data coverage while not overloading the system. The initial investment in the purchasing of wireless-capable devices, wireless infrastructure, and bandwidth is less than what it would cost to expand a fiber backbone but TMCs will have to commit to long-term maintenance and operating costs.

Agencies can benefit from data obtained through leased wireless service agreements between other agencies or with commercial providers. Leased wireless equipment can be installed on agency or third party property, with the wireless devices operated and maintained by others. Many agencies have leased wireless and wireline communication paths.

New technologies are continually being made available to improve system management and coordination with other agencies. Advanced transportation management technologies include wireless traffic signal systems connected to an agency's wireless network that allows TMC operators to view collected traffic data and use it to analyze and adjust signal timing in real-time, addressing immediate congestion and improving traffic flow. Data can be collected wirelessly from CCTV cameras, detectors installed in the roadway or mounted on other infrastructure, and even toll-tag readers. Adaptive signal coordination also benefits arterial operations across jurisdictional boundaries, such as at freeway ramp intersections, and along an arterial. An example is New York City's technology-based traffic management system called Midtown in Motion.

The private sector has seen a significant increase in mobile application developments and wide implementation across popular mobile software platforms that allow users to view traffic conditions in the palm of their hand. Third party involvement can help guide agencies in the best use of Smart phone applications and in the creation of a customized application. For example, application add-ons are much more cost effective than adding another menu option to a 511 service and it has a much higher impact with users.

The strategies for addressing the trend Mobile Communications and Wireless Networks are in section 4.2.3.

3.2.4 Social Media for Traveler Information and Crowdsourcing

Social media, such as tools like Twitter and Facebook, allow targeted, real-time two-way communication among and between agencies, travelers, and third parties. This opens great possibilities for TMCs to both receive and distribute information.

There are several platforms in use by agencies to share information via social networking tools; however, social media tools, like many technologies used by agencies, also are evolving. Agencies also are changing the way they use these tools in response to public interest and feedback received on their social media, in terms of keeping content updated, providing more dynamic information, and even in response to comments about certain DOT policies. These tools allow DOTs to explain to the public why and how the DOT does what it does.

A September 2012 *State DOT Social Media Survey* by AASHTO indicated that Twitter is the most used social media tool as reported by those who responded to the survey, with 88% of respondents indicating they use Twitter to share information (AASHTO, 2012). Twitter is used for real-time notifications such as crashes, closures or major weather impacts to the road network, and several states also use this tool for "softer" announcements such as public service messages, project and meeting announcements. In addition to Twitter, 76% of states responding to the AASHTO social media survey (32 or 42 states) indicated they use Facebook for project information, feature stories, and as a customer service tool. Several reported that they are integrating more multimedia, video and photos, which are valuable education tools about real-world DOT activities and allow a more personal connection with projects or programs.

There is an underlying trend toward greater emphasis being placed on customer service with agencies making more and better use of social media and networking, coupled with greater demands for information and customer service because of the availability of informational tools.

While platforms like as Twitter, Facebook and video (such as YouTube or Vimeo) are growing in popularity; some tools have started to decline in usage, such as LinkedIn, blogs or podcasts. This is indicative of the rapidly evolving social media marketplace and user interest and activity. Agencies that can react to the changes in social media demonstrate their ability to be nimble and search for ways to stay connected in the most effective ways possible. Emerging tools include Pinterest, an electronic bulletin board, or Storify, which is one of the newest social media tools that actually integrates multiple other social media feeds (such as Twitter, video, Facebook and others) into a single story. Iowa, North Carolina, and Washington DOTs are early adopters of this emerging platform.

These tools provide a mechanism to distribute information to users, but they can also be used to provide valuable information from and about users to transportation agencies, such as:

- Pins, hits, likes and retweets – what information or types of information is being endorsed or getting re-distributed by users, and how does that influence what kinds of information the DOT will share?
- Real-time vs. non-real-time information activity – the response by users to real-time information about impacts or events on the network.

Approaches to social media applications vary; some TMCs have implemented processes for operators to be able to utilize these tools while other DOTs have tightly controlled social media messages sent through their PIO/communications staff. To actively integrate real-time social media into real-time TMC operations will require new processes for the TMC operator to actively monitor various social media feeds.

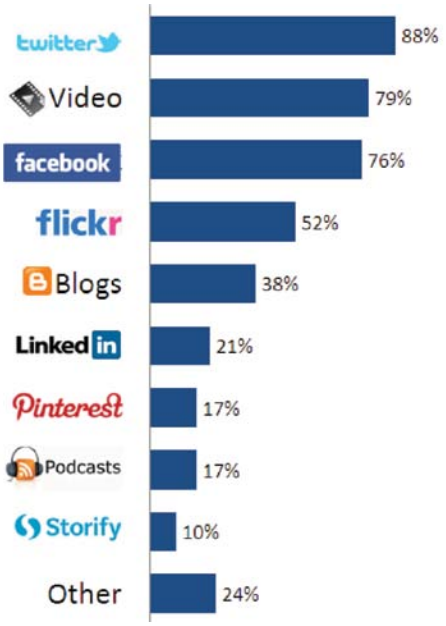


Figure 6: Percentage of 41 States and DC Using Social Media Tools in 2012

(Source: Adapted from AASHTO, 2012)

There is an underlying trend toward greater emphasis being placed on customer service with agencies making more and better use of social media and networking.

This could be accomplished via a new position or dedicated resource, which may not fit within the current DOT resource model. The value of this information and its impact on TMC operations will likely be assessed in the coming years to determine viability of this approach and resource allocation.

TMC managers will need to find a way to link social networking activity regarding traffic and road conditions and the actual impact on the network. A challenge is that many social media "pushes" are not actively monitored in real-time by DOTs or TMCs. TMCs would need to establish new processes for how to manage that flow of information IN to the TMC.

Crowdsourcing has the potential to significantly influence TMC operational strategies. However, the operational strategies should include ways to figure out how to verify and integrate this user-generated real-time content.

An important challenge is validating and verifying information received from social media. As a matter of policy for many TMCs, verification requires TMC operator visual confirmation, DOT field verification or other "trusted source" such as law enforcement.

During peak congestion periods or incidents, a future strategy can be to correlate social networking activity (for example, re-tweets or Smartphone app use) with transportation network conditions. Some correlation is done today by some TMCs that are able to monitor 511 web and phone usage. However, there would be many more channels of correlation available if social media was also used. Crowdsourcing has the potential to provide rich context to agencies about how users are responding to information they receive, and the real-time impact that their response has on the transportation network.

The strategies for addressing the trend Social Media for Traveler Information and Crowdsourcing are in section 4.2.4.

Chapter 4
Successful Practices and Strategies for TMC Managers

For each of the eight top trends described in Chapter 3, there are many specific strategies and technologies that TMC managers can consider to position themselves to address the resulting operational changes. This chapter identifies 80 individual strategies and provides introductory information on each, including successful practices and key references where appropriate. In recognition of the underlying influence of diminishing funds, extra emphasis is placed on strategies that are especially low cost and/or cost effective. The strategies were derived from the literature review as well as the expertise of the consultant team and the TMC PFS members.

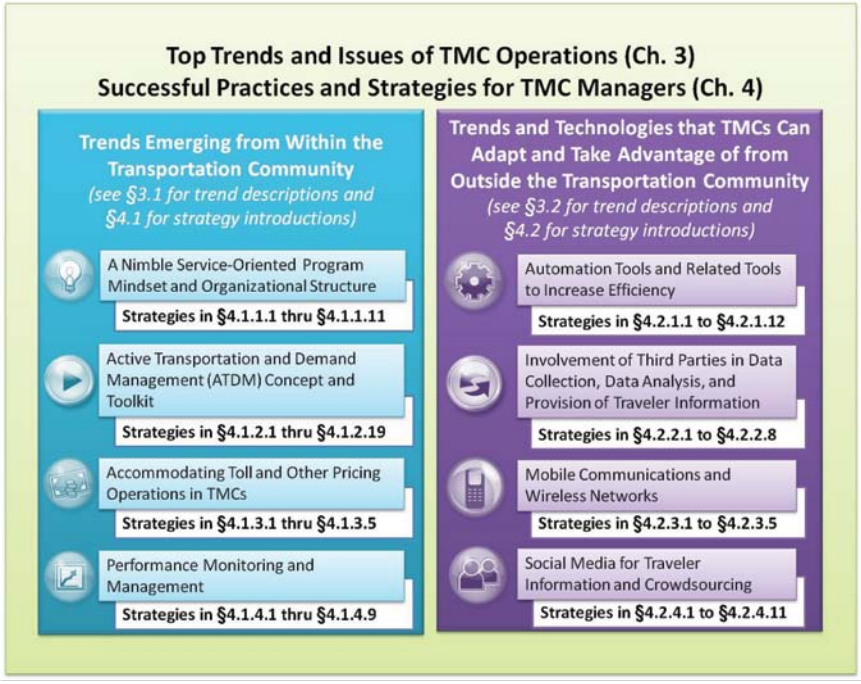


Figure 7: Relation of Chapter 3 to Chapter 4
(Source: Parsons Brinckerhoff)

To facilitate organization of strategies to address trends, a single primary association was identified between each strategy and one of the top

trends. That primary association is used to categorize the strategies by trend in sections 4.1 and 4.2 below. Therefore, both Chapters 3 and 4 are organized by trend. However, Chapter 3 describes the top trends themselves while Chapter 4 focuses on the strategies that the TMC manager can use to address those trends. Figure 7 above graphically reiterates this relation and provides the strategy numbers by trend for reference.

At the end of each strategy section, there is a list of secondary associations between the strategy and any of the other top trends.

Section 4.3 includes a table cross-referencing the 80 strategies with the 8 top trends by their primary and secondary associations. The table also highlights the associations with the highest potential to be feasible under a limited budget.

4.1 Trends Emerging from Within the Transportation Community

4.1.1 A Nimble Service-Oriented Program Mindset and Organizational Structure

The strategies in the following subsections are specific steps that TMC managers can consider for developing a nimble service-oriented program mindset and organization structure that will help them to adapt to changing technologies, expectations, and resources over the next decade.

The nimble mindset can permeate throughout most aspects of TMC operations as demonstrated by the successful practices with specific strategies below. Another example is the TIME Task Force in Atlanta, which uses the nimble mindset to promote faster response to incidents and events.

Embracing social media is a key part of a service-oriented mindset; it is covered in the top trend on social media.

4.1.1.1 **Strategy**: Foster an Agency Culture of Embracing Technological Change

Managing any kind of change, especially technological change, can be painful. There can also be a tendency for past problems to serve more as deterrents than as lessons learned. Fostering a culture of embracing technological change builds on concrete steps such as:

- Involving both operations and maintenance staff in evaluation of potential new technologies;
- Implementing a technology testing and piloting program;

- Supporting staff training and time to build familiarity with new technology;
- Establishing relationships with related departments within the agency, such as information technology, for consultation;
- Establishing relationships with peer agencies embracing technological change;
- Maintaining on-call contracts for experts outside the organization to assist with integration and trouble-shooting when needed;
- Highlighting the successes and efficiencies generated by technological change across the organization;
- Recognizing that not every well-planned technological change will be successful;
- Identifying staff enthusiastic about technology to serve as champions;
- Developing flexible procurement processes, including those for test equipment;
- Developing flexible performance-based specifications where applicable;
- Including training and support with new technology purchases; and
- Seeking feedback from TMC operators and field maintenance staff on existing deployed technology as well as areas they think could benefit from new technology.

Related Trends: Automation Tools and Related Tools to Increase Efficiency; Social Media for Traveler Information and Crowdsourcing

4.1.1.2 **Strategy**: Create a TMC Operator Training Program

While a regular TMC operator training program does require staff time, it has the potential to increase operator comfort and effectiveness, especially with new technology, and to serve as a forum for discussing the operator feedback on processes and technologies.

Recognizing the importance of “hands-on” training and the difficulty of getting emergency responders from disparate agencies and locations together for central training, the I-95 Corridor Coalition sponsored the development of an interactive simulation training that enables participants to role play from their home base via the Internet. The I-95 Corridor Coalition is an

alliance of transportation agencies, toll authorities, and other organizations from the Maine to Florida, which provides a forum for key decisions and policy makers to address common transportation management and operational issues. More information is available at http://www.i95coalition.org/i95/Projects/ProjectDatabase/tabid/120/agentType/View/PropertyID/310/Default.aspx.

The Arizona DOT (ADOT) is an example of a successful TMC certification program.

Related Trends: Active Transportation and Demand Management (ATDM) Concept and Toolkit; Automation Tools and Related Tools to Increase Efficiency

4.1.1.3 **Strategy**: Enhance Operational Communication, Which Will Promote a Culture of Open Communications Among Staff

This strategy includes shift change briefing and event debriefing along with better communications on specific events, as well as bigger picture communications among agency operations staff and potentially staff from other partners.

Related Trend: Performance Monitoring and Management

4.1.1.4 **Strategy**: Develop Memoranda of Understanding (MOUs) and Inter-Agency Agreements Facilitating Multi-Agency (sometimes Multi-State) Cooperation & Operations

Current operations activities usually require coordination and cooperation or even integration of operations with other government agencies or private vendors. Whenever agencies work together it is important that the roles, responsibilities, limitations, and liabilities are written down and agreed to by the participating parities. The creation of MOUs or agreements will help settle potential future disagreements, define agency roles, set up responsibilities for funding and staffing operations activities, and define the acceptable uses and procedures for sharing data or resources.

For additional successful strategies in MOUs and related agency agreements, including provisions for a common understanding of how to operate across modes and jurisdictions, consider consulting the

Denver Regional Council of Governments/Colorado Department of Transportation or the Atlanta Regional Traffic Operations Program.

There are many operations activities that benefit from having MOUs or agreements in place as the activity is initiated, such as:

- Data management/archiving;
- Data sharing;
- Incident management protocols and roles;
- Private vendor data collection;
- Traveler information dissemination;
- Use of data/traveler information by media;
- Roadway Incident management practices;
- Emergency operations;
- Ramp metering; and
- Inter-jurisdictional signal timing.

Most recently, the focus of the I-95 Corridor Coalition in the incident management area has been on quick clearance practice, promoting state legislation and good practice. More information is available through:

http://www.i95coalition.org/i95/Projects/ProjectDatabase/tabid/120/agentType/View/PropertyID/325/Default.aspx.

Related Trend: Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information

4.1.1.5 **Strategy**: Create New Technology Piloting and Testing Program

A program of testing and piloting new technologies can reduce the risk associated with implementing new technologies. TMC managers can start by creating a pilot plan that identifies objectives, participants, deployment schedule, and evaluation period and begin testing in a controlled environment in which operators perform their normal tasks using the new technology. This demonstrates that the technology works as expected and adds value to TMC functions. Evaluating the pilot and gathering feedback from the operators will allow TMC managers to fix any problems and issues that arise through testing and will allow for minimizing risk during full scale deployment. It often requires staff and capital

investment but can generate good returns. Consult peer agencies with experience in new technology and visit them when possible. Check with agency policies before investigating opportunities to borrow equipment from manufactures for evaluation.

Related Trends: Active Transportation and Demand Management (ATDM) Concept and Toolkit; Automation Tools and Related Tools to Increase Efficiency; Mobile Communications and Wireless Networks

4.1.1.6

Strategy: Develop Skill Sets of TMC Managers in Areas of Contracting, Privacy, Security, and Intellectual Property

TMC managers must understand privacy issues and be able to both manage data properly and develop contracts that protect the privacy of collected data, regardless of whether that data is collected through private vendors or by mobile communications.

Contracting for operations activities is quite different from traditional DOT design and construction contracting. In the operations world, contracting is often for services such as staffing, collecting data, or development of software. These activities often use new, different contracting methods and include issues not traditionally applicable to DOT contracting (for example, privacy, security, and intellectual property). Privacy issues are related to uses and dissemination of the public's personal data. As the ITS industry was being developed over the past 20 years, privacy of collected data has been a deal-breaker issue. The public has indicated through several lawsuits and passing of state and national laws that the use of all personal information must be anonymous and undiscoverable. TMC managers must understand these issues and be able to both manage data properly and develop contracts that protect the privacy of collected data, regardless of whether that data is collected through private vendors or by mobile communications companies. Along with privacy, security of collected data is an important issue. All public entities are subject to security breaches and transportation data is also vulnerable to hacking. Transportation management systems can be targets for terrorist attacks designed to create public chaos. TMC managers must understand security issues and include security features when contracting for software, managing data systems, and interfacing with toll collection systems. In the software world, including transportation management software, intellectual property issues are also important to TMC managers. When software is being purchased (off-the-shelf or developed), the contractor will likely insist on maintaining intellectual property rights to the software code. Understanding those rights and what issues can be compromised are important in developing contracts with the software vendor.

Related Trends: Accommodating Toll and other Pricing Operations in TMCs; Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information; Mobile Communications and Wireless Networks

4.1.1.7 **Strategy**: Adopt Standards on TMC Related Equipment and Processes

For TMC equipment and ITS field equipment, standardization can be beneficial when managed thoughtfully in light of each agency's needs and capabilities. Standardizing equipment can reduce the amount of inventory needed and the number of complex items that maintenance staff needs to learn and maintain skill supporting. Standardization can also improve interoperability. However, standardization can reduce innovation if the standards don't evolve as technology evolves. ITS technology develops rapidly so even within a brand line models are often discontinued.

A few successful practices are available. One is requiring national ITS standards compliance to support interoperability. However, the standards are more fully developed for some equipment and functions than others. Also, manufacturers may offer additional capabilities when their equipment utilizes some communications elements beyond base ITS standards. When developing equipment requirements, it is important to understand what capabilities may be sacrificed to maintain complete interoperability.

Another potential way to deal with varying and rapidly changing technology is to use performance based requirements rather than more proscriptive material descriptions that are typically found in roadway specifications. This may require discussions with other parts of the agency that control procurement processes.

For TMC processes, an example of standardization is the Virginia DOT's statewide TMC RFP that will establish a contract to develop and implement a standardized approach for common TMC functions and performance levels that will be applied to all TMCs throughout the state. The major service categories in the contract include dispatching safety service patrols, TMC floor operations, ITS infrastructure and field network maintenance, the design of a statewide ATMS and technology support, and program management and general support services.

Related Trends: Performance Monitoring and Management

4.1.1.8 **Strategy**: Use Open-Source or Non-Proprietary Software when Possible

Open-source or non-proprietary software may have the advantages of lower initial costs (if there is existing open-source or non-proprietary software available) and increased interoperability. However, depending on the software and its source, there may be less support available. (Developing new code will be more expensive and will carry more risk than using existing, proven software.) Careful consideration must be given by the agency, including weighing in-house and otherwise accessible support capabilities.

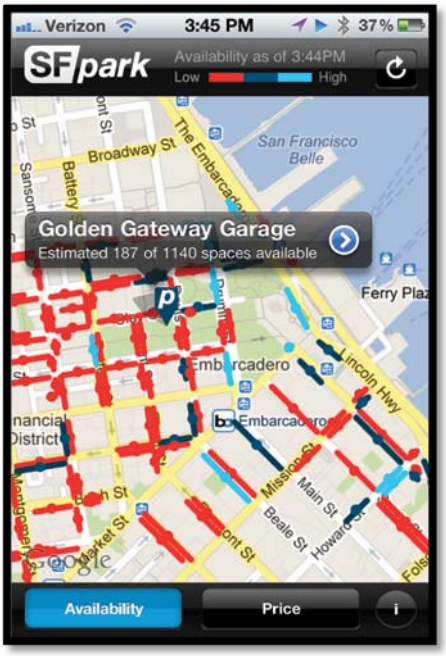
Related Trends: Automation Tools and Related Tools to Increase Efficiency

4.1.1.9 **Strategy**: Require Application Programming Interfaces (APIs) and Document for Future Development

With the worldwide proliferation of Smartphones, tablet computers, and other mobile devices, it is critical that DOTs include requirements that allow and support the use of Application Programming Interfaces (APIs) when contracting or developing traveler information software. APIs are a set of routines, protocols, and tools for building software applications and they guarantee that all programs using the API will have similar interfaces and make it easier for operators to learn new programs. The use of open source APIs provides for innovation and continued technological relevance of traveler information dissemination by government agencies. In order to provide for these enhancements through APIs it is essential that documentation of the interfaces and developer access be required. With an increase in use of third-party data sources, it is important that TMCs be able to balance the public interest in making data available to developers with any restrictions on the use of data purchased from third parties.

One successful example of public agencies sharing data with developers through APIs is the City of San Francisco's SF*park* program. The API specification, source code, terms of service, and developer FAQs are all available through http://sfpark.org/how-it-works/open-source-data/. Although SF*park* provides its own cell phone app, it also recognizes that providing the data to developers also supports its ultimate goal of making parking more readily available.

Related Trends: Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information; Mobile Communications and Wireless Networks; Social Media for Traveler Information and Crowdsourcing



(Source: Screen capture of SFpark App)

4.1.1.10 **Strategy**: Require Documentation on All Systems and Software – Include Search Capabilities and Provide Remote Accessibility

Related Trends: Performance Monitoring and Management; Mobile Communications and Wireless Networks

4.1.1.11 **Strategy**: Follow the Systems Engineering Processes

The systems engineering process, and the corollary FHWA Rule 940, grew out of acknowledgement that ITS systems were more complicated, dynamic, and interconnected than many other roadway endeavors. The underlying systems engineering concepts were proven from other industries including software development.

At the core of systems engineering is using consensus-based requirements to drive system design, procurement, implementation, testing, operations, and maintenance. This process inherently supports a service-oriented mindset because the needs drive the process and the results are managed. The process can also facilitate a nimble mindset because requirements can develop as needed and then solutions sought to meet them rather than being driven by pre-existing known technologies.

A significant number of high-quality systems engineering reference materials are available. Two are listed below.

Systems Engineering Guidebook for Intelligent Transportation Systems, Version 3.0. Available as an interactive, on-line version through (FHWA CA division; CalTrans, 2009), includes document templates, case studies, and checklists.

Systems Engineering for Intelligent Transportation Systems, An Introduction for Transportation Professionals, Available through (National ITS Architecture Team, 2011) Provides information on systems engineering principles.

Related Trends: Performance Monitoring and Management

4.1.2 Active Transportation and Demand Management (ATDM) Concept and Toolkit

The following subsections contain individual ATDM tools as well as more general strategies for supporting the general ATDM concepts of being more proactive and integrated.

4.1.2.1 **Strategy**: Implement a Suite of Emerging Transportation Concepts, Coordinating as Necessary

This strategy reflects the potential of combining multiple technologies and procedures to meet unique needs and capabilities of individual TMCs. While there are complications in integrating systems and procedures, there is also the potential for transportation improvements that are greater than the sum of their individual parts.

One example of implementing a suite of concepts that support ATDM is the Washington State DOT's success with using social media to reach travelers to explain and promote Active Traffic Management and other ATDM strategies.

Related Trends: Automation Tools and Related Tools to Increase Efficiency

4.1.2.2 **Strategy**: Integrated Corridor Management (ICM)

Another example of implementing a suite of ITS tools is Integrated Corridor Management. In 2005, the USDOT, ITS JPO, FHWA, and FTA began an ICM program. ICM utilizes a coordinated and integrated set of systems and tools across modes along a corridor (which may include multiple parallel roadways and tracks) to underpin a multi-jurisdictional, multi-modal, and multi-

technological approach to maximizing efficiency. It is rooted in systems engineering principles and relies heavily upon cooperation among agencies. It uses many ATDM and ITS tools that have been implemented separately, but in a more holistic way focused on a single corridor.

In early stages of the USDOT program, eight Pioneer Sites were selected to develop concepts of operations and requirements for ICM. Later, three of those sites were selected for modeling (Minneapolis, MN; Dallas, TX; and San Diego, CA) and the latter two are moving into the demonstration and evaluation phase. The results of this process are intended to support future ICM implementations.

ICM is more likely to be successful where there are preexisting working relationships among most of the involved agencies for a corridor, such as state DOT, toll authority, county/city/local DOTs, transit agencies, and freight operators.

Other examples of ICM initiatives outside the USDOT demonstration sites include the Niagara International Transportation Technology Coalition (NITTEC) cross-border project near Buffalo, NY, and the Interstate 80 Smart Corridor in the San Francisco Bay Area.

Extensive information is available through the RITA ICM page available at http://www.its.dot.gov/icms/index.htm (RITA USDOT).

Related Trends: Performance Monitoring and Management

4.1.2.3 **Strategy**: Active Traffic Management (ATM) Which May Include Lane Use Control, Variable Speed Limits (VSL), and Hard Shoulder Running

(Source: WSDOT Flickr Photostream)

According to FHWA's Active Traffic Management Guidebook (FHWA, 2012), "Active Traffic Management is the ability to dynamically manage recurrent and non-recurrent congestion on the mainline based on prevailing traffic conditions. Focusing on trip reliability, it maximizes the effectiveness and efficiency of the facility. It increases throughput and safety through the use of integrated systems with new technology, including the automation of dynamic deployment to optimize performance quickly and without delay that occurs when operators must deploy operational strategies manually."

ATM includes many specific strategies such as:

- **Lane Use Control** in which electronic signs above each lane (typically at half mile spacing) instruct drives on allowable lane use; such as instruction to merge ahead of a lane closed due to a crash, which can reduce congestion and increase safety by facilitating an early merge.
- **Variable Speed Limits or Advisories** in which speeds are adjusted by lane or by roadway segment, primarily aimed at improving safety by adjusting speeds based on downstream traffic conditions to minimize the likelihood of crashes caused by unexpectedly encountering a queue or severe traffic congestion.
- **Hard Shoulder running** in which shoulders of freeways designed to support full traffic loads are used on a part-time basis as a through traffic lane, such as during peak times and special events. Dynamic signing indicates the current shoulder state (open, closed, or open to only certain types of vehicles).

Until in-vehicle messaging is prevalent, which is expected to be beyond the 10-year horizon of this study, considerable field infrastructure will be needed to implement many of the ATM strategies. The costs can be significant, but less than some other options such as adding lanes.

The *ATM Guidebook* lists the indicators for potential ATM deployment shown in Figure 8.

The *ATM Guidebook* also describes factors influencing ATM feasibility, such as deployment area characteristics (collision patterns, speed profiles, major traffic flows, roadway geometry); existing and planned infrastructure/roadway facilities; construction activity and opportunity; data availability; cost/benefit estimates; transportation demand priorities, agenda and support; institutional policies and issues; legislative environment; and community support and acceptance.

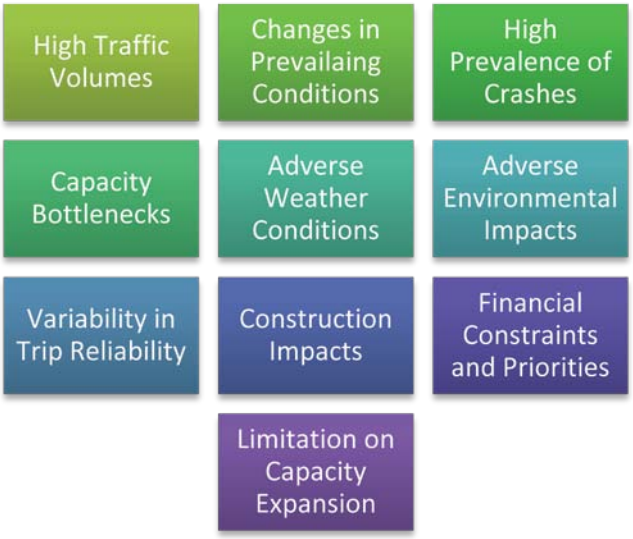


Figure 8: Indicators of Potential ATM Deployment

(Adapted from FHWA, 2012)

Many of the ATM strategies were pioneered in Europe. Successful use in the United States includes WSDOT's Smarter Highways system and MnDOT's Smart Lanes system. Both systems include variable speed limits, dynamic lane control, and dynamic messaging. Other agencies, such as Virginia DOT, which uses hard shoulder running on I-66, are currently expanding their existing program or are implementing or planning future deployments. More detailed descriptions of each can be found in the *ATM Guidebook.*

Related Trend: Performance Monitoring and Management

4.1.2.4 **Strategy**: High Occupancy Toll (HOT) Lanes

In high occupancy toll (HOT) lanes, excess high occupancy vehicle (HOV) capacity is sold to vehicles that do not meet HOV requirements. HOT tolls should be set to keep overall usage of the lane(s) low enough to prevent degradation of the performance of the HOT lane(s). The threshold or target performance indicator is usually described as maintaining a minimum average speed, often 45 MPH. While the decision to implement HOT lanes is beyond the scope of TMC managers, they should be aware that HOT pricing is a complex process that could bring new stakeholders and new priorities into operational procedures. They may also introduce payment and enforcement complications. Finally, as

with HOV and other managed lanes, TMC operators should work with stakeholders to define if there are circumstances, such as major multi-lane blockages, when lane restrictions should be relaxed to allow general purpose use of the lane(s).

Related Trend: Accommodating Toll and other Pricing Operations in TMCs

4.1.2.5 **Strategy**: Portable Work Zone ITS Systems

Leased wireless data plans, trailer mounted ITS equipment, and specialized software now makes a variety of temporary ITS systems in work zones possible. Some of the available features include:

- Dynamic Lane Merge Systems (DLMS);
- Queue detection and warning;
- Speed warning;
- Remote operation of CMS and CCTV; and
- Travel time estimates.

TMC managers and operations staff should be familiar with options so they can advocate for including appropriate types in construction contracts where they could provide a worthwhile benefit. TMC managers and operations staff should also consider how such temporary systems could interact with permanent ITS equipment.

One key reference is the FHWA Work Zone Safety and Mobility Program. It includes a website with over 50 links to resource documents on various work zone ITS systems, including many case studies. The URL is http://www.ops.fhwa.dot.gov/wz/its/index.htm#aut.

Related Trends: Automation Tools and Related Tools to Increase Efficiency; Social Media for Traveler Information and Crowdsourcing

4.1.2.6 **Strategy**: Regional or Multi-State Coordination of Detours and Traveler Information

Coordinating detours and traveler information across agencies increases their usefulness to travelers. Such coordination is built upon relationships among agencies that may benefit from interagency agreements that include roles, responsibilities, and policies. There are also technological challenges to be addressed.

Regions with long histories of such coordination can share valuable experience with other regions. The New York metropolitan region's Transportation Operations Coordinating Committee (TRANSCOM) began in 1986 focusing on coordination of construction activities across state lines to minimize impacts on transportation. It now includes sixteen transportation and public safety agencies across New York, New Jersey, and Connecticut with a much wider role in regional transportation management. During major emergencies, it builds on these established core working relationships to effectively coordinate even more agencies. During Hurricane Irene in 2011, 28 agencies participated in regular TRANSCOM conference calls facilitating emergency operations. The focus of the calls included review of regional conditions by agency, vehicle restrictions and possible full closing of river crossings, and recovery. TRANSCOM stresses the importance of both accurate data and strong working relationships. (Edelman, 2011) and (TRANSCOM)

In and around Washington, D.C., the Metropolitan Area Transportation Operations Coordination (MATOC) Program uses information sharing, planning, and coordination among transportation agencies in D.C., Maryland, and Virginia to improve safety and mobility. (MATOC)

Related Trends: Social Media for Traveler Information and Crowdsourcing

(Source: Parsons Brinckerhoff)

4.1.2.7 **Strategy**: Provide Real-time Travel Time Estimates on Full Range of Devices and Systems Available.

FHWA recommends that DMS display travel times as a default, even outside of incident and road-work periods (Chu, 2008). The information can be useful for travelers planning their routes and leverages the investment made in the DMS.

Travel time estimates are also useful to travelers through web sites and voice-activated 511 systems.

As agencies begin to achieve compliance with the FHWA-mandated Real-Time System Management Information Program, the amount of accurate and timely data will increase. The program is to be established on all Interstate routes within 4 years (November 8, 2014) and on other significant roadways as identified by the States and local agencies within 6 years (November 8, 2016).

The Real-Time System Management Information Program provides a foundation of basic traffic and travel conditions information that may be built upon and used by public agencies, other public and private parties who may deliver value-added information products, and the traveling public. Data exchange formats will allow the information to be more easily interchanged and used among agencies and other parties.

Related Trend: Automation Tools and Related Tools to Increase Efficiency

4.1.2.8 **Strategy**: Display Transit Info on Parallel Route DMS (Possibly with Comparative Travel Time and/or Parking Availability)

This strategy is closely associated with ICM as it provides travelers with information which may encourage them to shift mode from one experiencing delays to one with excess capacity.

Related Trend: Involvement of 3rd Parties in Data Collection, Data Analysis, and Provision of Traveler Information

4.1.2.9 **Strategy**: Parking Management Including Dissemination of Real-time Garage Space on DMS and Through Mobile Apps

Effectively directing vehicles to available parking can reduce congestion by preventing excess circulation when garages, lots, or spaces are full.

Including privately-managed garages increases the value of information to customers. However, some garage operators may be reluctant to participate because they may not want to ever direct traffic away from their facilities, even if they are full.

Real-time parking information is also increasingly being provided through agency and third party applications.

Successful practices in implementing parking management techniques, such as displaying parking garage space availability on arterial DMS, are currently being done by several jurisdictions, including the Cities of Minneapolis and Seattle. The City of San Francisco Municipal Transportation Agency also provides real-time parking availability at garages and in selected neighborhoods through a cell phone app. See www.sfpark.org.

Related Trends: Automation Tools and Related Tools to Increase Efficiency; Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information; Social Media for Traveler Information and Crowdsourcing

4.1.2.10 **Strategy**: Arterial Management with ITS Devices such as Closed Circuit Television Cameras (CCTV), Dynamic Message Signs (DMS), and Remote Access to Traffic Signal Controllers

Many successful ITS strategies and tools that are traditionally used on freeways can also provide benefits to arterials. The major complicating factor, and potential source of benefit, is coordination of arterial operations or integration of the traffic signal controllers across jurisdictional boundaries. There is a great variety of traffic signal equipment currently functioning, with many older systems not well suited for interoperability with other central software systems used by neighboring jurisdictions. However, traffic signal controller manufacturers have made great strides in recent years to provide more interoperable field equipment and central control software. While there are National Transportation Communications for ITS Protocol (NTCIP) standards governing traffic signal controllers, central software produced by controller manufacturers are often geared to provide optimal functionality using matched brand equipment. Having a single company responsible for controllers and software is less complicated for agencies, but may make integration with other equipment brands difficult in the long run.

DMS used on arterials need to be scaled appropriately and consideration given to the character of the arterial, especially if there are residences located adjacent to the arterial. CCTV's privacy zones may also be more significant than on most freeways. Travel time estimation on arterials can be more complicated than on freeways because traffic signal timing has a significant effect, many drivers link trips and stop along the way (for purposes such as getting fuel, stopping for coffee, or picking up supplies), and travel speeds can vary greatly along a corridor. Probe-based travel times, such as through Bluetooth detection or toll tag readers, can be more effective than spot speed measurements. However, it is still important to try to identify and eliminate non-representative travel times caused by trip-linking behavior.

(Source: Parsons Brinckerhoff)

Examples of successful practices include Burlington County, New Jersey, and San Francisco, California.

Related Trend: Automation Tools and Related Tools to Increase Efficiency

4.1.2.11 **Strategy**: Integrate Ramp Metering Schemes with Adjacent Arterial Signal Timing to Minimize Conflicts with Ramp Queues

When adjacent ramp metering signals and arterial traffic signals are operated independently, especially by different agencies with different priorities, it can be difficult to develop coordinated operations. However, the impact to travelers can be significant.

Related Trend: Automation Tools and Related Tools to Increase Efficiency

4.1.2.12 **Strategy**: Adaptive Signal Control Technologies (ASCT)

In recent years, ASCT implementations have risen dramatically as the software and detection costs have dropped and more commercial applications geared to arterials (rather than urban grids) have entered the marketplace. The core of ASCT is using near real-time detection to adapt signal timing at a series of traffic signals, often adjusting progression offsets between intersections as well as individual intersection split durations.

FHWA has recognized that ASCT, like traditional ITS systems, are complex systems with significant costs and risks as well as potential benefits. There is also variation in the available options on important points such as how involved operators and traffic engineers are with the system after initial configuration. Therefore, FHWA has made it clear that ASCT procurements are subject to the 29 CFR 940 requirements to follow the systems engineering process. To assist agencies, FHWA developed model systems engineering documents to help guide agencies (referenced below). An updated version was released in August 2012.

The following are key resources on ASCT:

NCHRP Synthesis 403: Adaptive Traffic Control Systems: Domestic and Foreign State of Practice. Washington, DC: Transportation Research Board. (Stevanovic, 2010)

Model Systems Engineering Documents for Adaptive Signal Control Technology (ASCT) (FHWA, 2012)

FHWA Everyday Counts Adaptive Signal Control web (USDOT - FHWA, 2012)

Related Trend: Automation Tools and Related Tools to Increase Efficiency

4.1.2.13 **Strategy**: Transit Signal Priority (TSP)

Transit Signal Priority (TSP) utilizes technology to give priority to transit vehicles at signalized intersections, such as adjusting green signal time to minimize transit delay or providing special phasing to bypass queues or make movements not available to other vehicles.

TSP can reduce transit travel time and increase reliability, but it needs to be evaluated for impacts on general traffic flow as well as on other transit vehicles in the system.

The following are key TSP resources:

- *Transit Signal Priority: A Planning and Implementation Handbook* (Smith & Hemily, 2005)*;* and
- RITA TSP Web page (RITA, 2012).

Related Trend: Automation Tools and Related Tools to Increase Efficiency

4.1.2.14 **Strategy**: Road Weather Integration

Managing the roadway system for weather is a way to be proactive and get the most out of the network.

A successful practice of road-weather integration can be found in Wyoming DOT and their variable speed limit system on I-80 in response to wind and weather conditions. The I-80 system relies on a manual process to activate variable speeds from the TMC in response to high wind conditions.

Related Trend: Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information

(Source: Parsons Brinckerhoff)

4.1.2.15 **Strategy**: Weather-Responsive Signal and Ramp Meter Timing Plans

Some of the assumptions used in developing traffic signal and ramp metering timing plans include the speed and acceleration of vehicles. Severe weather can dramatically change these values reducing the effectiveness of normal timings. Increasing the number of stops can be detrimental when roads are ice or snow covered. Weather-responsive signal and ramp meter timing plans, as well as some adaptive signal timing schemes, can address these issues.

An example of this successful practice is in Utah DOT's signal operations through implementing weather-responsive signal and ramp meter timing plans on major roadways.

Related Trend: Automation Tools and Related Tools to Increase Efficiency

4.1.2.16 **Strategy**: Develop Protocols and Maintenance Program to Address Increased Number and Complexity of ITS Field Devices

This section has highlighted some of the many ATDM tools available and each one involves multiple pieces of field equipment and software. It is critical to provide at least the minimal recommended level of maintenance in terms of staffing levels, personnel skills, replacement parts, and proper tools. Ideally, these needs should be identified and provided for early in the systems engineering process for each new system. However, the cumulative effect of seemingly small additions coupled with budget restrictions mean that many agencies are having difficulty with the increasing number and complexity of ITS systems.

One key to establishing a maintenance program is initiating a basic asset management system that includes, at minimum, an inventory of devices along with approximate age, life expectancy, regular maintenance needs, and notes such as frequency and impact of failures. Such information is useful not only for managing equipment, but for making a business case for assigning resources for a more robust maintenance program.

While there are strategies to ease the maintenance burden through technology, they will not substitute for having sufficient qualified staff. ITS systems require many specialized skills including those of electricians and networking professionals.

4.1.2.17 **Strategy**: Co-locate Freeway & Arterial Transportation Management

While the decision to co-locate freeway and arterial transportation management is a complex one including practical, political, and institutional facets, it should at least be considered because of the inherent interdependence of freeway and arterial management, especially as arterial management capabilities are growing rapidly. Another benefit of freeway and arterial co-location is that it promotes understanding of freeway and arterial operations by partner agencies.

Related Trend: A Nimble Service-Oriented Program Mindset and Organizational Structure

4.1.2.18 **Strategy**: Promote Coordination with Arterial Management Agencies

In recognition of the importance of coordinating with arterial management, 2012 Virginia Department of Transportation (VDOT) statewide TMC RFP contains provisions requiring coordination across facilities citing the need for the Contractor to manage traffic on available parallel routes or on detour routes for optimal system performance. It includes special emphasis on major arterials that are on the National Highway System and those that support the Interstate System.

A key resource is the *Coordinated Freeway and Arterial Operations Handbook* (FHWA, 2006). Another is the Atlanta Regional Traffic Operations Program Concept of Operations Report (URS Corporation, 2011).

Related Trend: A Nimble Service-Oriented Program Mindset and Organizational Structure

4.1.2.19 **Strategy**: Look for Opportunities to Share Resources with other Agencies (e.g., communication networks, cameras)

As more agencies implement ITS field devices, there is a greater potential to share resources. There are, however, institutional barriers, such as priority of image control, and technological barriers, such as communications protocols, that must be addressed.

Related Trend: A Nimble Service-Oriented Program Mindset and Organizational Structure

4.1.3 Accommodating Toll and Other Pricing Operations in TMCs

The strategies associated with this trend focuses on ways that TMC managers can successfully prepare for integrating toll and other pricing schemes into their operations. While the decisions to implement pricing are beyond the purview of TMC managers, it is anticipated that tolling will spread to many agencies over the next decade so TMC managers should be aware of implications.

For all of these strategies it is strongly recommended that general protocols and agency roles and responsibilities be defined at a high level as the initial toll and pricing feasibility studies are being conducted. These definitions will be included in interagency discussions and plans as the toll and pricing concepts are developed.

With most pricing operations, there is the potential for competing priorities that influence not only demand responsive pricing, but how to treat tolled lanes when there are major disruptions to parallel un-tolled lanes. Protocols need to be worked out. While the decisions may be politically or financially motivated, it is important for TMCs to collect accurate information to help inform reexaminations of policies.

Successful practices of directly facilitating integration of tolling/pricing with traffic management are currently being carried out in the Miami SunGuide Center and the Miami-Dade Expressway Authority (MDX). The New Jersey Statewide Transportation Management Center (STMC) houses traffic management functions on both the New Jersey DOT freeways and New Jersey Turnpike Authority (NJTA) tolled highways.

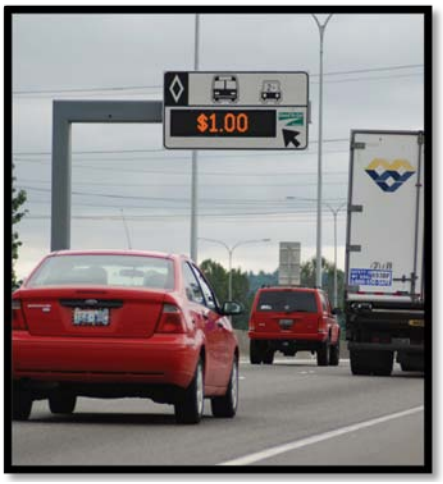
In Northern Virginia, the Beltway Express Lanes were opened to traffic on November 24, 2012. The Express Lanes were built under a public private partnership (PPP) and will be operated by the PPP. That necessitated an agreement between VDOT (who will continue to operate the general use lanes along the Beltway and I-95) and Transurban (the operator of the Express Lanes).

4.1.3.1 **Strategy**: Develop Protocols for Operations (Such as Pricing and Operations for Diversions to HOT Lanes during Major Main Lane Incidents) During Early Feasibility Planning

Protocols, roles and responsibilities should be defined in early project feasibility studies that defines which agency manages operations for opening and closing lanes for use, management of traffic during incidents (in both the general lanes and tolled lanes) and maintenance activities should be defined early in project planning. TMCs have access to significant amount of communications and roadway infrastructure that can be used to implement various types of pricing systems. Traveler information systems and methods already in

place can be used to educate the public on the pricing schemes rates, rules and regulations.

Related Trend: Active Transportation and Demand Management (ATDM) Concept and Toolkit



(Source: WSDOT Flickr Photostream)

4.1.3.2 **Strategy**: Develop Protocols for Joint Operation of Freeways and Toll Roads during Early Feasibility Planning

Protocols, roles and responsibilities should be defined in early project feasibility studies that define which agency conducts operations of lane opening and closing, traveler information dissemination, incident management, and maintenance.

Related Trend: A Nimble Service-Oriented Program Mindset and Organizational Structure

4.1.3.3 **Strategy**: Develop Protocols for Operations and Implementation of HOT Lanes with Variable Pricing During Early Feasibility Planning

Protocols, roles and responsibilities should be defined in early project feasibility studies that defines which agency collects money, how the money is handled, which agency administers systems users, which agency manages the financial transactions and what are the parameters of pricing (maximum and minimum tolls, the formula of pricing due to HOT lane congestion or any other pricing parameter, times and conditions that tolls are static or dynamic).

Related Trend: A Nimble Service-Oriented Program Mindset and Organizational Structure

4.1.3.4 **Strategy**: Develop Protocols for Operations for Cordon Pricing for Congested Areas during Early Feasibility Planning

TMCs should have a role in the definition of protocols, roles and responsibilities in early project feasibility studies that define which agency manages financial transactions, sets pricing parameters, administers systems users for cordon pricing projects. Also the cordon operations protocols should be set during early planning that define which agency is responsible for enforcement, what are the enforcement rules and how the users will participate (toll tags, GPS or Bluetooth readers, license plate readers, etc.). TMCs have access to significant amounts of communications and roadway

infrastructure that can be used to implement cordon pricing systems. Traveler information systems and methods already in place can be used to educate the public on the cordon pricings rates, rules and regulations.

Related Trend: A Nimble Service-Oriented Program Mindset and Organizational Structure; Active Transportation and Demand Management (ATDM) Concept and Toolkit

4.1.3.5 **Strategy**: Consider Increased Network Reliability and Data Security Needs

Pricing projects require a data intensive environment that is predicted on real time operations and financial management. This requires communications network reliability and data security beyond the normal DOT standards. These network and security needs must be considered as the pricing system is being developed.

Related Trend: Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information; Mobile Communications and Wireless Networks

4.1.4 Performance Monitoring and Management

The strategies discussed in this section highlight ways that TMC operators can fulfill requirements imposed by their agencies and also improve their effectiveness. Technology is sometimes a tool used to monitor performance and sometimes technology itself is the subject of the monitoring.

4.1.4.1 **Strategy**: Use Results of Performance Monitoring Related to Agency Goals to Support Funding Requests

Bridge and pavement ratings are commonly used to quantify needs and justify funding requests. While operations are inherently more difficult to measure, the results can be powerful tools to help support budget requests.

Related Trend: A Nimble Service-Oriented Program Mindset and Organizational Structure

4.1.4.2 **Strategy**: Proactively Develop Performance Metrics Based on Staff Priorities as well as Agency Goals

For example, the Rhode Island DOT (RIDOT)'s selection criteria for TMC performance measures:

- Follow FHWA/AASHTO recommendations;
- Support the TMCs mission statement;
- Can be computed periodically;
- Help improve safety and traffic operations;
- Demonstrate the benefits derived from ITS; and
- Are based on data which is reliable and readily available. (TrafInfo Communications, Inc., 2011)

RIDOT's resulting performance measures are shown in Figure 9.

Figure 9: Initial and Future RIDOT TMC Performance Measures

(Source: Adapted from TrafInfo Communications, Inc., 2011)

Reports of RIDOT TMC statistics including their performance measures are available through http://www.tmc.dot.ri.gov/statistics/.

Another key resource is the *National Transportation Operations Coalition (NTOC) Performance Measurement Initiative Final Report* (National Transportation Operations Coalition, 2005) available through http://www.ntoctalks.com/ntoc/ntoc_final_report.pdf

Related Trends: A Nimble Service-Oriented Program Mindset and Organizational Structure; Automation Tools and Related Tools to Increase Efficiency

4.1.4.3 **Strategy**: Use Multiple Data Sources to Monitor System Congestion, Including to Support Travel Time Estimation

Legacy sensors, such as pavement loops on freeways, can be supplemented with many different technologies. As different options have different costs and strengths, having a data fusion engine can greatly increase the opportunities that agencies have to develop reliable monitoring of system congestion and estimation of travel times.

An example of a successful practice is the New Jersey DOT's data fusion engine that combines data from multiple sources including toll tag readers through TRANSCOM and Bluetooth readers through the vendor. The Bluetooth system vendor provides an XML (eXtensible Markup Language) feed for the data fusion engine.

Related Trends: Active Transportation and Demand Management (ATDM) Concept and Toolkit; Automation Tools and Related Tools to Increase Efficiency; Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information; Mobile Communications and Wireless Networks

4.1.4.4 **Strategy**: Consolidate Efforts to Develop Data Management Tools across Agencies

The University of Maryland Center for Advanced Transportation Technology (CATT) Lab developed a suite of data management tools, the Vehicle Probe Project (VPP) Suite that is used by multiple agencies (CATT Lab, 2011). The tools utilize the I-95 Corridor Coalition's VPP data to display real-time operations as well as trend analyses over time. The data is presented in a variety of formats, including ones that are useful for performance

monitoring. Maryland and North Carolina have been particularly active in this area, as well as the MPOs in Baltimore, Philadelphia and Washington DC. (CATT Lab At The University of Maryland, 2011)

Related Trends: Automation Tools and Related Tools to Increase Efficiency; Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information

4.1.4.5 **Strategy**: Frequently Process and Distribute Measures of Effectiveness (MOE's), Including to Operators, to Improve Operational Effectiveness

There are some applications of performance measures that track trends over long periods of time, such as monthly, quarterly, and yearly that are well suited to reflective reports. However, there is also value in more frequent analysis and distribution of some factors, including those that can be used by operators to help them evaluate the effectiveness of strategies.

Related Trends: A Nimble Service-Oriented Program Mindset and Organizational Structure; Automation Tools and Related Tools to Increase Efficiency

4.1.4.6 **Strategy**: Utilize Features in Software to Track and Report Performance

Central system software is often the main generator and repository of system data that a TMC manager has access to. The data produced can be overwhelming, though. Identifying desired performance data and then setting up a customized report that can run automatically can be of great value. If current software does not have such capabilities, it should be considered a requirement in future procurements and upgrades.

The Georgia DOT has an excellent maintenance management reporting tool that shows equipment status and performance measures on a daily basis.

Related Trend: Automation Tools and Related Tools to Increase Efficiency

4.1.4.7 **Strategy**: Utilize On-Board Device data from Agency Vehicles to Monitor Pavement Condition

As the cost of sensors drop, it becomes feasible to collect data by outfitting agency vehicles engaged in their normal activities to collect basic information.

For example, Michigan DOT vehicles utilize on-board devices to monitor weather-related pavement conditions.

Taking this principle one step further, the City of Boston has been able to successfully identify pothole locations by having residents track road surface anomalies detected with iPhone accelerometers as the sensors. See http://streetbump.org/

Related Trends: Automation Tools and Related Tools to Increase Efficiency; Mobile Communications and Wireless Networks

4.1.4.8 **Strategy**: Train TMC Operators How to Use Performance Monitoring and How to Populate the Data Needed for Performance Monitoring.

While some data used in performance monitoring can be logged automatically, other information, such as incident detection and clearance times, need to be entered by TMC operators, often in close collaboration with on-site emergency service personnel. It is important that the TMC operators are properly trained to record this information using as much consistency as possible. TMC operators should be involved in developing the procedures and they should be informed of the uses of the data. This should improve data quality.

Related Trend: Automation Tools and Related Tools to Increase Efficiency

4.2 Trends and Technology that TMCs can Adapt and Take Advantage of from Outside the Transportation Community

4.2.1 Automation Tools

The strategies discussed in this section suggest ways that TMC managers can make use of automation tools in the areas of ITS devices, control software, and Smartphone applications to improve TMC operator functions and roadway operations. A periodic assessment of operator performance will help identify where processes are working well or where new approaches may be needed to improve efficiency.

4.2.1.1 **Strategy**: Use Advanced Graphical User Interfaces to Increase Operator Efficiency

Graphical user interfaces (GUIs) are customized interfaces that accept input from the operator through

a series of mouse-clicks or touch-screen commands and provide intuitive graphical output illustrating the effect of the operator's command. This type of streamlined delivery of all relevant data needed prior to the operator making a decision, allows for more control to specific information and a quicker response-time. One software application can be designed to handle all TMC processes, including direct control of field devices, and with an intuitive interface, operator training time is reduced or operators can even self or peer-train. Agency-wide deployment of the same traffic management GUI software promotes communication and information sharing.

One successful example is the WSDOT NG_TMS (abbreviation for Next Generation _Traffic Management Software), an in-house created traffic management control software that displays dynamic color-coded updates of freeway flow conditions with active control of the operation of ramp meters, DMS displays, HARs, and CCTVs. The operator can also click on individual freeway sections on the map to get traffic volume, speed, and occupancy data.

4.2.1.2 **Strategy**: Develop Decision Support Systems

Decision Support Systems (DSSs) are computer applications that enhance the operator's ability to make informed decisions. DSSs are a collection of integrated software applications that create the foundation of an agency's decision-making process. They are designed to process, format, and analyze data and knowledge in database-format based on the individual needs of the operator, and allow the operator to analyze the data and make a decision. A benefit to using a DSS is that it assists the operator in synthesizing various types of data in less time than required by using manual processes, and provides consistency in the way decisions are made. DSSs are interactive and user-friendly, but the iterative development process takes time to reach a final product.

The use of decision support systems to guide real-time winter maintenance activities is currently being done by multiple states through their Maintenance Decision Support System (MDSS). This decision support tool integrates roadway observations, relevant road weather forecasts, coded maintenance rules of practice, and maintenance resource data to provide managers with recommended road weather treatment strategies and a

measure of effectiveness. Results are displayed in both graphical and narrative form.

One example of this successful practice of integrating road conditions with weather data to develop automated winter operations plans is with Minnesota DOT and their MDSS.

Another successful example of a decision support system is the I-95 Corridor Coalition Traveler Information DSS (TIDSS) that processes data and provides travel time information across state lines.

TMCs should also consider the use of decision support systems to help manage evacuations or special events egress in real-time, or in developing dynamic pricing systems (such as in Miami, San Diego and Atlanta).

Related Trend: Active Transportation and Demand Management (ATDM) Concept and Toolkit

4.2.1.3 **Strategy**: Install Remote Power Cycling of Field Devices

In instances where field devices have crashed or are unresponsive, remotely powering off/on through a wireless communication link between the device and the TMC allow for instant recovery in surveillance and data collection and less downtime for the device to come back online if a crew member needed to go out in the field and hit the reset button. The operator still has the responsibility to be aware that the device isn't responding, manually verify and confirm the device before manually sending the remote command to power off.

Devices will need to have wireless capability and an internet connection back at the TMC. The cost to upgrade some or all ITS equipment should be weighed against total benefit to the system, including that operators would become more familiar with the technical aspect of operating and maintaining the device and not need a specialized technical staff member to keep the device operational. Another option is to add the requirement into specifications for new equipment installations and route upgrades.

One example application is for wireless CCTV cameras.

Related Trend: Mobile Communications and Wireless Networks

4.2.1.4 **Strategy**: Install Automatic Power Cycling of Field Devices

Automatic power cycling is another benefit of having IP-addressable devices. When the assigned server determines that the device is unreachable through a series of unresponsive contact attempts, the device can be automatically re-booted after a set number of failed attempts. Operators aren't consumed with equipment diagnostic tests while the automatic power cycling takes place in the background, either from an internal time-control setting on the device or through network software back at the TMC. This strategy has same benefits as 4.2.1.3, Install Remote Power Cycling of Field Devices.

4.2.1.5 **Strategy**: Specify Automation Features in Software Contracts

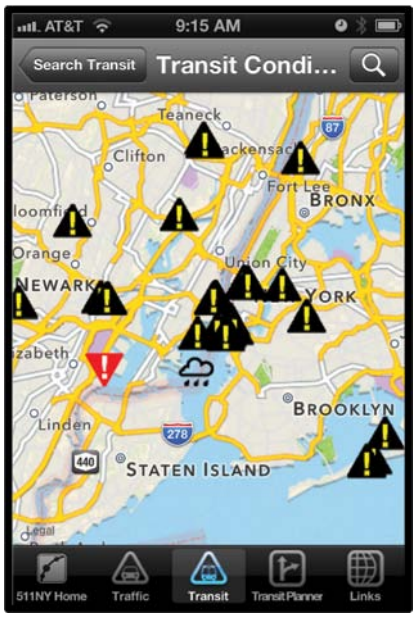
Software agreements that specify automation features for current or future expansion of network management and control give TMCs the capability to further enhance traffic management responsiveness and efficiency. Specified features could include remote management of devices, and automation such as active VMS travel time display, activating ramp metering rates, and implementing responsive signal timing plans. Benefits to these provisions include reduced system maintenance costs as software retains its functionality as more devices come online, control algorithms become integrated into the software, and devices are able to be under automatic operation.

Software agreements that specify automation features for current or future expansion of network management and control give TMCs the capability to further enhance traffic management responsiveness and efficiency.

Related Trends: Active Transportation and Demand Management (ATDM) Concept and Toolkit; Accommodating Toll and other Pricing Operations in TMCs

4.2.1.6 **Strategy**: Consolidate Interfaces to or Consolidate Alert Systems across Agencies

Consolidating software user interfaces across agencies promotes information and data sharing along with software or traffic problem-solving discussions through a unified interface. Agency operators can rely on interface settings that automatically notify other users of traffic network events and software bugs. Automating alert systems requires agreed upon notification policies and procedures defined across agencies, allowing



(Source: Screen Capture of New York's 511 Smartphone app)

TMC managers and emergency responders to oversee the joint response to alerts and traffic incidents. Consolidation requires a designated agency or external IT group to make software interfaces and network systems compatible and for wide deployment and trouble-shooting. Cost to upgrade and train operators could be shared across agencies for maximum benefit to all users.

In Utah and New York there are successful practices of developing Smartphone applications that generate alerts across multiple agencies. New York's 511NY app provides statewide region-based real-time traffic and transit information that encompasses construction and weather alerts, a travel planner, and screen for related transportation links like Amtrak, INRIX, and MTA Trip Planner. The app even includes surrounding regions in Connecticut and New Jersey.

Related Trend: A Nimble Service-Oriented Program Mindset and Organizational Structure

4.2.1.7

Strategy: Develop Default Sets of Traveler Information Messages across Devices (such as DMS) and Media for Quick Implementation during Recurrent Special Events or Incident Types/Sites

Many traffic management software programs have the functionality of creating default message sets for VMS display allowing operators to quickly select from a list of pre-written messages addressing most commonly encountered roadway events like traffic collisions or blocking disabled vehicles, for instant display and immediate driver notification. VMSs can be grouped by region or route for multi-display and maximum driver advanced warning. Standard pre-determined messages may only need slight modification and in the time it takes to create a message from scratch, the operator can attend to higher priority response tasks. Media sites can be linked to one messaging center, so when a traveler information message is sent out, it reaches all roadside devices along with all other forms of social media outlets.

Related Trends: A Nimble Service-Oriented Program Mindset and Organizational Structure; Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information; Social Media for Traveler Information and Crowdsourcing

4.2.1.8 **Strategy**: Utilize Low-Cost Low-Infrastructure Devices, such as Solar-Powered Pole-Mounted Traffic Sensors with Wireless Communications

Some advantages of purchasing affordable ITS devices include the flexibility for wide-deployment of updated, sustainable technologies that operate via a rechargeable battery or via remote control from the TMC. Solar powered devices have a long lifespan and require little maintenance, which makes them favorable for installation in rural areas, or in areas where a wireline power connection isn't feasible. These low-infrastructure devices can also be used in urban areas to enhance driver safety systems.

A successful practice is the solar powered wrong-way signs and motion sensors at freeway ramps in Milwaukee County, Wisconsin.

Related Trends: Active Transportation and Demand Management (ATDM) Concept and Toolkit; Mobile Communications and Wireless Networks

4.2.1.9 **Strategy**: Utilize Predictive Analysis and Forecasting for Anticipating Congestion

With the recent advancements in computer processing speed, data collection technologies and data storage capabilities, TMCs should consider the development of predictive analysis and forecasting of congestion. There are a number of prerequisites to developing a predictive analysis and forecasting program, including:

- Collection of real time data – data that includes gap filling by historical data is not valid for predictive analysis.
- Rigid data quality – detector and probe data must be of the highest possible quality, which, in turn, requires a stringent maintenance program as well as tight data quality and validation procedures.
- Data fusion – greater accuracy is needed for the available data, one way to achieve this accuracy is to fuse data from different sources to ensure that the best information is being provided. Likely data sources may include incident data from service patrol or law enforcement, travel times from private data providers, work zone information, toll or HOT lane pricing information and weather information.

- Development of predictive algorithms – congestion prediction is a new activity in TMC operations. Predictive algorithms needs to be conceptualized and tested prior to use in the field.
- Real time traveler information dissemination – users must be able to receive predictive traveler information in an accurate and timely manner.
- Research is needed on how drivers will respond to predictive traveler information, in particular how likely they are to change routes and under what circumstances. There will be opportunities to test these concepts as tools come on line.

Related Trend: Active Transportation and Demand Management (ATDM) Concept and Toolkit; Accommodating Toll and other Pricing Operations in TMCs; Performance Monitoring and Management; Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information

4.2.1.10 **Strategy**: Because the Private Sector Often Develops the Automation Tools, Support Strong Participation to Provide Better Tailored Tools.

Creating strong, respectful relationships and partnerships between agencies and private developers add value when requesting customized software applications that support automated functions. Developers are more apt to have a better understanding of agencies needs and can offer insight on new technologies and trends focusing on automated traffic management tools.

Related Trends: A Nimble Service-Oriented Program Mindset and Organizational Structure; Involvement of Third Parties in Data and Traveler Information

4.2.1.11 **Strategy**: Include Options for Manual Verification and Override to be used as Operators Fine Tune and Gain Confidence in New Applications

Automated software features and device control maximizes operator efficiency and reduces response time for commonly occurring traffic management scenarios. Giving operators the ability to override automatic settings based upon visual condition identification and evaluation leads to more accountability and a tailored response.

Related Trend: Active Transportation and Demand Management (ATDM) Concept and Toolkit

4.2.1.12 **Strategy**: Develop a Data Fusion Engine to Merge Data from Multiple Sources, such as Travel Time Information Coming from Toll Tag Readers, Bluetooth Sensors, and/or Third Party

An automated data fusion engine is designed to integrate multiple forms of raw data from different types of sensors, process and arrange the data into subsets, and present them in a way that provides a clear, more accurate picture for the operator to draw conclusions from, creating situational awareness. Algorithms can be written to perform complex functions that result in practical and timely information in different formats, more so than if the operator was analyzing data from single sources.

Related Trends: Active Transportation and Demand Management (ATDM) Concept and Toolkit; Performance Monitoring and Management; Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information

4.2.2 Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information

The strategies discussed in this section suggest ways that TMC managers can involve third parties and private vendors in TMC operations and enable inter-agency data sharing.

TMC managers' approach to integrating new data types should first be an assessment of current and future data management and storage needs and ways that private vendors, possibly through virtual data archiving, can help manage the demand for larger capacity storage. Included is a look at how current TMC functions accommodate travelers' needs and ways that the traveler experience can be improved through collaborative development with third party mobile applications that will manage the agency's social media efforts.

4.2.2.1 **Strategy**: Develop Prequalifications or Standards Regarding Data Accuracy and Validation (Potentially Both for Data Received and Data Provided)

As the demand for traveler information increases, it becomes ever more important that the information is accurate and timely. It is imperative that TMC managers establish data quality standards that travel time data need to meet. It is also recommended that when the agency purchases data, they consider requiring the private vendors provide raw data to the TMC as well as processed travel time estimates. TMC owner agencies should establish similar data quality standards for their own operations as well.

Standards for private data providers should include the following items:

- Data format – the format(s) in which data shall be delivered;
- Data elements – what data elements shall be included i.e. speed, travel time, status flags;
- Definition of roadway segments – including how to attach to a known geo-database;
- Route coverage – which highway routes are covered;
- Update interval – or refresh rate;
- Data access and archive – definition of methods to access and store the data;
- Accuracy – usually reported in speed error;
- Completeness – indication of missing data;
- Availability – indication of system down time; and
- Latency – indication of how long between data collection and reporting of that data.

Standards for data quality procedures by government agencies are described in *Quality Control Procedures for Archived Operations Traffic Data: Synthesis of Practice and Recommendations – Final Report,* (Texas Transportation Institute, 2007).

For an example of the quality control procedures used by Florida DOT for reporting statewide performance measures refer to Appendix A: ITS Program Performance Measures Review in FDOT's Statewide ITS Performance Measures Final Report (FDOT, 2008).

Related Trend: Performance Monitoring and Management

4.2.2.2 **Strategy**: Provide Real-Time Data to Third Party App Developers

TMCs can offer a valuable service to motorists by providing real-time data to third party application developers. Developers take this data and use it to calculate speed and travel times, both pre-trip and en-route, covering wider geographic areas, which are then disseminated to travelers through their smart phones or in-vehicle navigation. Because it is almost expected that agencies will make data available to the public, a challenge would be for agencies to have set agreements on data ownership, sharing, and usage once it is handed over. Many agencies currently have third party data agreements including WSDOT and VDOT. TMC managers should note that if they receive data through third parties, they may not be allowed to provide that data to others. It is important to check with data agreements or with the owner of the data before including it in the TMC datafeed.

INRIX is currently making real-time data available to all third party application developers for the development of mobile applications and websites.

Related Trends: Automation Tools and Related Tools to Increase Efficiency; Social Media for Traveler Information and Crowd sourcing

4.2.2.3 **Strategy**: Share Data among Agencies

Reductions in agency budgets are causing TMC managers to look at other ways of meeting their data needs. Interagency data sharing increases the efficiency in which these agencies work together by creating mutually beneficial, positive relationships. This leads to obtaining data from outside their area of coverage and enables them to provide a comprehensive traveler information plan. Sharing data also leads to standardization of data formats and equipment. If third-party data is part of the data to be shared, it is important to make sure the data agreements with the third party vendors allow sharing data covered by the agreement with other agencies.

One specific area of data exchange that can be helpful is between law enforcement computer aided dispatch

(CAD) and Advanced Transportation Management Systems (ATMS) software.

An example of a successful practice in multi-agency data sharing is AZTech and their ability to provide a consolidated data feed and a centralized, efficient mechanism to distribute private sector data to agencies.

Related Trends: A Nimble Service-Oriented Program Mindset and Organizational Structure; Social Media for Traveler Information and Crowd sourcing

4.2.2.4 **Strategy**: Develop Protocols for Data Privacy and Confidentiality, including for Media and other Agencies Co-located in the TMC Observing otherwise Restricted Material

Data collected, used, and archived in the TMC can be thought of in three categories: general user-profile data, service and payment related data, and location-based data.

General user-profile data is the more prevalent data set and includes toll tag information and related account information, camera images capturing license plate numbers, and, eventually connected vehicle data accounts. From a connected vehicle environment, drivers can opt into certain types of data agreements with the data being transferred between the vehicle and infrastructure and potentially stored or accessed by the TMC. These data sets will need to be safeguarded.

Service and payment related data that may be accessible from a TMC is more specifically related to tolling systems and the personal information stored in a toll tag account. Data and payment records collected from toll tag readers could contain confidential information such as home addresses and credit card numbers. Safeguards will need to be in place that will restrict access to these records if this data is stored and archived at the TMC.

Location-based probe data could be assigned back to a vehicle or even a person and be used for position tracking.

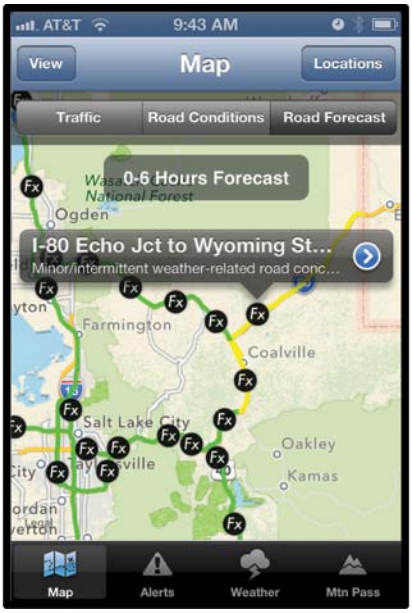
It is advised that all TMC personnel be restricted from accessing personal data records unless there is a compelling reason. TMC established privacy protocols would require a legal agreement to be drafted between the agency and necessary personnel.

As third party and interagency coordination grows, agreements will need to be in place to balance privacy and access. It is recommended that privacy audits be performed by a third party knowledgeable in privacy law, privacy issues, and how they relate to technology to promote a culture of transparency between the agency and the public.

Related Trend: Social Media for Traveler Information and Crowd sourcing

4.2.2.5 **Strategy**: Utilize Private Sector Meteorological Services or In-House Meteorological Resources

The integration of weather into traffic operations enhances the ability of operators to be more proactive and responsive to roadway incidents and congestion, and is part of a national weather integration planning effort. Weather information from private providers can be tailored to TMCs, including information on road conditions such as pavement wetness, interpretations and predictions of traveling weather systems and regional impacts. Meteorologists present in the TMC can provide continuous forecasting and interpretations and can coordinate directly with a designated TMC operator on providing travel advisories during weather events. Policies and procedures for handling weather events can be created.



(Source: Screen Capture of Utah DOT Traffic Smartphone app)

Utah DOT contracts with private meteorological services to work in the TMC and provide real-time updates for operations. TMCs have access to a myriad of weather data options, including private sector forecasting services. The challenge is finding ways to integrate weather information and use it to support TMC operations, such as is seen with the San Francisco Bay Area's 511 system, and maintenance weather data needs. TMCs will also need to be able to validate real-time weather conditions with forecasted weather data.

Related Trend: Active Transportation and Demand Management (ATDM) Concept and Toolkit

4.2.2.6 **Strategy**: Research Solutions that others have used to Solve Similar Problems

Various problem solving styles can help spur new thoughts and ideas that deviate from an otherwise expected approach to reaching a solution. TMC managers draw from their past experiences when determining a response plan but reaching out to

other TMCs for lessons learned on the challenges, benefits, and operational issues they've experienced on new system implementation makes for a more knowledgeable approach to creating a customizable solution.

There is a vast store of information available from other agencies, but it requires a time investment. It is often time and money well spent, though.

Related Trends: Applies to all

4.2.2.7 **Strategy**: Use Multi-Agency Procurement for Economies of Scale

The benefits of multi-agency procurement include:

- Gaining the experience and lessons learned from multiple states when crafting the RFP;
- Leveraging more competitive pricing through the scale;
- Providing more incentive for the winning vendor to be responsive to issues and problems as they arise (because everyone talks to each other);
- Minimizing procurement costs through sharing them across agencies; and
- Establishing common data standards.

In multi-agency procurements, agencies gain access to a wide array of experts, expertise, research, and secondary products developed by one agency and shared with the rest in the agreement.

Also, the cooperation among agencies forged during the procurement can lead to stronger interagency cooperation.

As the project progresses, agencies gain access to a wide array of experts and expertise, research, and secondary products developed by one state and shared with multiple states in the agreement. Expansions, extensions and other upgrades financed by one of the participating states may roll out to all states and agencies. Finally, agencies experience consolidated project overhead and administration costs.

An example of a successful practice is the I-95 Corridor Coalition agreement between the University of Maryland (acting on behalf of the Coalition) and INRIX. It enables Coalition members to acquire INRIX vehicle probe data using rates and contract terms negotiated as a multi-state procurement, rather than individual state-by-state negotiations. INRIX's multi-state agreement provides states with a more complete view of traffic conditions on their major

roads. INRIX's real-time traffic information has helped states more effectively allocate limited traffic operations resources.

According to the North Carolina DOT, where previous approaches to gathering traffic data had a life cycle cost of nearly $50,000 per mile, INRIX vehicle probe data has been proven to deliver more coverage at about 25 percent of the per mile life cycle cost. Similarly, South Carolina DOT claimed that maintaining coverage to gain speed data for over 300 miles of South Carolina roads using traditional methods is equal to the total cost of the INRIX speed and travel time data for 1,200 miles of roads. (I-95 Corridor Coalition – Vehicle Probe Project, 2010)

Another successful practice example is Michigan which has a statewide contract for real-time data from NAVTEQ.

Related Trends: A Nimble Service-Oriented Program Mindset and Organizational Structure; Mobile Communications for Wireless Networks

4.2.2.8 **Strategy**: Train TMC Operators on How to Interpret Alternate Data Sources to Support Operations Decision Making

Informed decision making takes into account all available data and weighted factors to come up with a final recommendation. With technology advances in traffic sensors, data collection and aggregation, operators are no longer just using agency collected data, but are turning to other sources such as third-party data providers and other public agencies. Incoming data is often not in the agency's standard format so will need some manipulation to become recognizable and usable to the operator. In order to get the most benefit from using varied data sources, operators will need to be trained on interpreting the different data types and outputs from decision support tools so they can integrate them into actionable decisions.

Related Trends: Active Transportation and Demand Management (ATDM) Concept and Toolkit; Accommodating Toll and other Pricing Operations in TMCs

4.2.2.9 **Strategy**: Consider Use of Applicable Standards to Simplify Data Exchange, such as XML

XML (eXtensible Markup Language) is a standard common to data integration in IT systems and is becoming the default standard for complex data exchange over IP networks. The XML protocol is one of a handful of data-transfer standards that allow a computer to encode data so that another computer receiving the encoded data will be able to understand its contents and process and display the information to an operator. Communication exchange between agencies requires a common set of parameters and a structured format that will enable sharing of real-time traffic data and traveler information between agencies that have differing requirements and policies. Developing a set of standards for importing and exporting data sets can be done through customizing the XML encoding rules and allows for seamless communication between agencies.

FHWA published an Interim Guidance on Information Sharing Specifications and Data Exchange Formats for the Real-Time System Management Information Program in October 2007 (FHWA, 2007 p 58347 - 58379). The real-time information program recognized under Section 1201 of SAFETEA-LU was intended to institute a standard data format for the exchange of travel- and traffic-related data between State and local government agencies and the traveling public.

Related Trend: Automation Tools and Related Tools to Increase Efficiency

4.2.3 Mobile Communications and Wireless Networks

This section includes ways to successfully utilize mobile communications over widely used wireless networks such as 4G, both within agencies for their own staff and equipment as well as personal mobile devices used by the public.

4.2.3.1 **Strategy**: Coordinate with Information Technology (IT) Staff to Develop Firewalls and Other Security Protocols that are Effective without Limiting Functionality

The nature of a multi-source data environment in a TMC requires that appropriate security firewalls and access protocols be in place to be able to leverage and benefit from multi-agency data sources, as well as provide access to remote users (DOT as well as other partners) so that TMC information can be maximized to support

transportation system functions. This concept applies not only to data, but also to accessing, viewing, and control functions of network infrastructure.

Many DOTs and TMCs have successfully implemented access privileges to non-TMC and non-DOT partners for access to systems like CCTV cameras. This can be accomplished in a variety of ways, and has been streamlined with the transition to a more network-based environment. Hard connections to the TMC are no longer needed in many instances to support this functionality; web-based access is a more cost-effective option. However, security protocols should be in place to:

- Provide "control" functions only to those authorized (i.e., PTZ is allowed for TMC, DOT and law enforcement, but not other partners); and
- Provide view-only access to those authorized (no control, but view images or data).

TMCs could consider establishing a neutral platform outside of the central system where multiple partners (including agencies as well as third parties) could be authorized to access without impacting IT security policies or security issues. In this example, data could be fed from multiple sources to a neutral server platform and be made available via web-based access to authorized users. Examples include:

RIMIS – developed by the Delaware Valley Regional Planning Commission. It provides multi-state and multi-agency access to real-time information about incidents, network conditions, facilitates alerts among agencies, and uses a secure web-based format.

AZTech Regional Archived Data Server – This is a publish-and-subscribe system that includes freeway detector data, incident data feeds, and a video distribution capability. Primary contributing agencies are the Arizona DOT and Maricopa County DOT, and incident data from local fire dispatch and the state police. Agencies and third parties are able to view and receive information via established protocols.

Related Trend: Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information

4.2.3.2

(Source: Parsons Brinckerhoff, Inc.)

Strategy: Efficiently Expand Field Device Coverage and Reduce Operations Cost Using Wireless Networks

Agencies that want to fill in the gaps in their data or video coverage can deploy wireless devices, such as CCTV cameras, in specific, remote areas to expand their communication network without the added cost of installing new fiber optic infrastructure.

Wireless networks can either be leased data services or agency-owned wireless microwave Ethernet systems. Modern Ethernet systems provide greatly advanced capabilities over older 900 MHz systems. In general, as data rates and distances increase, the beam narrows requiring greater stiffness of the mounting structure to hold the radios and antennas in alignment. For millimeter range systems, such as the licensed 80 GHz band, deflections may need to be less than ½ inch at the top of the pole under design wind loading.

When considering using CCTV poles for microwave radio equipment, even in the more tolerant unlicensed 2.4 GHz-5.8 GHz ranges, designs should be reviewed structurally to be incompliance with radio/antenna manufacture's requirements and Electronic Industries Alliance (EIA)/Telecommunications Industry Association (TIA)-222 Revision G Structural Standard for Antenna Supporting Structures and Antennas.

Another consideration for agency owned wireless infrastructure is interoperability. Some manufactures offer enhanced data rates and securities when using proprietary protocols.

It is recommended that a network capacity analysis be conducted as part of evaluating communications media options.

Also, during design, it is recommended that link loss analysis and a line-of-sight study be conducted to minimize most costly changes during construction.

Related Trend: A Nimble Service-Oriented Program Mindset and Organizational Structure

4.2.3.3 **Strategy**: Allow Appropriate Remote Access into TMC Software or Devices (primarily for Maintenance Staff and Appropriate Coordinating Staff from Partner Agencies)

The ability to remotely access or log in to central TMC software is an integral part of many current systems. Web-based capabilities can allow for secure log-in without the user having to access systems through a dedicated workstation (as was the typical model in the past). Although a significant amount of operational functions are housed within the TMC, the ability to allow staff not located in the TMC with access to monitor, update and access information in real-time supports both operations and maintenance.

Remote access can be accomplished through:

- Web-based applications that link to a central system;
- May provide full or limited functionality via the web-based application; and
- Can establish permission levels linked to user log-ins.

Benefits:

- Information can be viewed and updated in real-time. An example is maintenance technicians in the field being able to update repair status once complete, or be able to view other open work requests that are in close proximity.
- Supports remote corridor monitoring or in-the field monitoring of strategies such as during incidents and special events.
- Can support joint operations by allowing remote access by partner agencies (such as law enforcement or partner jurisdiction).
- May allow TMC staff to support emergency operations from a remote location. If staffing does not allow for TMC presence during non-business hours, critical TMC functions can still be performed remotely by someone with authorized access and an enabled device (such as laptop, tablet or Smartphone).

Enabling this capability would require TMC managers to consider:

- Potential access requirements, such as in-house staff from remote locations (laptop, tablet or Smartphone).
- Functionality requirements, which will dictate bandwidth needs. For example, the ability to monitor and control devices will be more bandwidth intensive than the ability to view and update a simple data base.
- Establish permissions for remote users (in house vs. partner agencies) and link permissions to log-ins. This will allow the TMC to be able to track activity, but also will help to automate security functions and access protocols.
- Establish network security features to prevent unauthorized access.
- Ongoing staff/technical support needs. New applications will require ongoing support and maintenance. TMC managers will need to identify funding or staff technical resources that would be responsible for ongoing technical oversight and periodic updates.

Remote access by partners will likely require some sort of formal agreement or protocols be put in place. Operating procedures can be documented and agreed to by partners, but a formal agreement will help to ensure that security and other protocols are understood.

Related Trend: A Nimble Service-Oriented Program Mindset and Organizational Structure

4.2.3.4 **Strategy**: Utilize Commercial Mobile Devices and Apps to Support Collaboration between Freeway Service Patrol and Other Emergency Responders, TMC Operations Staff, and Field Maintenance Staff for Improved Communication and Enhanced Field Collaboration

The information exchange between TMC operators and emergency responders needs to be accurately and efficiently communicated for successful incident response. For example, application sharing between the operator's machine and the responder's mobile device can be used. Detailed information on the location, type, and severity of the roadway incident communicated directly from the emergency responder to the operator will result in implementing a response plan, quicker

than if the operator had to rely on fixed locations of ITS devices to provide information or for information to be relayed through the emergency response dispatch center. The use of devices by emergency response and transportation personnel to send pictures/video of crash scenes to hospitals is also being done.

The same method of exchanging pictures and video can be helpful for field trouble-shooting of equipment. For example, an on-scene maintenance staff member may be able to better coordinate with maintenance staff at other sites or in the shop for certain problems, especially if the on-site staff member is not as familiar with one of the pieces of equipment. Some on-site field staff may also benefit from being able to access network diagnostics or ATMS software logs from a mobile device rather than speaking with a staff member off-site. All of these strategies can yield enhanced personnel efficiency and shorter downtimes.

A successful practice of integrating road-weather applications into mobile communications is seen in the Integrated Mobile Observation activities through FHWA and the National Center for Atmospheric Research (NCAR). Field tests are currently taking place in Minnesota and Nevada in which DOT maintenance vehicles are outfitted with detectors for road weather conditions and transmit data back to NCAR (and eventually TMCs if tests are successful).

For successful examples of multi-state cooperation among responders, look to the I-95 Corridor Coalition, GDOT HERO and TDOT HELP.

Related Trend: Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information

4.2.3.5 **Strategy**: Operate Mobile Command Centers or Satellite Centers with TMC Software Access

Satellite TMCs are equipped with identical hardware and software providing them with all the same controls and access to roadside devices and data they would have in the main facility, necessary integration tools for traffic response, with a network-based system that allows full real-time information and data sharing. These centers can be activated for special events or emergency situations, to offer extra staff to help accommodate the resulting increase in congestion and traveler delays. A TMC manager with network access to control software

on their personal PC allows them to seamlessly connect to the main TMC and make effective decisions from virtually anywhere.

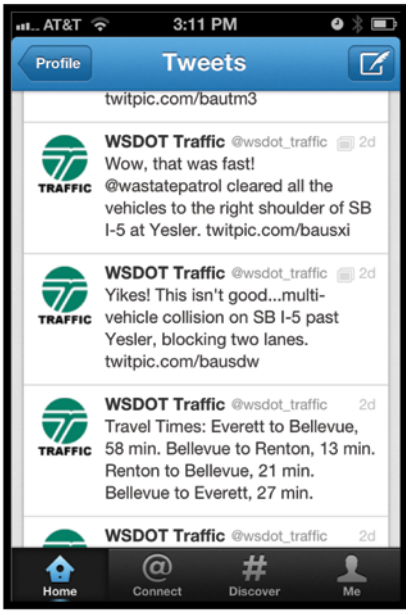
Related Trend: A Nimble Service-Oriented Program Mindset and Organizational Structure

4.2.4 Social Media for Traveler Information and Crowdsourcing

The strategies discussed in this section highlight ways that TMCs can navigate the potential overwhelming trend of the rise of social media tools with suggested strategies that will enable them to balance demands of driver expectations while enhancing operational performance.

4.2.4.1 **Strategy**: Develop Procedures and Protocols for Use of Social Media

This strategy emphasizes a uniform policy for DOT use of social media, such as Facebook, Twitter, Pinterest and video distribution platforms such as YouTube, among others. Social media can provide an important connection to users to disseminate travel warnings and alerts, as well as promote projects or public interest campaigns.



(Source: Screen Capture of WSDOT Twitter Feed)

Many transportation agencies are actively using one or more social media applications for communicating with citizens and travelers. A recent AASHTO report on DOT use of social media indicated 88 percent are using Twitter and just under 80 percent are using some sort of video platform (such as YouTube or Vimeo). Social media impact can vary; tools such as Facebook are utilized more for information purposes (project information, safety campaigns, and public interest messages), whereas the more dynamic nature of Twitter lends itself to alerts and incident warnings.

Policies on DOT usage of social media continue to evolve. The 2012 AASHTO Social Media survey indicated 66.7 percent of respondents had a social media policy, while 28.6 percent indicated there was not a policy. Some transportation agencies manage social media through their Public Information Officers (PIO) or Communications office, so that content and messages on social media are treated the same way as a press release. Others allow TMC operations staff to distribute alerts via Twitter for specific incidents and events.

TMCs will need to work within broader institutional policies (and in some cases State level policies) regarding social media and authorized users to disseminate information via social media. In some cases, IT policies might restrict social media usage to only communications, PIO, or media staff at the agency.

Procedures should be developed for the individual social media formats, although these procedures should be inclusive of a broader social media policy. At a minimum, a social media policy should include:

- Who is authorized to disseminate information via social media channels;
- What information is allowable using social media;
- Message guidelines (composition and structure; example Twitter traffic alert message could be structured as event, location, impact, where to go for more information);
- Linking guidelines (i.e., linking to video clips from a Facebook or Twitter post); and
- Policies for retweeting or forwarding messages received from others (such as agency versus individual).

Social media policies should be reviewed on an annual basis; as tools evolve and emerge, new platforms may require new procedures or protocols.

The successful practice of providing traveler information in many forms such as Twitter, Facebook, and agency Smartphone applications is seen in Georgia DOT's NaviGAtor 511 system.

A successful strategy for social networking is in using multiple sources of information, including both public and private sources, to monitor congestion on the system. This also allows for tracking alerts to subscribers, as in Florida DOT's Statewide 511 system.

Related Trend: A Nimble Service-Oriented Program Mindset and Organizational Structure

4.2.4.2 **Strategy**: Foster Relationship among Agency Public Relations Groups

This strategy involved coordination and collaboration among multiple public relations groups from agencies within a region or neighboring states. Many agencies are often involved in responding to large-scale events

or incidents, and a coordinated approach to lines of communication and points of contact for information is essential to consistent information being disseminated to the public.

This coordination can also be extended to include local or regional media, as these are valuable partners in communicating with the public, particularly during large-scale special events or major incidents or weather events.

Providing local media and partner agencies with PIO/public relations/communications contacts can foster improved working relationships among these partners.

An example is the media and PIO collaboration in Phoenix, Arizona through the AZTech consortium. AZTech hosts a Media Summit on a bi-annual basis that brings together transportation operations and management, public safety, agency transportation PIOs and local media. The objective is to collaborate and share information on how to better communicate transportation impacts to the public. These forums have resulted in several key initiatives and benefits, including:

- An after-hours contact list for media for state and local transportation management centers;
- Common naming conventions for highways and limited access roadways that are numbered but also have a local "name" (for example, SR101 in the east part of the metro area is also called the Pima Freeway);
- Heightened awareness by media of where transportation agencies get their information and how information is verified and validated; and
- Heightened awareness by transportation agencies of what kinds of information media needs and how frequently they seek updates.

Related Trend: A Nimble Service-Oriented Program Mindset and Organizational Structure

4.2.4.3 **Strategy**: Co-Locate Traveler Information Provider Staff with TMC Staff and Agency Public Relations Staff

This strategy involves co-locating key partners involved in disseminating information to travelers, and making real-time information available from the TMC more

accessible to communications and traveler information provider staff.

Several TMCs make information available to local media (such as data feeds or access to CCTV cameras) and traffic reporting/data providers, and co-locating these information disseminators with the TMC provides a direct link to real-time information about incidents, impacts, and strategies being implemented. Co-locating provides the added benefit of TMC staff knowing what kinds of information is getting disseminated by these other partners.

Other key benefits:

- Third party data and information validated using real-time TMC systems such as CCTV, detectors, field reports;
- Improved working relationship between transportation management and private sector providers due to proximity;
- Increased knowledge of PIO or communications staff and traveler information providers about available TMC tools and systems, as well as information about response actions; and
- More consistent traveler information being disseminated through multiple channels, such as agency systems (511, DMS), press releases, social media updates and media reports.

There are several successful examples of this strategy, including:

- Arizona DOT has maintained a work space in the Traffic Operations Center for a private sector traffic information service for many years. This third-party provider supplies several local radio stations in the Phoenix area with traffic updates during peak commute hours. ADOT also recently hired additional communications/PIO staff to be housed in the TOC which provides for extended coverage of communications/PIO beyond standard business hours.
- Minnesota DOT's TMC co-locates transportation management and MSP dispatch, and also includes a workstation for a radio/traffic reporter. The traffic information resource has access to video images, and can distribute

real-time updates from both MnDOT and MSP during incidents or major weather events.

- Houston TranStar's multi-agency TMC has on-site media traffic reporters that have broadcast booths located on the main floor, behind the control room.

With the evolution of web-based data access and third-party data providers, the trend is to provide this information from the TMC to multiple media and third party outlets, rather than dedicating space within the TMC. However, there is tremendous benefit in supporting closer working relationships between these information disseminators as well as providing real-time verification of traveler information being disseminated through third party channels.

Related Trend: Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information

4.2.4.4 **Strategy**: Support Two-Way Information Exchange Via Social Media

Social media can provide a valuable tool to reach out to travelers and residents, but also can provide an important source of data for the TMC.

Enabling a two-way information exchange would require:

- Policy in place that would support access to social media platforms by TMC staff (many policies today restrict social media usage on agency networks, other than by PIO staff);
- New processes and procedures for how to integrate social media information into TMC processes;
- New processes for validating and verifying information received by the TMC via social media platforms; and
- Ability to adapt to new social media tools and data as they evolve (every 1-3 years).

An important challenge with integrating social media data into TMC operations comes down to resources. Operators are tasked with monitoring and managing several systems, as well as coordinating with numerous agencies. Adding such a dynamic element, such as monitoring social media, may require dedicated staff,

or allocating time for a portion of an existing operator or TMC staff to be able to monitor social media feeds affecting the TMC.

Agency-issued social media alerts have the potential to replace agency center-to-center or direct coordination for updates on major incidents or conditions on a regional basis. With so many agencies now using Twitter to alert travelers about impacts or hazards, and then providing updates via that same platform, several agencies already are "following" neighboring jurisdictions or partner agencies for up-to-date information. Many media outlets have indicated that Twitter has replaced e-mail for traffic alerts.

Agencies within a region can establish a "trusted partner" agreement that would either establish an agency-only social media feed, or establish operating guidelines that would ensure information received from transportation, law enforcement, or other related agency would be deemed verified and reliable.

4.2.4.5 **Strategy**: Designate a Larger or Statewide TMC to Take Responsibility for Social Media Alerts on Behalf of Multiple Agencies in a Region

A regionally centralized TMC that has the capacity to handle dissemination of all traffic alerts to social media sites allows for consistent messaging across DMS, social media sites, and other traveler information outlets. The appointed TMC for social media alerts will have to develop polices for coordinating timely traveler information sharing across agencies and increase their communication efforts. The TMC operators will have a more complete picture of traffic conditions on connecting routes outside area of visual coverage, and more detailed and specific traveler information to communicate to the public. Other agencies that don't have the staff to otherwise handle these alerts are now able to provide this service to travelers in their region.

4.2.4.6 **Strategy**: Provide Information through Social Media and Mobile Apps Focused on Pre-trip Planning to Minimize Driver Distraction (Near Term)

(Source: Screen Capture of VDOT Traffic Smartphone app)

Many DOTs have already implemented mobile traveler information applications or versions of their traveler information websites optimized for mobile platforms in response to the growing mobile application marketplace. These mobile apps provide a more streamlined version of information, such as specific alerts (traffic and weather), corridor conditions, or planned work zone restrictions. Providing this information on a mobile platform supports pre-trip planning capabilities for users, which can help to minimize en-route driver distraction.

Utah DOT, Virginia DOT, and Washington DOT were among the early adopters of implementing stand-alone "apps" for traveler information. Response by users has been generally very positive. Enhancing information on the application platform also is much more cost effective than adding an additional menu to a 511 phone based system.

Implementing a mobile version of a website requires restructuring information so that it will be accessible via a mobile platform, and also requires some adjustments to functionality. It is not merely making the full website available for viewing on a mobile device.

Many agencies that have implemented this capability have streamlined the information available, which is similar to the approach taken by other industries. For example, an airline website accessed via a mobile device may provide only a limited menu of options, such as advisories, flight status, flight check in, a simplified reservations/change flight functionality, and perhaps a menu option to access the full site. Similarly, several of the available mobile versions of agency traveler information sites include streamlined information such as:

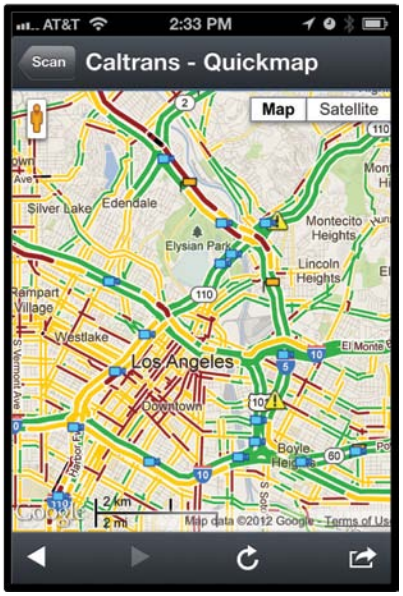
- High level color-coded corridor speed map;
- Alerts, incidents and advisories (including weather);
- Limited number of corridor travel times;
- Still-frame CCTV images;

- Regional quick reports; and
- Multi-modal links/alerts/advisories.

Agencies that have not yet implemented this capability should evaluate the benefits of doing so versus implementing a stand-alone application. Important considerations are:

- The long-term investment in an agency website;
- Available technical resources to develop and sustain a mobile version in parallel with a website (including server and bandwidth requirements); and
- Current business model for information dissemination and whether or not the website functionality would adapt to a new business model/contract if the business model changes.

There are several excellent examples of agency sites that have been enabled for the mobile platform. A listing is provided in Table 1.



(Source: Screen Capture of CalTrans Quickmap Smartphone app)

Table 1: Successful Practices in Mobile Platform Traveler Information

Organization	Mobile Platform Web Address
Arizona DOT	http://www.az511.com/pda/
Houston TranStar	http://traffic.houstontranstar.org/mobile/
Kansas City Scout	http://www.kcscout.com/mobile/
Maryland CHART	http://m.chart.maryland.gov/home/
San Francisco Bay Area Metropolitan Transportation Commission	http://m.511.org/
Washington DOT	http://www.wsdot.wa.gov/Small/
Wisconsin	http://www.511wi.gov/mobile/

4.2.4.7 **Strategy**: Utilize En-route Social Media (including Crowdsourcing) as Voice Activation Becomes More Common (Longer Term)

This strategy is identified as a longer-term option due to the likelihood that en-route voice activated options may be better led by the private sector, mobile developers or auto manufacturers. This kind of "push" of information requires some alignment between current network impacts, available information about impacts, a process to integrate

crowd-sourced data, and logic to determine who needs to receive what messages or alerts.

These kinds of automation tools may be best led by the private sector, which may be able to develop a sustainable business model to support such an activity. TMCs can play an important role in provision of data and impact information (verification). As DOT use of social media continues to evolve, there may be an opportunity to further refine the requirements for this strategy and how it fits with a future TMC.

It is also likely that emerging research within the Connected Vehicle program could address some of the data sharing, automation and crowdsourcing logic that would be required to support this strategy.

Related Trends: Automation Tools and Related Tools to Increase Efficiency; Mobile Communications and Wireless Networks

4.2.4.8 **Strategy**: Utilize Crowdsourcing for traffic information, incident information, feedback on department performance, pavement roughness

This strategy would enable real-time feedback from users on a variety of transportation issues and impacts, with an emphasis on crowdsourced information. Today's mobile environment has added thousands of potential data points to a regional transportation system; crowdsourced information can provide important context for TMC operations, as well as inform operational strategies, particularly if this information is received in real-time. For example, The Weather Channel, at www.weather.com, uses a Twitter search to display weather tweets sorted by trending terms by location to infer weather conditions and share weather tweets amongst local twitter conversations, which TMCs can factor in to their operations.

To date, that has been the largest gap between mobile users and TMCs – the ability for the USER to inform the TMC with automated real-time information about location, situational context, user information needs and user information preferences. This strategy references previous discussions about the potential for TMCs and transportation management agencies pulling information from users, rather than focused solely on pushing it to them.

To effectively enable this strategy, a TMC would need to:

- Implement processes to allow for diverse and disparate data points to be viewed or otherwise accessed;
- Identify what kinds of crowdsourced information would be able to support TMC/DOT performance monitoring objectives;
- Implement automated processes and analytics to be able to parse through disparate crowdsourced data to identify applicability of data; and
- Establish an archive which could then be queried to support longer-term performance management activities, as well as information that could support non-real-time (and non-TMC) DOT functions.

Connected vehicles represent a future opportunity to be able to leverage real-time user context and align with real-time performance. Partnerships with third parties would be essential to delivering this service. A future strategy might also see a business model emerge where this kind of contextual crowdsourced information could be packaged and provided to TMCs to support system management and performance monitoring.

The TMC should confer with multiple groups to determine requirements for this strategy. These include:

- Communications/Public Information Office;
- Planning;
- Maintenance; and
- IT/Information Systems.

Related Trends: Performance Monitoring and Management; Mobile Communications and Wireless Networks

4.2.4.9 **Strategy**: Provide Incentive for Drivers to Participate in Crowdsourcing

A successful strategy that utilizes crowdsourced information needs to provide some level of incentive for users to participate. Some models for obtaining this data (such as speed and location information being obtained from Bluetooth devices) do not require formal “opt in” for data to be provided.

In many instances, a smart phone or Smartphone application may transmit user location data without the user realizing it is being used. Privacy is a big concern among many users, in spite of the growing proliferation of personal information being exchanged with social media sites. A very recent news article (McCullagh, 2012) highlighted that a major wireless provider was selling information about user locations, app usage and web browsing activities. While users are able to "opt out" of this activity, many users are likely unaware that they are opted in by default. This raises important concerns in a mobile and connected environment, where more and more potential information about users can be extracted from mobile devices.

In the 1980's and 1990's, as many freeway management programs were emerging, DOTs and TMCs were faced with educating the public about the true purpose of CCTV, which was to monitor traffic conditions, detect incidents, and that policies were in place to safeguard privacy of the public.

For a crowdsourced strategy to be successful and be viewed as a positive program for users to participate in, the TMC will need to:

- Demonstrate how information will be obtained and be used;
- Clearly allow for an opt- in or opt-out;
- Define and share a strict privacy policy and operating principles that emphasize privacy; and
- Show how this kind of real-time information will contribute to more effective transportation system operations, more reliable travel times.

One very successful private sector traveler information system that relies on crowdsourced information is Waze. As of July 2012, the company reported 20 million downloads of its app (iOs, Android, Blackberry, Windows Mobile). Waze gathers information about users' locations, geographic landmarks, amenities, and also allows users to contribute specific information about congestion, incidents, as well as updates to road names, numbers, etc. Waze also uses anonymous information about users' speed and location, which is then used to improve the information and navigation features. Waze also builds in an entertainment component, essentially combining video game and navigation support. Waze clearly articulates as part

of its terms of use that location-based services are dependent on obtaining user location data; if users do not want to transmit that information, they will not have access to the real-time features.

This model is not likely suited for DOT or TMC operations, but there are elements of this successful model that TMCs can consider, including:

- Showing value of information quid-pro-quo (by obtaining this anonymous user information we are able to provide more accurate and route-specific traveler information); and
- Utilizing information about users to improve information provided by the TMC.

Successful strategies in crowd sourcing and providing an incentive for drivers to participate in crowd-sourcing is highly beneficial in road-weather integrated Smartphone applications, such as Utah DOT's traffic application, which is fundamentally based on weather warnings and alerts. Agencies can have other built in capabilities, but weather is most commonly a driving force.

Related Trend: A Nimble Service-Oriented Program Mindset and Organizational Structure; Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information

4.2.4.10 **Strategy**: Partner with the Private Sector to Facilitate Social Media Outlets and Realize Cost Efficiencies.

TMCs that don't have the means to create and manage their own social media accounts can team up with the private sector as a way to provide traveler information. The third party will take the data and traffic information supplied by the TMC and disperse it to the social media accounts. Third parties can customize an application that will take a message input from the TMC operator and send it out to multiple social media sites, thus consolidating the amount of time spent on updating multiple accounts.

Related Trends: Automation Tools and Related Tools to Increase Efficiency; Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information

4.2.4.11 **Strategy**: As More Traveler Information Content is Available to Travelers through Third-Party Apps, TMCs Can Focus on Providing Content that Third Parties Would Not Have, Such as Construction and Estimated Time to Reopen Lanes

TMC operators have the local knowledge that can enhance traveler information and supplement the data provided by third party apps. Instead of TMCs spending resources on designing a user-friendly interface for construction closures and other local events that could impact traffic patterns, TMCs in some markets can rely on third party Smartphone apps to disseminate that information. Drivers receive a more complete picture of current and on-going roadway incidents on freeways and adjacent arterial routes that would directly impact their travel patterns.

Related Trends: A Nimble Service-Oriented Program Mindset and Organizational Structure; Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information

4.3 Cross-Reference between Trends and Strategies

As previously noted, each strategy has a primary association to one of the eight top trends. That association was used to organize the strategies in sections 4.1 and 4.2 above. The description of each strategy also listed additional related trends. Those relations are secondary associations between strategies and trends.

To illustrate the primary and secondary associations, Figure 10 below shows sample strategies with sample trends. For example, the green arrow between Strategy #4 and Trend C indicates that Strategy #4 has a stronger association with Trend C than with any other trend. The orange arrow between Strategy #4 and Trend A indicates that Strategy #4 can also help address Trend B, but it is secondary association rather than a primary association. There can be multiple secondary associations between strategies and trends.

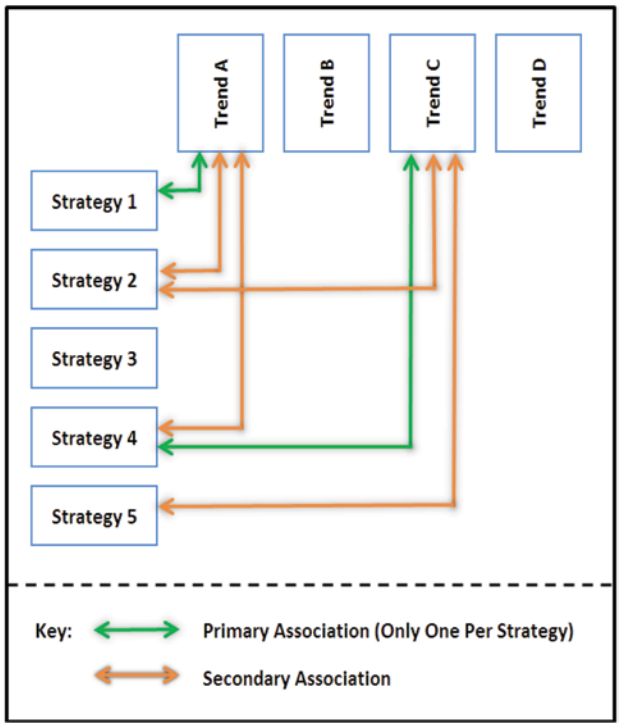


Figure 10: Illustration of Primary and Secondary Associations among Trends and Strategies

(Source: Parsons Brinckerhoff)

To help TMC operators quickly see which strategies can be used to address a particular trend as well as which trends a particular strategy will be useful for, a version of Figure 10 was created with all 80 strategies and 8 trends. However, it is a table and instead of arrows between trends and strategies, when there is an association between a trend (in columns) and a strategy (in rows), the intersecting cell is shaded. When the cell is shaded green with a green 1, it denotes a primary association and when the cell is orange with an orange 2, it denotes a secondary association.

Thus, to see all of the strategies that address a specific trend, find the trend's column and read down. For each row that is shaded, the strategy in the row is applicable. To find all of the trends that a strategy is applicable to, find the row of the strategy and read across. For each column that is shaded, the corresponding trend is related.

The table of trends and strategies is Table 2 below. It also includes the section number of each strategy for quick reference.

Awareness of changing and limited TMC-related budgets has led to the identification of the strategies within each trend that could be used with limited budgets or even save TMC-budgeted expenditures. Such strategies are identified with the "$."

Table 2: Top Trends with Applicable Strategies to be Considered by TMC Operators

		A Nimble Service-Oriented Program Mindset and Organizational Structure	Active Transportation and Demand Management (ATDM) Concept and Toolkit	Accommodating Toll and other Pricing Operations in TMCs	Performance Monitoring and Management	Automation Tools and Related Tools to Increase Efficiency	Involvement of Third Parties in Data and Traveler Information	Mobile Communications and Wireless Networks	Social Media for Traveler Information and Crowd sourcing
4.1.1.1	Foster an Agency Culture of Embracing Technological Change	1				2			2
4.1.1.2	Create a TMC Operator Training Program	1 $	2 $			2 $			
4.1.1.3	Enhance Operational Communication, Which Will Promote a Culture of Open Communications Among Staff	1			2				
4.1.1.4	Develop Memoranda of Understanding (MOUs) and Inter-Agency Agreements Facilitating Multi-Agency (sometimes Multi-State) Cooperation & Operations	1 $					2 $		
4.1.1.5	Create New Technology Piloting and Testing Program	1 $	2 $			2 $		2 $	
4.1.1.6	Develop Skill sets of TMC Managers in Areas of Contracting, Privacy, Security, and Intellectual Property	1		2			2	2	
4.1.1.7	Adopt Standards on TMC Related Equipment and Processes	1 $			2				
4.1.1.8	Use Open-Source or Non-Proprietary Software when Possible	1				2			
4.1.1.9	Require Application Programming Interfaces (APIs) and Document for Future Development	1					2	2	2
4.1.1.10	Require Documentation on All Systems and Software - Include Search Capabilities and Provide Remote Accessibility	1			2			2	
4.1.1.11	Follow the Systems Engineering Processes	1			2				
4.1.2.1	Implement a Suite of Emerging Transportation Concepts, Coordinating as Necessary		1			2			
4.1.2.2	Integrated Corridor Management (ICM)		1		2				

Key: 1 = Primary trend that strategy addresses
2 = Secondary trend that strategy addresses
$ = Potentially feasible on limited budgets or may reduce budget expenditures

Table 2: Top Trends with Applicable Strategies to be Considered by TMC Operators (continued)

		A Nimble Service-Oriented Program Mindset and Organizational Structure	Active Transportation and Demand Management (ATDM) Concept and Toolkit	Accommodating Toll and other Pricing Operations in TMCs	Performance Monitoring and Management	Automation Tools and Related Tools to Increase Efficiency	Involvement of Third Parties in Data and Traveler Information	Mobile Communications and Wireless Networks	Social Media for Traveler Information and Crowd sourcing
4.1.2.3	Active Traffic Management (ATM) Which May Include Lane Use Control, Variable Speed Limits (VSL), and Hard Shoulder Running		1		2				
4.1.2.4	High Occupancy Toll (HOT) Lanes		1 $	2					
4.1.2.5	Portable Work Zone ITS Systems		1			2			2
4.1.2.6	Regional or Multi-State Coordination of Detours and Traveler Information		1 $						2 $
4.1.2.7	Provide Real-Time Travel Time Estimates on Full Range of Devices and Systems Available		1 $			2			
4.1.2.8	Display Transit Info on Parallel Route DMS (Possibly with Comparative Travel Time and/or Parking Availability)		1				2		
4.1.2.9	Parking Management Including Dissemination of Real-time Garage Space on DMS and through Apps		1			2	2		2
4.1.2.10	Arterial Management with ITS Devices such as Closed Circuit Television Cameras (CCTV), Dynamic Message Signs (DMS), and Remote Access to Traffic Signal Controllers		1			2			
4.1.2.11	Integrate Ramp Metering Schemes with Adjacent Arterial Signal Timing to Minimize Conflicts with Ramp Queues		1			2			
4.1.2.12	Adaptive Signal Control Technologies (ASCT)		1 $			2			
4.1.2.13	Transit Signal Priority (TSP)		1			2			
4.1.2.14	Road Weather Integration		1 $				2		
4.1.2.15	Weather-Responsive Signal and Ramp Meter Timing Plans		1			2			
4.1.2.16	Develop Protocols and Maintenance Program to Address Increased Number and Complexity of ITS Field Devices		1						

Key: 1 = Primary trend that strategy addresses
2 = Secondary trend that strategy addresses
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Table 2: Top Trends with Applicable Strategies to be Considered by TMC Operators (continued)

		A Nimble Service-Oriented Program Mindset and Organizational Structure	Active Transportation and Demand Management (ATDM) Concept and Toolkit	Accommodating Toll and other Pricing Operations in TMCs	Performance Monitoring and Management	Automation Tools and Related Tools to Increase Efficiency	Involvement of Third Parties in Data and Traveler Information	Mobile Communications and Wireless Networks	Social Media for Traveler Information and Crowd sourcing
4.1.2.17	Co-locate Freeway & Arterial Transportation Management	2 $	1						
4.1.2.18	Promote Coordination with Arterial Management Agencies	2	1						
4.1.2.19	Look for Opportunities to Share Resources with other Agencies (e.g., communication networks, cameras)	2 $	1 $						
4.1.3.1	Develop Protocols for Operations (Such as Pricing and Ops for Diversions to HOT Lanes During Major Main Lane Incidents) during Early Feasibility Planning		2	1					
4.1.3.2	Develop Protocols for Joint Operation of Freeways & Toll Roads during Early Feasibility Planning	2		1					
4.1.3.3	Develop Protocols for Operations and Implementation of HOT Lanes with Variable Pricing During Early Feasibility Planning	2		1					
4.1.3.4	Develop Protocols for Operations for Cordon Pricing for Congested Areas during Early Feasibility Planning	2	2	1					
4.1.3.5	Consider Increased Network Reliability and Data Security Needs			1			2	2	
4.1.4.1	Use Results of Performance Monitoring Related to Agency Goals to Support Funding Requests	2 $			1 $				
4.1.4.2	Proactively Develop Performance Metrics Based on Staff Priorities as well as Agency Goals	2			1	2			
4.1.4.3	Use Multiple Data Sources to Monitor System Congestion, Including to Support Travel Time Estimation		2		1	2	2	2	
4.1.4.4	Consolidate Efforts to Develop Data Management Tools Across Agencies				1	2	2		

Key: 1 = Primary trend that strategy addresses
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Table 2: Top Trends with Applicable Strategies to be Considered by TMC Operators (continued)

		A Nimble Service-Oriented Program Mindset and Organizational Structure	Active Transportation and Demand Management (ATDM) Concept and Toolkit	Accommodating Toll and other Pricing Operations in TMCs	Performance Monitoring and Management	Automation Tools and Related Tools to Increase Efficiency	Involvement of Third Parties in Data and Traveler Information	Mobile Communications and Wireless Networks	Social Media for Traveler Information and Crowd sourcing
4.1.4.5	Frequently Process and Distribute Measures of Effectiveness (MOE's), Including to Operators, to Improve Operational Effectiveness	2 $			1 $	2 $			
4.1.4.6	Utilize Features in Software to Track and Report Performance				1 $	2 $			
4.1.4.7	Utilize On-Board Device data from Agency Vehicles to Monitor Pavement Condition				1 $	2		2	
4.1.4.8	Train TMC Operators How to Use Performance Monitoring and How to Populate the Data Needed for Performance Monitoring				1 $	2 $			
4.2.1.1	Use Advanced Graphical User Interfaces to Increase Operator Efficiency					1			
4.2.1.2	Develop Decision Support Systems		2			1			
4.2.1.3	Install Remote Power Cycling of Field Devices					1 $		2	
4.2.1.4	Install Automatic Power Cycling of Field Devices					1 $			
4.2.1.5	Specify Automation Features in Software Contracts		2	2		1 $			
4.2.1.6	Consolidate Interfaces to or Consolidate Alert Systems across Agencies	2				1			
4.2.1.7	Develop Default Sets of Traveler Information Messages across Devices (such as DMS) and Media for Quick Implementation during Recurrent Special Events or Incident Types/Sites	2 $				1 $	2 $		2 $
4.2.1.8	Utilize Low-Cost Low-Infrastructure Devices, such as Solar-Powered Pole-Mounted Traffic Sensors with Wireless Communications		2			1 $		2	
4.2.1.9	Utilize Predictive Analysis and Forecasting for Anticipating Congestion		2	2	2	1	2		

Key: 1 = Primary trend that strategy addresses
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Table 2: Top Trends with Applicable Strategies to be Considered by TMC Operators (continued)

		A Nimble Service-Oriented Program Mindset and Organizational Structure	Active Transportation and Demand Management (ATDM) Concept and Toolkit	Accommodating Toll and other Pricing Operations in TMCs	Performance Monitoring and Management	Automation Tools and Related Tools to Increase Efficiency	Involvement of Third Parties in Data and Traveler Information	Mobile Communications and Wireless Networks	Social Media for Traveler Information and Crowd sourcing
4.2.1.10	Because the Private Sector Often Develops the Automation Tools, Support Strong Participation to Provide Better Tailored Tools	2				1	2		
4.2.1.11	Include Options for Manual Verification and Override to be used as Operators Fine Tune and Gain Confidence in New Applications		2			1			
4.2.1.12	Develop a Data Fusion Engine to Merge Data from Multiple Sources, such as Travel Time Information Coming from Toll Tag Readers, Bluetooth Sensors, and/or Third-Party Providers		2		2	1 $	2		
4.2.2.1	Develop Pre-qualifications or Standards Regarding Data Accuracy and Validation (Potentially Both for Data Received and Data Provided)				2		1		
4.2.2.2	Provide Real-Time Data to Third Party App Developers					2	1		2
4.2.2.3	Share Data Among Agencies	2					1 $		2
4.2.2.4	Develop Protocols for Data Privacy and Confidentiality, including for Media and other Agencies Co-located in the TMC Observing otherwise Restricted Material						1		2
4.2.2.5	Utilize Private Sector Meteorological Services or In-House Meteorological Resources		2				1		
4.2.2.6	Research Solutions that Others have used to Solve Similar Problems	2 $	2 $	2 $	2 $	2 $	1 $	2 $	2 $
4.2.2.7	Use Multi-Agency Procurement for Economies of Scale	2					1 $	2	
4.2.2.8	Train TMC Operators on How to Interpret Alternate Data Sources to Support Operations Decision Making		2	2			1		
4.2.2.9	Consider Use of Applicable Standards to Simplify Data Exchange, such as XML					2	1		

Key: 1 = Primary trend that strategy addresses
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Table 2: Top Trends with Applicable Strategies to be Considered by TMC Operators (continued)

		A Nimble Service-Oriented Program Mindset and Organizational Structure	Active Transportation and Demand Management (ATDM) Concept and Toolkit	Accommodating Toll and other Pricing Operations in TMCs	Performance Monitoring and Management	Automation Tools and Related Tools to Increase Efficiency	Involvement of Third Parties in Data and Traveler Information	Mobile Communications and Wireless Networks	Social Media for Traveler Information and Crowd sourcing
4.2.3.1	Coordinate with Information Technology (IT) Staff to Develop Firewalls and Other Security Protocols that are Effective without Limiting Functionality						2	1	
4.2.3.2	Efficiently Expand Field Device Coverage and Operations Cost Using Wireless Networks	2						1 $	
4.2.3.3	Allow Appropriate Remote Access into TMC Software or Devices (primarily for Maintenance Staff and Appropriate Coordinating Staff from Partner Agencies)	2 $						1 $	
4.2.3.4	Utilize Commercial Mobile Devices and Apps to Support Collaboration between Freeway Service Patrol and Other Emergency Responders, TMC Operations Staff, and Field Maintenance Staff for Improved Communication and Enhanced Field Collaboration						2	1	
4.2.3.5	Operate Mobile Command Centers or Satellite Centers with TMC Software Access	2						1	
4.2.4.1	Develop Procedures and Protocols for Use of Social Media	2							1
4.2.4.2	Foster Relationship among Agency Public Relations Groups	2							1
4.2.4.3	Co-Locate Traveler Information Provider Staff with TMC Staff and Agency Public Relations Staff						2 $		1 $
4.2.4.4	Support Two-Way Information Exchange Via Social Media								1
4.2.4.5	Designate a Larger or Statewide TMC to Take Responsibility for Social Media Alerts on Behalf of Multiple Agencies in a Region								1 $

Key: 1 = Primary trend that strategy addresses
2 = Secondary trend that strategy addresses
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Table 2: Top Trends with Applicable Strategies to be Considered by TMC Operators (continued)

		A Nimble Service-Oriented Program Mindset and Organizational Structure	Active Transportation and Demand Management (ATDM) Concept and Toolkit	Accommodating Toll and other Pricing Operations in TMCs	Performance Monitoring and Management	Automation Tools and Related Tools to Increase Efficiency	Involvement of Third Parties in Data and Traveler Information	Mobile Communications and Wireless Networks	Social Media for Traveler Information and Crowd sourcing
4.2.4.6	Provide Information through Social Media and Mobile Apps Focused on Pre-trip Planning to Minimize Driver Distraction (Near Term)								1
4.2.4.7	Utilize En-route Social Media (including Crowd sourcing) as Voice Activation Becomes More Common (Longer Term)					2		2	1
4.2.4.8	Utilize Crowd sourcing for traffic information, incident information, feedback on department performance, pavement roughness				2			2	1 $
4.2.4.9	Provide Incentive for Drivers to Participate in Crowd sourcing	2					2		1
4.2.4.10	Partner with the Private Sector to Facilitate Social Media Outlets and Realize Cost Efficiencies.					2	2		1 $
4.2.4.11	As More Traveler Information Content is Available to Travelers through Third-Party Apps, TMCs Can Focus on Providing Content on Core Mission (Such as Upcoming Construction and Estimated Time to Reopen Lanes)	2					2		1

Key: 1 = Primary trend that strategy addresses
2 = Secondary trend that strategy addresses
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Chapter 5
Program-Level Implementation and Integration

In Chapter 3, top trends of TMC operations were identified and in Chapter 4 individual strategies were presented to assist TMC managers with addressing the trends. Chapter 5 recognizes that tools are needed at a program-level that support implementation of the set of strategies selected. The purpose of Chapter 5 is to identify some of the tools that can help TMC managers in implementing these strategies.

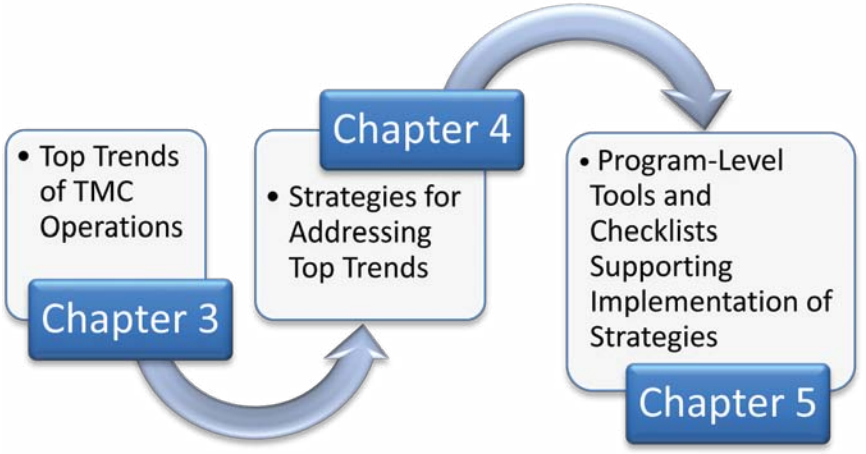

Figure 11: Chapter 3, 4, and 5 Flow

(Source: Parsons Brinckerhoff)

Chapter 5 discusses two areas of the supporting organizational change:

- Technological and internal processes that can typically be applied directly by the TMC manager; and
- Coordination of TMC processes within the broader organizational context.

The two program level categories presented here should not be viewed as independent, but rather should be coordinated in implementation. For example, each TMC manager will have his or her own unique views on how to improve operations while satisfying drivers' needs for instantaneous information. However, cautious consideration should be given to local and regional transportation issues. The TMC managers' preferred technological implementation approach should first be an

The checklists are starting points for TMC Managers to use to examine their current practices and investigate tools that can support implementation of strategies that will help them address the top trends they are expected to face over the next decade.

assessment of the current technology environment both internal and external to the agency and identify ways to make smart investments in the right technologies that align with agency policies and strategic business goals, such as performing a cost benefit analysis of specific ITS projects to aid in short-term and long-range project planning.

For both of these areas, there is a section that includes applicable tools followed by a section with a corresponding checklist. The checklists are starting points for TMC managers to use to examine their current practices and investigate tools that can support implementation of strategies that will help them address the top trends they are expected to face over the next decade. Some TMCs will already perform items on the checklists. In such cases, managers are encouraged to continue using them, appreciating their importance for adapting to technological change. Some TMC will have unique characteristics that require modifications and additions. However, on the whole, the checklist items will provide a strong base that TMC managers can use to help implement the strategies they select.

5.1 Internal TMC Processes

5.1.1 Description

The purpose of this section is to present ideas on how TMC managers can best use the resources within their control to implement new strategies and successfully integrate them into daily TMC operations. The intent is to provide an overall sense of the actions that will result in an environment that will encourage innovation and facilitate the use of technology that results from the trends identified in Chapter 3.

These tools may be self evident for many TMC managers who have progressed through positions at the TMC or who are in other operations positions. Many are simply good management practices. However, it is still worthwhile to keep them in mind and pay attention to them. They may be easy to put off considering how busy most TMC managers are and the number of urgent issues that surface nearly every day in a TMC. However, using these tools can be of utmost importance in the long term and when considering how to make best use of new technological developments.

5.1.2 Tools

The tools for technological and internal process can be thought of in three categories – technical processes, being prepared (plans and readiness), and staff development.

Technical processes are used to make sure the TMC implements new systems and technologies *in ways that will facilitate integration* and *allow for continued innovation*.

Developing **plans** covering technology advances are forward looking actions that *prepare TMC managers* and staffs *for deploying* new technologies, systems, and subsystems.

Staff development provides a *strong base* from which operations staff *can effectively implement and operate* new systems and technologies.

The highlighted tools for each are shown in Figure 12 and described further below.

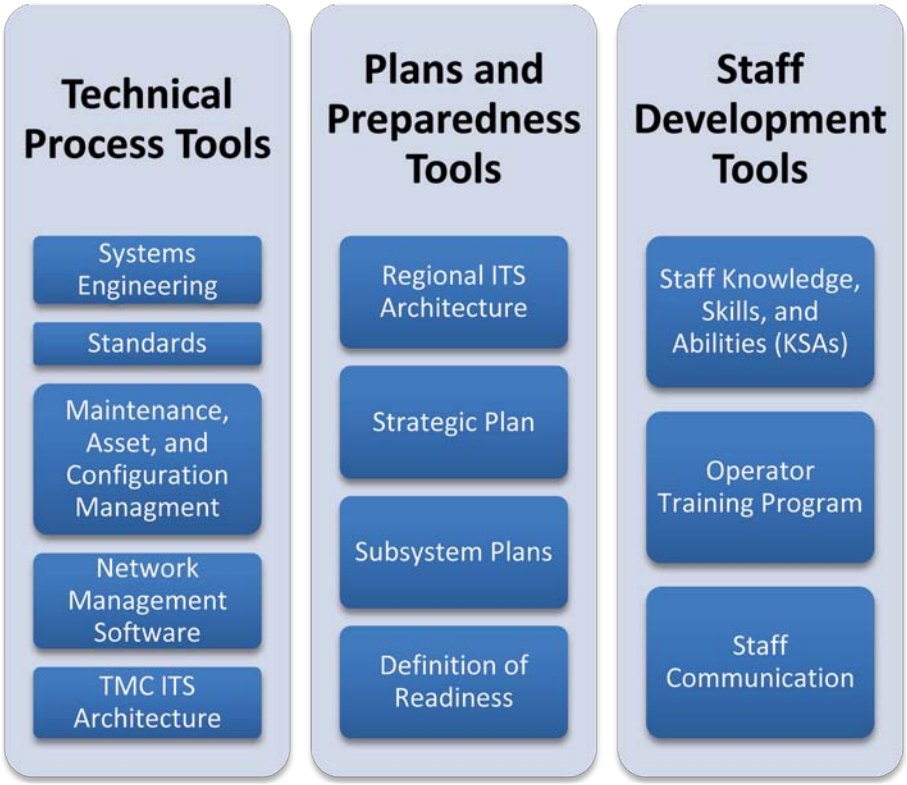

Figure 12: Internal TMC Process Tools

(Source: Parsons Brinckerhoff)

- **Systems Engineering –** The systems engineering process provides a framework for helping select key strategies, and then successfully implementing technologies and systems. It guides the agency in evaluating needs, translates the needs into requirements, and traces requirements through design and implementation. The requirements are then tested, verified, and validated to make sure that the needs that were originally identified are addressed in the implemented system. The systems engineering process is particularly important when new technology is deployed because less is known about the new technology and implementers may not be able to fall back on previous experience to deliver success. The systems engineering process should be used throughout the entire lifecycle of a project and not just done

at the beginning of a project to check off a box. Oftentimes, personnel who are responsible for project development and implementation are not part of the TMC and may not fully understand TMC day-to-day operations. By requiring that the systems engineering process be followed, identifying user needs of the TMC and the TMC staff are integral to the development of the project concept and are woven into all aspects of the project.

- **Standards –** ITS standards, other communications standards, and equipment standards can support interoperability among disparate equipment and systems. They are especially important when hardware is procured through low-bid contracts. They also have the potential to manage the size of spare equipment inventories.

- **Maintenance, Asset, and Configuration Management –** The rapid changes in technology advancements make it necessary to consider robust asset and configuration management programs. As agencies deploy devices and technological systems throughout their jurisdiction, it is critical to not only keep track of physical placement and configuration, but from a software and firmware angle to keep track of version control. Many devices can offer expanded or enhanced capabilities simply through software or firmware upgrades, and keeping track of the logical configuration is now of equal importance to keeping track of physical configuration. In addition, new technology often brings with it unknown life-cycle needs, which can be evaluated and tracked through proper maintenance management processes and systems.

- **Ethernet Network Management Software –** For Ethernet networks, management software is a valuable tool for evaluating available network capacity when considering additional systems, maintaining IP address records during deployments, supporting acceptance testing, monitoring network uptime, and trouble-shooting faults.

- **TMC ITS Architecture –** The TMC ITS Architecture includes the data flows, standards, and interfaces among TMC systems and subsystems. As in the Regional ITS Architecture, it includes both existing and planned components.

- **Regional ITS Architecture –** Each region should have an ITS architecture in place. The TMC is likely to be a central concept in the architecture. The architecture illustrates the functions and subsystems that have been determined to be part of the long-term ITS program in the region. The architecture identifies key interfaces that are needed to implement the ITS program. Standards for these

interfaces are also identified. Keeping the architecture current and following the architecture when new technologies and systems are implemented maximizes the likelihood of successful integration of new technology and reduces the cost and difficulties in deploying new technologies.

- **Strategic Plan –** Developing a strategic plan for the TMC will focus on near-term vision (generally 2 to 5 years). The strategic plan will look at developments and conditions that are likely over the timeframe of the plan. This will allow the TMC manager to look ahead and to plan actions and activities that will further the TMCs goals and objectives over that time period. A strategic plan is critical in positioning the TMC to adapt to and utilize new technologies and impacts of new technologies. It also often supports funding requests. It is the look-ahead that helps prepare the TMC and its staff for upcoming developments and changes that will affect the operation and success of the TMC.

- **Subsystem Plans –** The strategic plan should cover all aspects of the TMC and its subsystems. However, some functions and subsystems within the TMC may need specialized plans, especially when a major effort to implement or update these functions or subsystems is underway. Examples of subsystems that may warrant a specialized plan include traffic incident management, ramp metering, and traveler information. It is especially important to have these specialized plans for subsystems that involve multiple agencies, include private sector participation, or require significant public involvement and information. Subsystem plans should identify technologies that can be used and what technologies are evolving that may allow objectives to be more effectively met.

- **Clear Definition of Deployment "Readiness"–** Whenever a system is implemented or expanded, it is important to know when the system is ready for deployment and initial activation. It is important that all necessary functions of the system will operate correctly, that interfaces with field equipment and other systems work properly, and that staff know what they need to do under a wide array of conditions that could occur during system operation. Clearly defining readiness identifies system capabilities and correlates those capabilities with conditions that could occur during operation. Checklists of activities that are needed to assure readiness can be developed. Activities include installation, testing, staff training, agency coordination, and possibly public information.

- **TMC Staff Knowledge, Skills, and Abilities (KSAs) –** It is critically important that TMC staff, including the manager, have the needed skills and abilities to make the best use of new technologies that may be implemented. As strategic plans and subsystem plans are developed, skills needed by staff should be identified. A comparison of the needed knowledge, skills, and abilities can be compared to existing staff KSAs to identify gaps that need to be filled. Identifying KSAs are a needed first step in identifying and providing training that will allow staff to make the use of the full capabilities of technologies and systems implemented through the TMC. The KSAs should be identified by specific role, position or task within the TMC.

- **Regularly Scheduled Operator Training Program –** After identifying the KSAs that are needed by TMC staff, it is important to identify ways that staff can acquire the KSAs. Training programs, either formal or informal, are the typical ways to develop staff with the needed KSAs. Training programs should be identified for the full breadth of KSAs needed at the TMC. The programs can include a set of specific training courses that are needed or a set of tasks that need to be completed in a less formal way to acquire the KSAs. However, it is important that specific mechanisms are identified to each KSA that is identified. The KSAs should include knowledge of and skills needed to operate emerging technologies. Debriefing after major events, system activation, or other critical activities is one of the best training opportunities. Debriefing is also a key to any process improvement activity.

- **Staff Communication –** It is critical that the staff of the TMC is aware of developments that are imminent or on the horizon. This includes technologies that are planned to be implemented or are being considered. Staff will be more involved and have a stronger sense of ownership. In addition, staff may be able to identify promising technologies that should be considered. Open communication with staff is a key component of a vital staff that is able to adapt to changes and the adoption of new techniques and technologies.

5.2 TMC Manager Checklists for Internal Processes

The set of checklists in this section apply to technological and internal processes that are typically under the purview of the TMC manager. This is in contrast with sections 5.3 and 5.4 which focus instead on coordination of the TMC manager's activities with external processes and the broader organizational context.

Table 3 Internal TMC Process Checklist for Technical Processes	
❍	**Develop specific systems engineering actions tailored to your TMCs' processes**
	◇ TMC role in system/project requirements definition
	◇ TMC role in system/project implementation
	◇ TMC role in system/project integration
	◇ TMC role in system/project verification and testing
	◇ TMC role in system/project operations and maintenance
❍	**Adopt standards and include them in applicable agency specifications**
	◇ National ITS standards
	◇ Ethernet networking, including network architecture and IP addressing schemes
❍	**Implement maintenance, asset, and configuration management systems**
	◇ Link maintenance management system to developed data quality standards
❍	**Use Ethernet network management software**
❍	**Develop ITS Architecture for the TMC and its systems**
	◇ Assure that the TMC architecture is consistent with the Regional ITS Architecture
	◇ Review and update the TMC architecture when new systems are implemented

Table 4 Internal TMC Process Checklist for Plans and Preparedness	
❍	**Actively use and update the ITS Architecture**
	◇ Review contents, including any standards for data interfaces
	◇ Document needed updates to reflect current conditions
	◇ Participate in ITS Architecture revision activities
	◇ Propose updates including desired data flows, systems/processes, partner agencies, interfaces, and standards
	◇ Use ITS Architecture to support applicable funding requests
❍	**Prepare and update TMC Strategic Plan**
	◇ Include short-term TMC vision and goals
	◇ Include opportunities for funding support
	◇ Highlight ways that TMCs can position themselves to adapt to new technologies
❍	**Prepare subsystem plans**
	◇ Create a technology-focused plan for traffic incident management
	◇ Create a technology-focused plan for ramp metering
	◇ Create a technology-focused plan for disseminating traveler information
	◇ Create a plan for incorporating multi-agency and private sector participation
	◇ Create a plan for handing input obtained through public involvement
❍	**Create clear definitions of "Readiness" for each system to be deployed**
	◇ Include new TMC processes or procedures to support new or expanded system
	◇ Request specific technical experiences to be shared through outside agency TMC operator-designed webinars to highlight system challenges and benefits
	◇ Collaborate across multiple agencies on new system rollouts and discuss technical challenges, operational strategies, and opportunities for operator training

Table 5 Internal TMC Process Checklist for Staff Development	
❍	**Develop Staff Knowledge, Skills, and Abilities (KSAs) and updated position descriptions**
	◇ Include operators, managers, field technicians, and other related staff
	◇ Collaborate with staff to accurately capture and document job duties and functions
	◇ Initiate personnel outreach to discuss operations, position descriptions, and career paths
	- Obtain job descriptions from similar TMC environments
	- Work with Human Resources to implement updated position descriptions
❍	**Create a regularly scheduled TMC operator training program**
	◇ Formalize a training program for supervisors to implement with operators
	◇ Evaluate gaps between staff qualifications and desired KSAs to identify training topics
	◇ Use data from system performance management to identify training topics and underscore influence operators have on agency goals
	◇ Have documentation of emerging technology training available for new employees
	◇ Prepare a “quick start” operations guide for staff unfamiliar with system, or staff that does not routinely use system. Focus on troubleshooting and basic system functions
	◇ Integrate TMC staff with broader departmental training initiatives (project management, leadership training, communications training)
❍	**Promote staff communication**
	◇ Schedule periodic staff meetings to encourage open communication
	◇ Promote knowledge transfer and TMC staff leadership of technical discussions
	◇ Share relevant performance data, including operational performance data, TMC performance data, and customer feedback
	◇ Conduct debriefings with TMC staff on major incidents and TMC processes during these incidents
	- Lessons learned and potential improvements
	- Document and acknowledge successes
	- Seek periodic input from police, fire, or other first-responders to ensure mutual needs are met
	- Encourage participation and feedback on changes or process improvements
	◇ Involve key contractors that are housed in the TMC (sometimes there is a definitive line between DOT and contractor staff)
	◇ Seek out opportunities for the TMC to be represented in broader organizational meetings (i.e., Communications/PIO, IT)
	◇ Update TMC staff with important initiatives or activities at the department level

5.3 Coordination of TMC Processes with the Broader Organizational Context

5.3.1 Description

This section presents ideas on how TMC managers can increase the support for the TMC and the systems and activities housed therein.

All of the strategies and technological changes identified in the previous chapter require TMC managers to be aware of current and evolving changes in technology and to have some idea of what operational changes they want to make. TMC managers usually cannot fund and implement these strategies with the budgets given them. They have to garner support from agency executives, partner agencies, and decision-makers in order to fund these activities and projects. It is important to have a coherent, compelling plan (or set of plans) that provide a vision for the role of the TMC and how it can enhance the performance of the transportation network.

TMC managers should research what other agencies with similar transportation issues have done, not only to discover solutions, but also to substantiate their proposals for adopting new technologies that benefit operations, travelers, and the community.

Knowledge of other local and regional agencies' operations functions, procedures, processes, what their needs are along with what they can offer to others is extremely valuable in giving TMC managers direction on how to lead the TMC in responding to local transportation needs. It is evident that there are infinitely more benefits to agencies that have shared vision and values. The shared vision and values are realized through agency coordination agreements, whether it be inter-agency, inter-state, inter-system, such as tolling, or multi-state contracts.

The local and regional transportation issues vary across TMCs and the TMC manager knows which issues are of utmost concern to their agency. Common issues agencies deal with include reduced operating budgets and funding sources, decreased staffing levels, lack of effective projects and programs in the pipeline that improve roadway operations, driver safety and environmental concerns, and even a shift of drivers utilizing multiple modes of transportation all in one trip. TMC managers should research what other agencies with similar transportation issues have done, not only to discover solutions, but also to substantiate their proposals for adopting new technologies that benefit operations, travelers, and the community.

5.3.2 Tools

These tools are primarily intended to help TMC managers enhance the position of the TMC in their agency and in the transportation community at large. The tools can be thought of in three categories - planning, visibility, and communication. These tools are geared to increase the visibility of the TMC and highlight the transportation benefits the TMC provides.

Planning tools are effective management tools that apply business planning principles to help strategize on ways to incorporate new technology strategies focused on achieving TMC and agency-wide goals.

Actions that increase the **Visibility** of the TMC and emphasize the critical role that TMC managers and staff play in providing valuable services to the public can support funding requests for implementing new technologies and generally maintaining agency support.

Communication tools are significant ways that TMC managers can establish a network to effectively communicate TMC purpose, visions and objectives to others.

The highlighted tools for each are shown in Figure 13 and described further below.

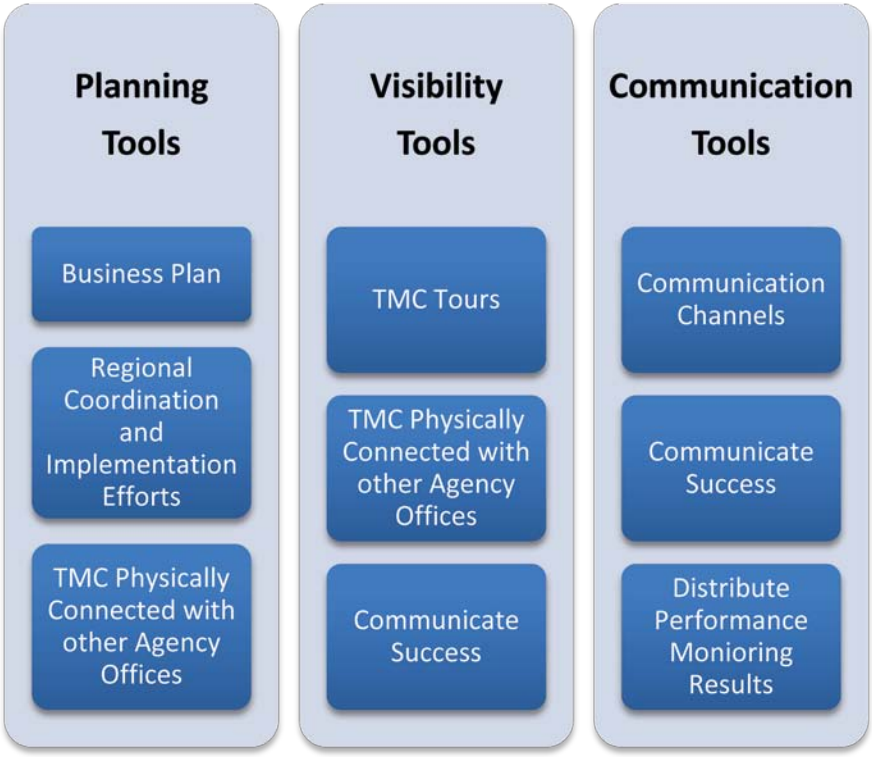

Figure 13: Broader Organization Context Tools

(Source: Parsons Brinckerhoff)

- **Business Plans –** In the previous section, plans are highlighted that are primarily geared internally to TMC operations (strategic plans and subsystem plans). It is also important to develop business plans that can be geared toward external audiences to show how the TMC can meet larger agency and regional goals and objectives. Business plans are often written specifically for external audiences and they demonstrate the value of the TMC.

- **Regional Coordination and Implementation Efforts –** these efforts include multi-agency traffic incident management (TIM) strategic plans or TIM coalition initiatives. There are many examples of multi-state efforts (for example, the I-95 Corridor Coalition, Northwest Passage, and ENTERPRISE) and even more examples of multi-agency efforts within a single metropolitan region. TMCs play a key role in developing these coordinated programs. By being at the core of the regional efforts, the TMC increases its visibility within its agency and with decision-makers in partner agencies.

- **TMC Tours –** Tours may seem like an added burden, but the value to the organization is significant. Tours for groups within the agency provides an opportunity to educate staff from other divisions and groups about the value of the TMC. Tours for external groups, if communicated to agency management, demonstrates the value of the TMC. If outside groups and agencies, especially from other states or countries, want to visit your TMC, it must be worth visiting and the TMC must have value. It is important to let agency management know about tours from external groups, especially if senior or executive managers may know any of the people in the tour group.

- **Keeping TMC Physically Connected with Other Agency Offices –** Being physically located with an agency's main office can help prevent the TMC from suffering from organizational isolation. It is easier to rotate staff into and out of the TMC, increasing understanding of the role the TMC plays, its benefits, and its value to the organization. If the TMC can't be physically located with the main office, then robust communication links should exist. Although this strategy helps the visibility of the TMC and leads to stronger support of the TMC, the primary benefit is operational and strategic. The TMC has an incredibly rich set of data and tools that can help other disciplines in the agency and can be vital when decisions need to be made by executives in emergency situations.

- **Communication Channels –** Whether internal, to external partner agencies, or to decision-makers and elected officials, it is critically important to be aware of the proper communication channels and protocols to use. Effective communication to groups outside the TMC can be one of the most effective ways to garner support for the TMC and its programs. It is particularly important to utilize the appropriate channels and protocols when communicating with elected officials.

- **Communicate Success –** One of the trend areas is performance management. A key aspect of monitoring performance is measuring performance. It is important to communicate the successes that are demonstrated by the performance management system. Objective measures of the benefits of the TMC and its systems and programs are data that can be used in communicating success. But, subjective measures are also important, such as positive communications from the public, commendations from national organizations, and thank-you letters from groups that tour the TMC. One approach to communicating success is to generate a regular internally distributed bulletin about TMC successes. In addition to performance measures, kudos, and commendations, narrative about critical roles the TMC played during a major incident, storm event, or other emergency demonstrate the successes of the TMC.

- **Distribute Performance Monitoring Results –** In communicating success, it is important to communicate with easy to understand terminology and graphics. Keep in mind that some of the performance measures may be technical in nature. Keeping the writing and graphics simple and easy to understand will maximize the audience that can be targeted with these results and successes.

5.4 TMC Manager Checklists for Coordination of TMC Processes within the Broader Organizational Context

These checklists highlight the activities TMC managers should focus on for coordination and integration of external processes within the broader organizational context of the transportation industry.

Table 6 Broader Organizational Context Checklist for Planning	
❍	**Develop TMC Business Plan**
	◇ Base the business plan on agency goals and objectives
	◇ Demonstrate in the plan how the TMC supports and furthers agency goals and objectives
	◇ Include plan for long-range TMC vision and goals
	◇ Outline requirements for executing the plan, such as operational, staffing, and interface requirements
	◇ Use Checklist for Identifying Strategies to determine those strategies that will translate into specific action items
❍	**Initiate involvement in developing coordinated regional programs**
	◇ Assign a TMC representative to attend regional planning meetings that have other local agencies, commissions, and councils on the roster
	◇ Research lessons learned on establishing multi-agency programs
❍	**Volunteer TMC data and decision support tools to other agency divisions**
	◇ Volunteer decision support tools to help create annual maintenance and preservation budgets
	◇ Share historic traffic data in strategic planning situations

Table 7 Broader Organizational Context Checklist for Visibility	
❍	**Assume a principal role in regional planning efforts**
❍	**Conduct tours of the TMC with other agency staff**
	◇ Reach out to other agency divisions or regions and offer to host a tour
	◇ Distribute Fact Sheet on TMC devices as a form of calling card
❍	**Volunteer to conduct tours of the TMC with external agencies and groups**
	◇ Reach out to the local community to start “marketing” efforts
	◇ Reach out to local colleges and universities to generate interest in TMC data and operations from undergrads and researchers
	◇ Designate a webpage on the TMC within the agency website.
	◇ Engage the local media in doing a segment on “a day at the TMC”
❍	**Identify training opportunities that the TMC could initiate for internal agency staff in other departments, such as on traveler information tools and resources, TMC capabilities, and performance management**
❍	**When considering TMC location, consider the importance of co-locating with groups and divisions of your own agency, not just co-locating with other agencies**
❍	**Establish robust communication links between the TMC and other agency offices**

	◇ Develop remote access for software to transfer full control over TMC functions
❍	**Establish lines of communication between a designated point of contact at the TMC and external partner agencies and decision-makers**
	◇ The points of contact should be at the TMC manager level or a direct report.
❍	**Create a regularly distributed TMC bulletin on noteworthy news**
	◇ Highlight TMC successes and critical roles played during major events
	◇ Include excerpts of correspondence received from agencies that tour the TMC
	◇ Include positive feedback received from the public

Table 8 Broader Organizational Context Checklist for Communication	
❍	**Use proper communication channels and protocols for internal discussions regarding the TMC**
	◇ Establish these rules if they aren't documented
❍	**Follow the appropriate agency rules for communicating with elected officials**
❍	**Seek out opportunities for the TMC to be represented in broader organizational meetings (i.e., Communications/PIO, IT)**
❍	**Create reader-friendly performance monitoring reports in an easy to understand format**
	◇ Create visual analysis tool for recording TMC performance data
❍	**Develop procedures for collecting, analyzing, and distributing performance measures**
	◇ Examine internal and agency goals to determine appropriate metrics
	◇ Search existing processes and software for opportunities to collect data on metrics
	◇ Contribute to quarterly agency-published documents on congestion, mobility, accountability, and performance

Chapter 6
Summary and Conclusions

Chapter 6 highlights key concepts from the report and presents the resulting conclusions. It also presents a checklist of next steps for TMC managers on how to start using the report contents to affect the changes that will support their TMC operations.

6.1 Summary

Through preparing a literature review and consulting with experts, big picture influences were identified which, when coupled with ITS technologies and technological trends, created a basis for targeting top trends. The big picture influences were in three areas:

- **Societal and technological trends –** including rapid expansion of mobile communications, social media, computing, and automation tools;
- **Funding opportunities –** including tightening of governmental budgets, growing interest in pricing/tolling, and increasing requirements for performance monitoring and management; and
- **Vehicle-based systems –** including emerging connected vehicle technologies, developing autonomous vehicle technologies, and planning for integrated mobile devices and voice-activated technologies to mitigate distracted driving.

The ITS technologies and technological trends relevant to TMC operations were in the areas of data/communications, connected vehicle, agency processes, control technologies, and traveler information.

Eight top trends and issues of TMC operations were selected as the focus of the project. The selections were based on many factors including the big picture influences, the ITS influences, the magnitude of possible impacts, the frequency of citation in literature and by TMC operators, and the likelihood that the issue would be widely influential to TMCs within the project's 10-year horizon. The trends fall into two broad categories. The first is those predominantly developing in TMC operations from within the transportation community. The second is those trends emerging outside transportation that have aspects which TMCs can leverage. The trends are shown in Figure 14.

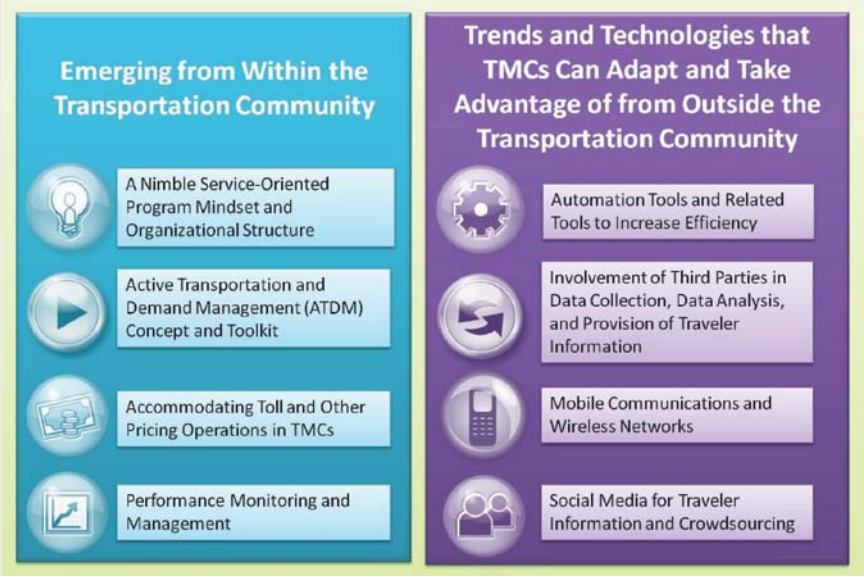

Figure 14: Top Trends and Issues of TMC Operations

(Source: Parsons Brinckerhoff)

Brief descriptions of each trend are as follows:

Trends Emerging from within the Transportation Community

- The **Nimble Service-Oriented Program Mindset and Organizational Structure** trend represented the framework of being positioned to successfully select and rapidly adopt changing technologies and processes to address growing and changing expectations from travelers for efficiency and communication.
- The core of the **Active Transportation and Demand Management (ATDM) Concept and Toolkit** trend is using a wide variety of the tools at one's disposal to proactively make operations more efficient, including through staff and technology.
- While TMC managers do not have authority to implement toll operations, the strong trend toward integrating pricing makes it important that TMC managers begin to consider **Accommodating Toll and Other Pricing Operations in TMCs**. The limited funding from traditional sources encourages obtaining revenue through tolling, including financing infrastructure expansion based on the expected toll revenue stream.
- **Performance Monitoring and Management** is influenced by funding pressures as a result of reduced operating budgets along with the need for greater accountability. Increasing data collection and analysis can lead to improved operations, enhanced customer service, and documented effectiveness of TMC actions.

Trends that TMCs can Adapt and Take Advantage of from outside the Transportation Community

- The **Automation Tools** trend includes new technologies that improve system management and cost-effectiveness thus resulting in greater productivity. Automation tools also improve the quality of decision support systems.
- The growing trend of the **Involvement of Third Parties in Data Collection, Data Analysis, and Provision of Traveler Information** to meet the TMC's needs for a variety of data types utilizes the data services that third-party vendors provide to manage traffic on their roadway network and deliver traveler information to the public.
- The **Mobile Communications and Wireless Networks** trend highlights the advances in wireless technology that are giving agencies options when it comes to modernizing their field equipment and increasing their data coverage while not overloading the system.
- The popular trend of using **Social Media for Traveler Information and Crowdsourcing** uses social networking tools to receive and distribute information among agencies, travelers, and third parties.

Several strategies are provided for addressing each trend. Descriptions include references to agencies with successful practices in the strategy as well as key reference documents were applicable.

A cross-listing of the trends with strategies to address them is provided in Table 2 in Section 4.3. Many of the strategies are applicable to more than one trend. The table provides a quick reference for looking up potential strategies to deal with a particular trend as well as considering how a particular strategy could be of assistance with several trends. The table also highlights strategy/trend pairs most likely to be feasible under limited budgets or to save on budget expenditures.

Adopting identified strategies as part of a program of progressive TMC operations over the coming decade is a major undertaking. Program-level implementation and integration tools help to establish a climate conducive to successful implementation, operations, and funding.

The tools for technological and internal processes that can typically be applied directly by the TMC manager are:

- Technical Process Tools: Systems Engineering, Standards, Maintenance, Asset, and Configuration Management, Network Management Software, and TMC ITS Architecture;
- Plans and Preparedness Tools: Regional ITS Architecture, Strategic Plan, System Plans, and Definition of Readiness; and

- Staff Development Tools: Staff Knowledge, Skills, and Abilities (KSAs), Operator Training Program, and Staff Communication.

The second set of tools is for coordination of TMC processes with the broader organizational context in order to increase support for the TMC's programs, systems, and staff. They are:

- Planning Tools: Business Plan, Regional Coordination and Implementation Efforts;
- Visibility Tools: TMC Tours, Keeping the TMC Physically Connected with Other Agency Offices; and
- Communication Tools: Communication Channels, Communicate Success, Distribute Performance Monitoring Results.

Implementing these tools builds a framework for successful deployments of the strategies that allow TMC operators to take advantage of trends and technology in fulfilling their missions.

6.2 TMC Manager Programmatic Checklist of Recommended Actions

These checklists are intended to help TMC managers get the most out of this report by recommending a process for recognizing trends and associated strategies that align with agency program goals and budgets while benefitting the transportation community as a whole.

Table 9 Recommended Actions Checklist for Selecting Strategies	
❍	**Use the Top Trends and Applicable Strategies table (Table 2) to identify trends that the TMC needs to prioritize**
	◇ Identify strategies for implementation under those trend headings
	◇ Focus on strategies that will have the most benefit within limited operating budgets
❍	**Think of agency constraints and how each strategy will create opportunities to move forward**
❍	**Consider the likelihood of the strategy meeting agency goals and objectives**
❍	**Compile supporting facts, reasoning, and justification for strategy implementation to present to decision-makers**
❍	**Devise a back-up plan if initial strategy selection is deemed infeasible by upper management**
❍	**Gather input from stakeholders on identifying strategies, including operators, maintenance and IT staff, traffic engineering, management, and others as appropriate**
❍	**Include selected strategies in TMC Business Plan**
❍	**Investigate funding mechanisms**

Table 10 Recommended Actions Checklist for Staying Informed on Technological Advancement	
❍	**Allocate time to participate in industry webinars and other trainings that offer direct access to experts**
❍	**Allocate time to read newsletters, reports, journals, e-mails, and websites from top industry associations**
	◇ Focus on gaining a high-level understanding rather than delving into specifics
	◇ Call upon colleagues, consultants, and vendors to clarify and/or share lessons learned
❍	**Activate society memberships to get updates on current technologies and standards**
❍	**Reach out to ITS device sales representatives for a demonstration of new products or product features**

Table 11 Recommended Actions Checklist within the Broader Organizational Context	
❍	**Be active in regional and national professional societies, user groups, associations, and governmental programs**
	◇ Share meeting minutes and notable highlights with other engineering staff

6.3 Conclusions

Successful practices in emerging technologies begin to show how TMC managers can harness technology to improve the effectiveness of their operations. As pressures mount, TMCs will need to implement suites of these technologies and processes to meet the needs within limited budgets. In order to make such changes, TMC managers need to develop the organizational structures and tools to deal with rapidly evolving technologies, processes, funding requirements, and customer service expectations.

Through a review of literature and consultation with experts, top trends and issues of TMC operations were identified and then corresponding strategies for addressing them were developed. The most profound trends are based on the proliferation of wireless communication, the rise of social media, and the involvement of third parties. Together, they create massive potentially two-way data and communication streams throughout the transportation network. New classes of real-time holistic data become available to TMC operations, often through third parties. As travelers access increasingly personalized and user-friendly information through their mobile device apps, their expectations for information provided by transportation agencies increases.

The implication is that the role of the TMC can begin to shift away from collecting limited data from agency-owned field equipment and distributing it one-way directly to consumers and traditional media outlets. It can shift toward leveraging third party data for increased variety and coverage while providing third parties with only the unique agency based information.

The major changes created by such technology trends may benefit from a multitude of strategies to address each of them. TMC managers should consider the strategies presented herein. Many of the strategies are applicable to more than one trend. A few examples of **successful practices** that agencies have implemented **that address multiple trends**, are:

- The use of **third-parties** for custom developed **Smartphone applications** to improve agency processes on systems integration and enhance traveler information through a more **comprehensive integration** of weather, real-time data, and operational decisions;
- A more prevalent **social media presence** that enables implementation of new ATDM technologies and the gathering of crowd-sourced data to boost **performance management**;
- More efforts at **inter-agency coordination**, co-location, and collaboration **across regions and state lines** for dissemination of traveler information and the efficient **exchange of data** through the use of mobile apps, and **teaming up for purchasing third-party data**; and

- The use of **decision support systems** for automating some TMC processes, additional support and guidance for special roadway traffic and weather circumstances, and to **facilitate system integration with tolling** and other pricing strategies.

A common theme of agencies that have demonstrated success with these strategies is that the TMC manager had the support he or she needed to make the underlying strategic and organizational changes. Strategic actions for each of the practices above dealt with an overall level of increased communication and collaboration within the agency and with other agencies to promote sharing of experiences, knowledge, and lessons learned. This formed a solid basis for interagency coordination and sharing of data. Successful TMC managers also shifted to a nimble service-oriented mindset that proactively sought to improve the transportation system.

Given the day-to-day pressures that TMC managers are inherently subject to, it is very helpful to commit to developing some specific tools, such as developing a TMC ITS Architecture, which will require a thoughtful examination of needs and opportunities. Developing these tools will help position the TMC managers to select and successfully implement technologies and strategies that fit their agencies goals and objectives. The tools geared toward coordinating within the broader organizational context will also facilitate the needed institutional support and funding.

The impacts of technology trends on the operation of individual TMCs depend on how well each TMC positions itself to seize the opportunities offered by technology trends rather than to be overwhelmed by it and the related rising expectations from funding agencies and travelers.

Chapter 7
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Appendix A
TMC Manager Checklists for Internal Processes

Internal TMC Process Checklist for Technical Processes	
❍	**Develop specific systems engineering actions tailored to your TMCs' processes**
	◇ TMC role in system/project requirements definition
	◇ TMC role in system/project implementation
	◇ TMC role in system/project integration
	◇ TMC role in system/project verification and testing
	◇ TMC role in system/project operations and maintenance
❍	**Adopt standards and include them in applicable agency specifications**
	◇ National ITS standards
	◇ Ethernet networking, including network architecture and IP addressing schemes
❍	**Implement maintenance, asset, and configuration management systems**
	◇ Link maintenance management system to developed data quality standards
❍	**Use Ethernet network management software**
❍	**Develop ITS Architecture for the TMC and its systems**
	◇ Assure that the TMC architecture is consistent with the Regional ITS Architecture
	◇ Review and update the TMC architecture when new systems are implemented

Internal TMC Process Checklist for Plans and Preparedness	
❍	**Actively use and update the ITS Architecture**
	◇ Review contents, including any standards for data interfaces
	◇ Document needed updates to reflect current conditions
	◇ Participate in ITS Architecture revision activities
	◇ Propose updates including desired data flows, systems/processes, partner agencies, interfaces, and standards
	◇ Use ITS Architecture to support applicable funding requests
❍	**Prepare and update TMC Strategic Plan**
	◇ Include short-term TMC vision and goals
	◇ Include opportunities for funding support
	◇ Highlight ways that TMCs can position themselves to adapt to new technologies
❍	**Prepare subsystem plans**
	◇ Create a technology-focused plan for traffic incident management
	◇ Create a technology-focused plan for ramp metering
	◇ Create a technology-focused plan for disseminating traveler information
	◇ Create a plan for incorporating multi-agency and private sector participation
	◇ Create a plan for handing input obtained through public involvement
❍	**Create clear definitions of "Readiness" for each system to be deployed**
	◇ Include new TMC processes or procedures to support new or expanded system
	◇ Request specific technical experiences to be shared through outside agency TMC operator-designed webinars to highlight system challenges and benefits
	◇ Collaborate across multiple agencies on new system rollouts and discuss technical challenges, operational strategies, and opportunities for operator training

Internal TMC Process Checklist for Staff Development
❍ **Develop Staff Knowledge, Skills, and Abilities (KSAs) and updated position descriptions**
◇ Include operators, managers, field technicians, and other related staff
◇ Collaborate with staff to accurately capture and document job duties and functions
◇ Initiate personnel outreach to discuss operations, position descriptions, and career paths
- Obtain job descriptions from similar TMC environments
- Work with Human Resources to implement updated position descriptions
❍ **Create a regularly scheduled TMC operator training program**
◇ Formalize a training program for supervisors to implement with operators
◇ Evaluate gaps between staff qualifications and desired KSAs to identify training topics
◇ Use data from system performance management to identify training topics and underscore influence operators have on agency goals
◇ Have documentation of emerging technology training available for new employees
◇ Prepare a “quick start” operations guide for staff unfamiliar with system, or staff that does not routinely use system. Focus on troubleshooting and basic system functions
◇ Integrate TMC staff with broader departmental training initiatives (project management, leadership training, communications training)
❍ **Promote staff communication**
◇ Schedule periodic staff meetings to encourage open communication
◇ Promote knowledge transfer and TMC staff leadership of technical discussions
◇ Share relevant performance data, including operational performance data, TMC performance data, and customer feedback
◇ Conduct debriefings with TMC staff on major incidents and TMC processes during these incidents
- Lessons learned and potential improvements
- Document and acknowledge successes
- Seek periodic input from police, fire, or other first-responders to ensure mutual needs are met
- Encourage participation and feedback on changes or process improvements
◇ Involve key contractors that are housed in the TMC (sometimes there is a definitive line between DOT and contractor staff)
◇ Seek out opportunities for the TMC to be represented in broader organizational meetings (i.e., Communications/PIO, IT)
◇ Update TMC staff with important initiatives or activities at the department level

Appendix B

TMC Manager Checklists for Coordination of TMC Processes within the Broader Organizational Context

Broader Organizational Context Checklist for Planning	
❍	**Develop TMC Business Plan**
	◇ Base the business plan on agency goals and objectives
	◇ Demonstrate in the plan how the TMC supports and furthers agency goals and objectives
	◇ Include plan for long-range TMC vision and goals
	◇ Outline requirements for executing the plan, such as operational, staffing, and interface requirements
	◇ Use Checklist for Identifying Strategies to determine those strategies that will translate into specific action items
❍	**Initiate involvement in developing coordinated regional programs**
	◇ Assign a TMC representative to attend regional planning meetings that have other local agencies, commissions, and councils on the roster
	◇ Research lessons learned on establishing multi-agency programs
❍	**Volunteer TMC data and decision support tools to other agency divisions**
	◇ Volunteer decision support tools to help create annual maintenance and preservation budgets
	◇ Share historic traffic data in strategic planning situations

Broader Organizational Context Checklist for Visibility	
❍	**Assume a principal role in regional planning efforts**
❍	**Conduct tours of the TMC with other agency staff**
	◇ Reach out to other agency divisions or regions and offer to host a tour
	◇ Distribute Fact Sheet on TMC devices as a form of calling card
❍	**Volunteer to conduct tours of the TMC with external agencies and groups**
	◇ Reach out to the local community to start "marketing" efforts
	◇ Reach out to local colleges and universities to generate interest in TMC data and operations from undergrads and researchers
	◇ Designate a webpage on the TMC within the agency website.
	◇ Engage the local media in doing a segment on "a day at the TMC"
❍	**Identify training opportunities that the TMC could initiate for internal agency staff in other departments, such as on traveler information tools and resources, TMC capabilities, and performance management.**
❍	**When considering TMC location, consider the importance of co-locating with groups and divisions of your own agency, not just co-locating with other agencies.**
❍	**Establish robust communication links between the TMC and other agency offices**
	◇ Develop remote access for software to transfer full control over TMC functions
❍	**Establish lines of communication between a designated point of contact at the TMC and external partner agencies and decision-makers**
	◇ The points of contact should be at the TMC manager level or a direct report.
❍	**Create a regularly distributed TMC bulletin on noteworthy news**
	◇ Highlight TMC successes and critical roles played during major events
	◇ Include excerpts of correspondence received from agencies that tour the TMC
	◇ Include positive feedback received from the public

Broader Organizational Context Checklist for Communication	
❍	**Use proper communication channels and protocols for internal discussions regarding the TMC**
	◇ Establish these rules if they aren't documented
❍	**Follow the appropriate agency rules for communicating with elected officials**
❍	**Seek out opportunities for the TMC to be represented in broader organizational meetings (i.e., Communications/PIO, IT)**
❍	**Create reader-friendly performance monitoring reports in an easy to understand format**
	◇ Create visual analysis tool for recording TMC performance data
❍	**Develop procedures for collecting, analyzing, and distributing performance measures**
	◇ Examine internal and agency goals to determine appropriate metrics
	◇ Search existing processes and software for opportunities to collect data on metrics
	◇ Contribute to quarterly agency-published documents on congestion, mobility, accountability, and performance

Appendix C

TMC Manager Programmatic Checklist of Recommended Actions

Recommended Actions Checklist for Selecting Strategies	
❍	**Use the Top Trends and Applicable Strategies table (Table 2) to identify trends that the TMC needs to prioritize**
	◇ Identify strategies for implementation under those trend headings
	◇ Focus on strategies that will have the most benefit within limited operating budgets
❍	**Think of agency constraints and how each strategy will create opportunities to move forward**
❍	**Consider the likelihood of the strategy meeting agency goals and objectives**
❍	**Compile supporting facts, reasoning, and justification for strategy implementation to present to decision-makers**
❍	**Devise a back-up plan if initial strategy selection is deemed infeasible by upper management**
❍	**Gather input from stakeholders on identifying strategies, including operators, maintenance and IT staff, traffic engineering, management, and others as appropriate**
❍	**Include selected strategies in TMC Business Plan**
❍	**Investigate funding mechanisms**

Recommended Actions Checklist for Staying Informed on Technological Advancement	
❍	**Allocate time to participate in industry webinars and other trainings that offer direct access to experts**
❍	**Allocate time to read newsletters, reports, journals, e-mails, and websites from top industry associations**
	◇ Focus on gaining a high-level understanding rather than delving into specifics
	◇ Call upon colleagues, consultants, and vendors to clarify and/or share lessons learned
❍	**Activate society memberships to get updates on current technologies and standards**
❍	**Reach out to ITS device sales representatives for a demonstration of new products or product features**

Recommended Actions Checklist within the Broader Organizational Context	
❍	**Be active in regional and national professional societies, user groups, associations, and governmental programs**
	◇ Share meeting minutes and notable highlights with other engineering staff

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