



Illinois Statewide



ITS Architecture Concept of Operations

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Table of Acronyms

AAMVNET	Association of American Motor Vehicle Administrators Network
AASHTO	American Association of State Highway and Transportation Officials
AFT	Automatic Funds Transfer
AHS	Automated Highway System
APCO	Association of Public Safety Communications Officials
ASPEN	Commercial vehicle reporting system software
ASTM	American Society for Testing and Materials
ATIS	Advanced Traveler Information System
ATMS	Advanced Traffic Management System
ATS	Area Transportation Study
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
BSRC	Bi-State Regional Commission
CAA	Clean Air Act
CAD	Computer-Aided Dispatch
CAPRI	Audit inspection software
CAV	Connected and Autonomous Vehicles
CCRPC	Champaign County Regional Planning Commission
CCTV	Closed-Circuit Television
CDL	Commercial Driver's License
CDLIS	Commercial Driver's License Information System
CDPD	Cellular Data / Packet Data
CI	Credentialing Interface
CIPT	Central Illinois Public Transit
CMAQ	Chicago Metropolitan Agency for Planning
CMAQ	Congestion Mitigation and Air Quality (Improvement Program)
CMS	Central Management Services
CT	Connect Transit
CUMTD	Champaign-Urbana Mass Transit District
CUUATS	Champaign-Urbana Urbanized Area Transportation Study
CVIEW	Commercial Vehicle Information Exchange Window
CVO	Commercial Vehicle Operations
CVRIA	Commercial Vehicle Reference Implementation Architecture
DATS	Danville Area Transportation Study
DMS	Dynamic Message Signs
DMV	Department of Motor Vehicles
DoIT	Department of Innovation and Technology
DOT	Department of Transportation
DPTS	Decatur Public Transit System
DSATS	Dekalb/Sycamore Area Transportation Study

DSRC	Dedicated Short Range Communications
DUATS	Decatur Urban Area Transportation Study
EAS	Emergency Alert System
ECIA	East Central Intergovernmental Association
EFT	Electronic Funds Transfer
EMC	Emergency Management Center
EOSS	Electronic One-Stop Shopping
EPV	Emergency Patrol Vehicle
ESDA	Emergency Services and Disaster Agency
ETC	Electronic Toll Collection
ETP	Emergency Traffic Patrol
ETSA	Emergency Telephone System Act per 50 ILCS 750
ETSB	Emergency Telephone System Board
EWGCOG	East-West Gateway Council of Governments
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FTA	Federal Transit Administration
FTP	File Transfer Protocol
GAI	Getting Around Illinois
GERPDC	Greater Egypt Regional Planning Development Commission
GIS	Geographic Information Systems
GPS	Global Positioning System
GTIS	Gateway Traveler Information System
HAR	Highway Advisory Radio
HAZMAT	Hazardous Materials
HOV	High Occupancy Vehicle (lane)
HRI	Highway Railroad Intersection
HTML	Hypertext Markup Language
ICC	Illinois Commerce Commission
ICJIA	Illinois Criminal Justice Information Authority
ICM	Integrated Corridor Management
IDOT	Illinois Department of Transportation
IEEE	Institute of Electrical and Electronics Engineers
IEMA	Illinois Emergency Management Agency
IEPA	Illinois Environmental Protection Agency
IFERN	Interagency Fire Emergency Radio Network
IFTA	International Fuel Tax Agreement
ILAVA	Illinois Autonomous Vehicle Association
ILEAS	Illinois Law Enforcement Alarm System
INDOT	Indiana Department of Transportation
IPS	Itinerary Planning System

IREACH	Illinois Radio Emergency Assistance Channel
IRP	International Registration Plan
ISP	Information Service Provider
ISP	Illinois State Police
ISPERN	Illinois State Police Emergency Radio Network
ISTHA	Illinois State Toll Highway Authority
ITAP	Illinois Technical Assistance Program
ITD	Innovative Technology Deployment
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITSPO	Intelligent Transportation Systems Program Office
ITTF	Illinois Terrorism Task Force
IWIN	Illinois Wireless Information Network
JCMTD	Jackson County Mass Transit District
JDCT	Jo Daviess County Transit
KATS	Kankakee Area Transportation Study
LEADS	Law Enforcement Agency Data Service
LM	Legacy Modification
LMIGA	Lake Michigan Interstate Gateway Alliance
L RTP	Long Range Transportation Plan
LSI	Legacy System Interface
MABAS	Mutual Aid Box Alarm System
MCMIS	Motor Carrier Management Information System
MCR	Mobile Capture & Reporting System
MCRPC	McLean County Regional Planning Commission
MCT	Madison County Transit
MDT	Mobile Data Terminal
MMIS	Maintenance Management Information System
MoDOT	Missouri Department of Transportation
MOE	Measures of Effectiveness
MOU	Memorandum of Understanding
MPO	Metropolitan Planning Organization
MYP	Multi Year Plan
NCIC	National Crime Information Center
NEMA	National Electronics Manufacturers' Association
NLETS	National Law Enforcement Telecommunications System
NMVTIS	National Motor Vehicle Title Identification System
NTCIP	National Transportation Communications for ITS Protocol
ONVIF	Open Network Video Interface Forum
OSOW	Oversize-Overweight
Pace	Pace Suburban Bus
PRISM	Performance and Registration Information Systems Management

PSAP	Public Safety Access Point
PTZ	Pan-Tilt-Zoom
RICMMD	Rock Island County Metropolitan Mass Transit District
RITIS	Regional Integrated Transportation Information System
RMTD	Rockford Mass Transit District
RPC	Regional Planning Council
RTA	Regional Transportation Authority
RVMMD	River Valley Metro Mass Transit District
RWIS	Road Weather Information Systems
SAE	Society of Automotive Engineers
SAFER	Safety and Fitness Electronic Records
SCT	South Central Transit
SEMPO	Southeast Metropolitan Planning Organization
SEOC	State Emergency Operations Center
SLATS	State Line Area Transportation Study
SMART	Southern Most Area Rural Transit
SMTD	Sangamon Mass Transit District
SSCRPC	Springfield-Sangamon County Regional Planning Commission
SSRS	Single State Registration System
STIP	Statewide Transportation Improvement Plan
SWS	Safety Warning System
TCIP	Transit Communications Interface Profiles
TCRPC	Tri-County Regional Planning Commission
TIMS	Traffic Incident Management System
TIP	Transportation Improvement Plan
TMC	Traffic Management Center
TRB	Transportation Research Board
TSC	Traffic Systems Center
TSMO	Transportation Systems Management and Operations
UIC	University of Illinois at Chicago
USCG	United States Coast Guard
USDOT	United States Department of Transportation
VMS	Variable Message Signs
WCMTD	West Central Mass Transit District
WIM	Weigh-in-Motion
WisDOT	Wisconsin Department of Transportation
XML	Extensible Markup Language

1. Executive Summary

The State of Illinois has been active in the planning and deployment of Intelligent Transportation Systems (ITS) for over 40 years in cooperation with local agencies and bordering states. The purpose of the Concept of Operations is to identify the current and planned ITS services and functions of IDOT and participating agencies. This Concept of Operations supports the implementation of the Statewide ITS Architecture and associated Regional ITS Architectures (RITSA) across the state of Illinois.

As a result of consensus building with ITS stakeholders across the state, the ITS Vision for Illinois was updated as follows:

Informed choices for improved operations using technology to provide safe, secure, and seamless services to the traveling public in real-time

This vision can be achieved within a flexible, adaptable framework enabling integration and coordination of transportation systems and operations. This document presents the updated Concept of Operations for the Illinois Department of Transportation's (IDOT) ITS program. It is a living document and shall evolve as the work related to the Statewide ITS Strategic Plan continues to progress.

In Illinois, transportation management and operations services are provided at the District level and IDOT Regions coordinate services that cross District boundaries. Each IDOT District provides transportation services that implement functions identified in the Statewide ITS Architecture. The statewide Concept of Operations leverages the existing ITS infrastructure throughout the state.

Each District communicates and shares information with IDOT Central Operations (Station One), where that information is distributed to all impacted regions. In the metropolitan areas, relationships with the media to distribute real-time information are routine and include travel times, congestion and incident data where available. In parallel, the IDOT Communications group in Springfield provides centralized communications on major roadwork, weather events and critical closures. This centralization remains integrated with District-level or municipal area communications staff to ensure consistency and coordination in reporting and distribution of information to agencies and the public.

While IDOT Districts 1, 4 and 8 operate 24/7/365 Communications Centers, the other IDOT districts primarily operate five (5) days per week, during business hours with on-call services for emergencies such as incidents, severe weather and major crashes. Station One coordinates reporting and response for circumstances such as hazmat crashes, emergency re-routing, AMBER Alerts, Endangered Missing Persons' and major weather events that have broader, statewide impacts. Station One also manages major evacuation activities, and collects and distributes information regarding the status of rest areas and weigh stations.

During the development of this updated Concept of Operations, statewide goals, objectives, system components, and stakeholders were identified through stakeholder outreach. To illustrate the operational concept, the system diagram uses graphical icons to represent entities and the relative services, functions, and requirements. The solid line between entities represents the information

exchange protocols and procedures used in performing transportation operations.

Figure 1 illustrates, at the highest level, an IDOT Station One centric statewide concept of operations for ITS. Looking at the overall diagram, the IDOT/Regional TMCs to Station One connections are the core interfaces to geographically connect the state. Regional transportation operations routinely include connectivity between regional operators and IDOT. Looking at both the Tri-County Regional ITS Architecture and Northeastern Illinois ITS Architecture (and associated systems), as examples, there is direct sharing of incident data from regional dispatching entities with county, city, and IDOT systems.

Figure 2 adds some representative details, including a broader range of stakeholders that are expected to exchange information through a typical Illinois District or regional communications center. This diagram is intended to focus on the concept that each region and district will gather information locally about the surface transportation network and share information between and among the various state and local agencies as necessary.

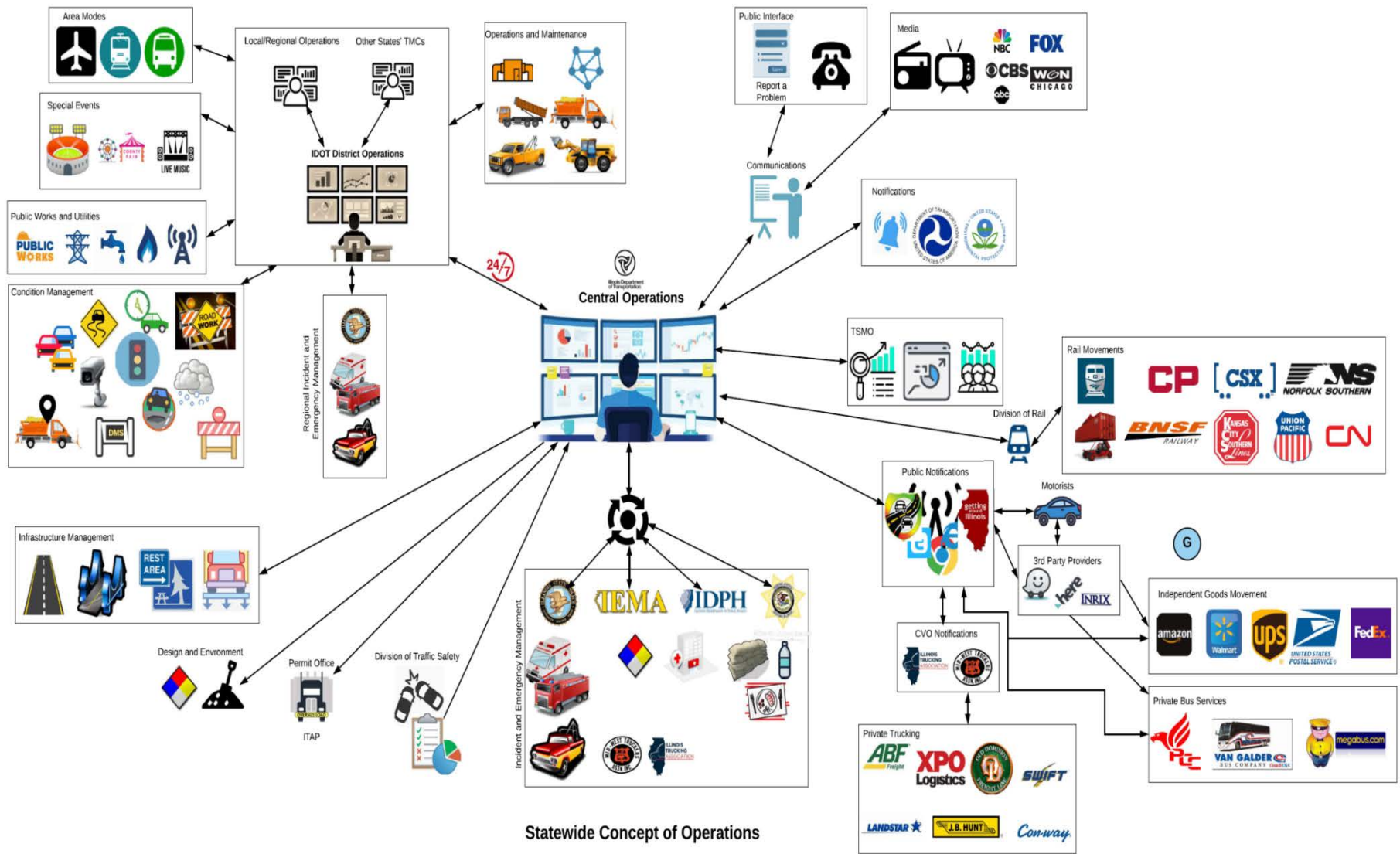


Figure 1: Illinois Statewide Operational Concept

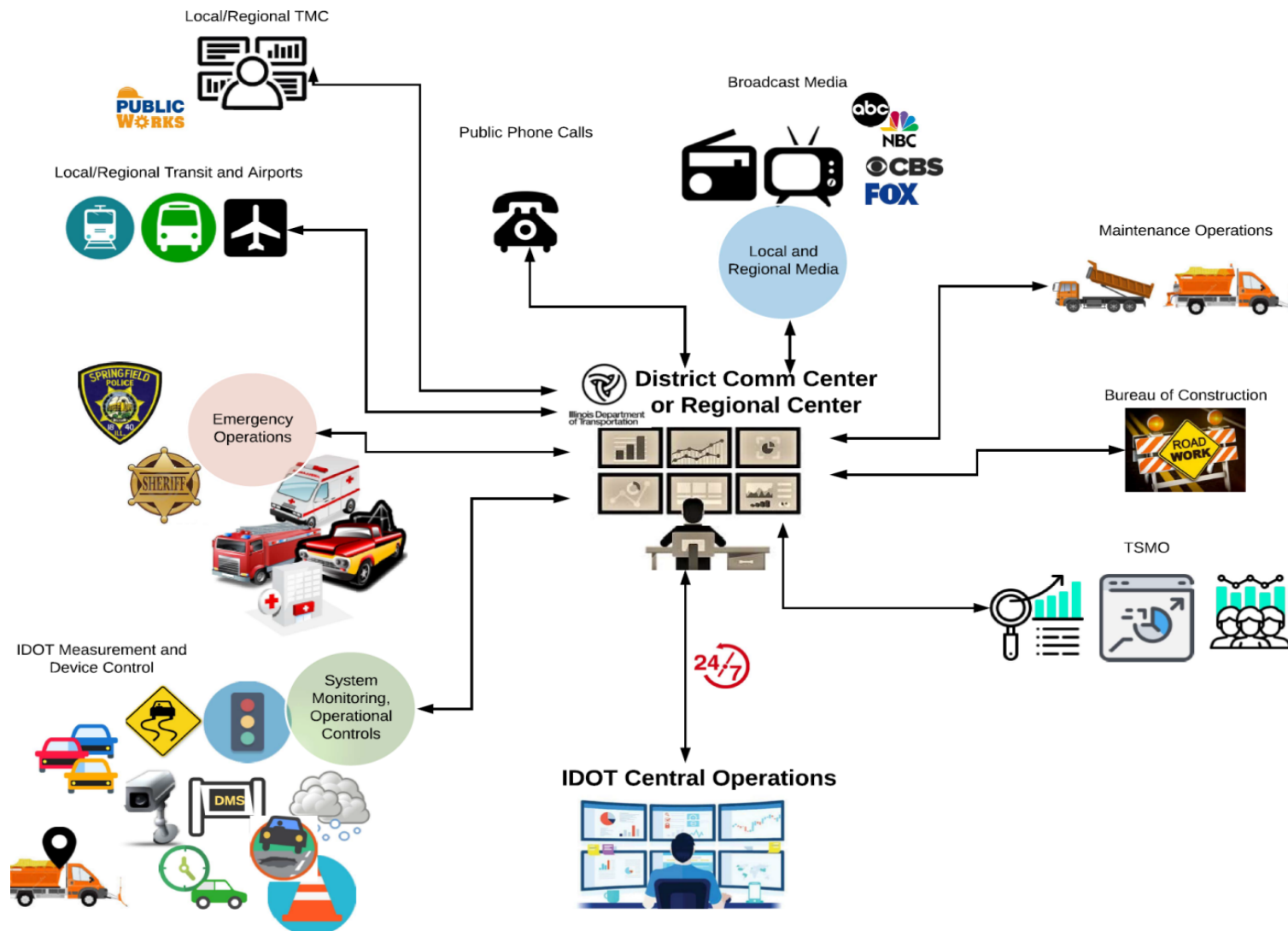


Figure 2: Illinois Statewide Regional Operational Concept

2. Introduction and Background

The Statewide ITS Concept of Operations represents both distributed and centralized functions with regard to transportation management. From a statewide perspective, policy and operational approaches to commercial vehicle operations, hazardous material responses, evacuations, and disaster responses are managed through a centrally coordinated function at IDOT Central Operations with real-time activities centrally at Station One. In parallel, the regions, counties, cities, transit agencies, IDOT and other system operators collect and maintain real-time transportation network condition data on congestion, construction, property and infrastructure damage, and incidents.

Regional agencies manage traffic operations and the associated ITS equipment and systems that support real-time operations. The Regions generally maintain a level of autonomy for most day-to-day operations utilizing a combination of shared resources, personnel, expertise, system operations, and device control strategies. Similarly, there are data collection and traffic management components that have extended connectivity to multiple Districts and Regions or are Statewide in nature. Three examples stand out:

- 1) Gateway Traveler Information System and www.travelmidwest.com has extended from a Northeastern Illinois and neighboring states system to a one stop entry point for statewide construction information, and statewide IDOT ITS device state information. However, access to statewide incident data and statewide congestion and travel times has progressed at a more modest pace.
- 2) 3GIS Fiber Inventory System. IDOT has procured a statewide fiber and communications inventory management system with substantial capabilities. The roll-out and integration into standard operating procedures has proceeded slowly and somewhat in parallel to localized network inventory systems.
- 3) Getting Around Illinois (GAI) serves as a statewide clearinghouse for road condition data, but is not necessarily optimized to perform real-time activities in a manner similar to Gateway.

Over the past decade, regions and local stakeholders have been implementing communications and control systems for CCTV, Dynamic Message Signs (DMS), and arterial traffic signals at a rapid pace. While there has been strong coordination of these activities among stakeholders, the ability to capture, catalog, promote, and improve best practices has been a challenge from an efficiency standpoint. The Strategic ITS Plan proposes improvements in cooperative staff planning to support more advanced coordination of ITS activities.

For the users of this Concept of Operations, high-level decision makers will be able to see the big picture and reference the Statewide and Regional Architectures for details on project stakeholders, interfaces, and operational flow requirements for specific projects. For example, a project at a statewide level to collect Illinois State Police crash data in real-time for operations, will have obvious connectivity opportunities for IDOT Districts and municipalities to utilize portions of that information for operations, traveler information, and performance monitoring. District Communication Centers could individually consume and distribute information, or utilize

centralized systems like the Gateway Traveler Information System (GTIS) and Getting Around Illinois (GAI), or a new operational system within Station One to consume and share information across Districts. Notably, the purpose of the current Statewide Advanced Traffic Management System (ATMS) Study project is to dive more deeply into the opportunities to detail the best-fit systems approaches to statewide operations. Regardless of the approach that project defines, the need for stakeholders to access real-time traffic and incident data remains a primary goal.

Regional agencies manage traffic operations and the associated ITS equipment and systems that support real-time operations. While there is a mix of urban, suburban, and rural operational scenarios and needs statewide, the equipment, information, and basic management strategies are consistent. For example, when incidents occur and diversion of traffic is required, the overall response focuses on securing and deploying proper resources to a scene with notification to emergency personnel and the traveling public. This type of coordinated response serves to reduce potential for secondary incidents and supports the efficient movement of people, goods, and services.

Across the state, IDOT and municipalities coordinate to identify and construct fiber optic connectivity for traffic signal systems, while connecting to neighboring municipalities where possible and affordable. These connections support traffic signal control, while also providing sufficient bandwidth for data and video sharing and enabling of advanced operational strategies.

As the state has collectively improved the transportation system, the use of communications including wireless, leased internet, and fiber optic systems has continued to be accomplished using the cost-effective technology selections. In parallel, various regional operating philosophies and sharing of resources has meant that some sharing of operational and integration support activities have already taken place. For Example, IDOT District One ATMS communicates with District 2 DMSs in the Rockford area. Similarly, IDOT District 3 installations of Bluetooth travel time equipment is also being integrated into the District 1 ATMS. Similarly, IDOT District 4 has provided ITS device integration support for multiple districts, including integration with the District 4 ATMS. Routinely, these installations include substantial fiber infrastructure that provides bandwidth that can readily support future transportation connected vehicle (CV) strategies.

While the forecasted growth and technology choices for CV are far from 'set in stone,' it is widely understood that the communications infrastructure will remain critical to safe and efficient operations, statewide.

Throughout project outreach for identification of key stakeholders, their functions, and existing implementations, Station One has been noted as the central hub considering the operations as the leading functional area. The intent behind operations being the focal set of functions is the understanding that real-time data and information gathering will support both real-time and off-line strategies and initiatives. For example, real-time access to crash and roadwork information supports both traffic management and traveler information functions, while off-line analysis and performance measurement and planning start from portions of the same datasets.

Station One has been exploring more advanced operational driven approaches for use of data and technologies to better manage and coordinate statewide. At the system and software level, the technology is already available. There are cooperative agreements via Station One that provide IDOT with the responsibility to support major emergencies including personnel and trucks to provide food, water, and other supplies. The key to developing and sustaining the operational side will be in the definition of roles and responsibilities, critical staffing and training elements to ensure success.

Operational opportunities to share command and control strategies and/or provide off hour and emergency operations support are being considered as part of a recently started Statewide ATMS assessment project. It is understood that this project will help formalize operational concepts and workflows, software licensing, system requirements, and the operational strategies statewide. It is understood that the assessment will also consider IT needs, operational staffing, and likely updates to standard operating procedures.

National State of the Practice, Federal Regulations and Guidance

The Transportation Equity Act for the 21st Century (TEA-21) required all ITS projects funded through the Highway Trust Fund to be in conformance with the National ITS Architecture and applicable standards. On January 8, 2001, FHWA issued a Final Rule and the Federal Transit Administration (FTA) issued a parallel Policy intended to foster integration of ITS systems. The Rule and Policy require that ITS projects conform to the National ITS Architecture and standards, in order to receive federal funding (23 CFR Parts 655 and 940).

This Rule and Policy applies to all ITS projects funded from the Highway Trust Fund and requires all ITS projects to be based on systems engineering analysis on a scale commensurate with the project's scope. A regional ITS Architecture is needed whenever ITS technologies are being implemented in the region, an ITS project is planned, or when system integration opportunities exist. At a minimum, all ITS projects must accommodate interface requirements and information exchanges identified in Regional ITS Architectures. Regional ITS Architecture, from the FHWA perspective, is defined as a regional framework for ensuring institutional agreement and technical integration for implementing ITS projects or groups of projects.

The ITS vision adopted for Illinois creates a picture of the future state of the system in which all the stakeholders' needs are met to the greatest degree possible, improving the efficiency, safety, and predictability of travel. The statewide concept of operations involves complex systems, combining field equipment, operations personnel, communications, and advanced information technology to accomplish the vision.

In the current technological environment, information hubs or centralized points of integration are still viable and are often quite useful to bridge information from disparate systems. However, the ITS marketplace has shown a much stronger commitment to Application Programming Interfaces (APIs) and use of standards to share data, meaning that software platforms for shared multimodal ITS command and control is significantly easier than 15 years ago.

An important aspect of the National ITS Architecture is the use of service packages. Table 2 lists the NITSA Program Areas and Service Packages as related to the statewide transportation needs. Please refer to Appendix A for a detailed list of all Service Packages.

Table 1: Illinois ITS Needs and related Program Areas and Service Packages

Illinois Statewide ITS Needs		ITS Program Areas	Service Packages
1	Enhanced interagency coordination and data sharing	Data Management, Support, Traffic Management	DM01, DM02, SU03, TM08
2	Enhanced data collection and monitoring capabilities for traffic management	Support, Traffic Management	SU08, SU09, TM07, TM08
3	Expanded communications network infrastructure	Support, Traffic Management	SU03, TM07, TM08, TM09
4	Additional funding for ITS deployment, operations, and maintenance	IDOT ITS Program Office	n/a
5	Enhanced multimodal mobility coordination and operations	Public Transportation	PT01, PT06, PT08, PT09
6	Enhanced incident management programs (includes construction and unplanned incidents)	Maintenance and Construction, Traffic Management	MC07, MC08, TM07, TM08
7	Centralized operations 24/7 traffic management	Support, Traffic Management	SU09, TM07, TM08, TM09
8	Preparation for connected vehicles	Support, Traveler Information, Traffic Management, Vehicle Safety	SU07, TI01, TM04, VS02
9	Stronger partnerships with private industry	Parking Management, Public Transportation,	PM04, PT18, TI05, TI06
10	Improved and expanded traveler information	Public Transportation, Traffic Management	PT08, TI04, TM06, TM08
11	Improved safety through use of ITS	Public Safety, Support, Traffic Management	PS01, PS02, SU08, TM08
12	Statewide ITS standards and procurement options	IDOT ITS Program Office	n/a
13	Improved commercial vehicle administration	Commercial Vehicle Operations	CVO01, CVO04, CVO06, CVO12

Illinois Statewide ITS Needs		ITS Program Areas	Service Packages
14	Advanced traffic signal systems	Traffic Management	TM03, TM04, TM07, TM08
15	Increased capacity of the transportation system	Maintenance and Construction, Sustainable Travel, Traffic Management	MC09, ST06, TM10, TM16

ITS Standards

Adoption of industry standards related to ITS communications interoperability allows transportation managers to realize long term benefits, such as lower technology costs and easier operations and maintenance. The challenge that stakeholders face is absorbing the initial cost for standards deployment, to obtain the larger benefits of lower cost and improved interoperability. ITS standards are industry-consensus standards that define how system components operate within the framework of the National ITS Architecture. The standards promote interoperability by specifying how systems and components interconnect.

To continue to expedite deployment of nationally interoperable ITS systems and services, the USDOT supports specific ITS standards initiatives, especially in areas that have significant public benefit. By adopting appropriate ITS standards, state Departments of Transportation can deploy systems that are vendor-neutral, obtaining interoperable systems at a lower cost.

Most recently, the USDOT has become active in developing or promoting standards related to Connected Vehicles. Many of these come from IEEE (Institute of Electrical and Electronics Engineers) and SAE (Society of Automotive Engineers). For information on both ITS standards and the related National ITS Reference Architecture, see <https://www.standards.its.dot.gov/>.

National Transportation Communications for ITS Protocol (NTCIP) is a true national development that has created a very high level of expectations in the transportation industry. The protocol developed jointly by public agencies, private companies, and the Federal government to provide device-level interoperability and device-level interchangeability to implement (deploy) ITS user services. The National ITS Architecture and policy for deployment depends on uniform standards to develop and deliver ITS functions in 12 Service Package Areas including Traffic Management (TM), Traveler Information (TI), Public Transportation (PT) and Commercial Vehicle Operations (CVO). The implications of fitting NTCIP into DMS and other devices are enormous, in that NTCIP makes ITS deployment possible using a mixture of devices and cutting communication costs to the bare minimum because multiple devices share the same channel.

The standard for Transit Communications Interface Profiles TCIP-S-001 specifies the rules and terms for the automated exchange of information in transit applications such as operations,

maintenance, planning, management, and customer services. TCIP is an interface standard whose primary purpose is to define standardized mechanisms for the exchange of information in the form of data among transit business systems, subsystems, components, and devices. TCIP provides a standardized definition of data to be used for transit agency information transfers. The standard supports both file transfers and automated information transfers. For automated interfaces, TCIP defines the sequence of interactions between the interfaced systems in the form of dialogs.

In the last 20 years, the adoption of NTCIP and other related standards have provided an encouraging level of interoperability to ITS integration projects. IDOT has been steadfast in including standards in its RFPs and construction bid packages. That said, it is also notable that not all ITS Standards have become mainstream. In fact, in some cases, parallel industries and more common standards from other product industries have become just as amenable, by allowing for more competitive procurements. For example, NTCIP 1205 - Object Definitions for Closed Circuit Television (CCTV) Camera Control was last updated in 2009. Since that time, industries associated with security have centered on standards such as Open Network Video Interface Forum (ONVIF) and have become more typical in the product market, with vendors recognizing that support for multiple control protocols increases access to more bid opportunities.

With the rapid growth of Connected and Autonomous Vehicles (CV/AV), a plethora of new standards have been developed to address Vehicle-to-Vehicle (V2V), and Vehicle-to-Infrastructure (V2I). The majority of these standards are under the purview of the Society of Automotive Engineers (SAE). These standards are presently covering Basic Safety Messages (BSM) and provide a set of real-time vehicle behavior data including safety systems, trajectory, speed, acceleration and braking system status. SAE is also the managing body for MAP and SPaT messages. MAP messages are the intersection geometrics for a given location and SPaT refers to the traffic signal phasing and timing data. These standards work hand in hand to support intersection safety and mobility applications. Per the USDOT web site, <https://www.standards.its.dot.gov/>, standards are routinely maintained with ongoing development and updates. As of 2019, one key security standard, the Security Credential Management System (SCMS) standard is still being evaluated in the three connected vehicle pilot projects. The connected vehicle security standards, while not deterring pilot programs, are paramount to the future of secure and anonymous communications with vehicles. Naturally, the CV/AV environments will require an extremely high secured environment to ensure safe operations.

Costs and Benefits of ITS

As ITS transforms transportation to be fully connected and information-rich, addressing safety, mobility, and environmental effects, benefits are wide-ranging and powerful. The overall impact promises greater livability to our communities and to our daily lives. As research develops from research into deployment, benefits will accrue that we are just beginning to understand:

- The public will be the primary beneficiaries. They will experience improved safety of travel, including reduction in fatalities, injuries, and the costs associated with crashes. Travelers will also benefit from real-time, multimodal information that will lead to more

efficient and eco-friendly choices regarding travel routes and modal choices. Informed travelers may decide to avoid congestion by taking alternate modes such as walking, biking, or public transit; by rescheduling their trip; or by taking alternate routes.

- Transportation agencies will benefit by being able to see and respond dynamically to conditions on the transportation network as they evolve and expand across all of modes. Operators will have the tools to manage the multi-modal system more efficiently, saving fuel, and reducing environmental impact. Data generated by Connected Vehicle systems should provide transportation operations centers with detailed, real-time data on traffic volume, speeds, transit schedule status, parking availability, evolving weather conditions, and other roadway conditions. This information can be used to optimize transit capacity, traffic signal timing and ramp meter operations, corridor management, incident and emergency response; and implement variable speed limits, dynamic road pricing, road weather surface treatments, plus improved real-time travel alerts and advisories.
- Industry will benefit with the introduction of a new marketplace in support of Connected Vehicle technologies, applications, and new, creative products and services. A key component of associated research programs is the focus on catalyzing new markets and the assurance that resulting policy will support market growth.
- Industry will also benefit from efficiencies delivered by Connected Vehicles deployment. Organizations that engage in freight and passenger transportation will find that seamless, real-time information enabled by wireless communication between vehicles and with infrastructure will translate into greater economic productivity, administrative cost savings, and profits. System and operational efficiencies will be gained through real-time information on system conditions, routing recommendations, vehicle diagnostics, and fleet and capacity usage. New applications will also enable interoperable operations and real-time data sharing and exchange to facilitate automated screening, inspections, credentialing, and other processes. For those organizations that provide information services, wireless technologies will deliver a more ubiquitous range of data sources for developing new applications and services.

3. Review of State and Local Related Documents and Efforts

In many ways, Illinois is the transportation center of America. Chicago has been the hub of the nation's rail system for more than 150 years. Over 50 railroads currently traverse the state, providing links between all corners of the country. O'Hare International Airport and Midway International Airport make Chicago one of the busiest air destinations in the world. 115 public-use airports, 273 heliports, and over 750 aviation facilities further emphasize the state's standing in aviation. Illinois also has 1,118 miles of navigable waterways which link the Mississippi River (and the Gulf of Mexico) to the Great Lakes and beyond to the Atlantic Ocean. To augment these other forms of freight shipping, over 5,700 commercial trucking companies are based in Illinois. These trucking companies, as well as the over eight million registered drivers in Illinois, provide a significant demand on the state's 147,028 miles of roadways. This road system includes 2,185 miles of interstate highways; the third highest total of any state in the nation, and about 14,000 additional miles of state roadways.¹ Further complicating the picture of Illinois' transportation infrastructure is the fact that vast portions of the state are not densely populated. Approximately 65.9 percent of the state's roadways are classified as rural.

With this enormous transportation infrastructure comes a multitude of challenges, all of which revolve around the safety, mobility, and economic viability of the transportation system. Illinois has been a pioneer in the use of ITS to address these challenges. ITS began in Illinois in the Chicago area as early as 1963 when IDOT's Traffic Systems Center (TSC) established one of the first real-time expressway surveillance and management systems in the world. The detectors, ramp meters, variable message signs, and highway advisory radio (HAR) systems have been operated continuously ever since. Some of these technologies have since been deployed outside of the Chicago area, in the Illinois portion of the St. Louis metropolitan area, Peoria and-East Peoria, Quad Cities, and Rockford. ITS components have also been deployed in rural areas of the state for road weather information systems and rural transportation management. To manage emergency traffic incidents, Chicago Emergency Traffic Patrol (ETP) and Metro-East Emergency Patrol Vehicle (EPV) serve two metropolitan areas in Illinois. In other areas not covered by ETP/EPV staff "Minutemen", IDOT highway maintainers assist with traffic incidents across the state.

The benefits provided by such systems have set an example for other ITS initiatives throughout the state, both in urban and rural settings. As a result, the State of Illinois and many of its municipalities have applied technology and management strategies to improve the safety, capacity, and efficiency of the transportation system.

These initiatives focus on a wide range of transportation goals including transit management, traveler information, electronic toll collection, traffic management, highway-rail crossings, commercial vehicle operations, incident/emergency response, and maintenance/construction management. The priority initiatives for Illinois appear in various strategic planning documents along with system performance measures. Plans reviewed for ITS related aspects are listed below:

¹ Illinois road system introduction: <http://idot.illinois.gov/about-idot/idot-regions/idot-region-1/index>

- Illinois Statewide Transportation Improvement Plan, FY 2018-2021 (IDOT)
- Illinois FY 2019 Proposed Highway Improvement Program (IDOT)
- Illinois Long Range Transportation Plan, 2018 draft update
- Illinois Strategic Highway Safety Plan, 2017
- Illinois Transit Plan, February, 2018
- Illinois State Freight Plan, IDOT, October, 2017
- 2017 Illinois State Rail Plan Update
- USDOT's Intelligent Transportation Systems (ITS) ITS Strategic Plan 2015-2019
- Illinois Comprehensive Highway Safety Plan (IDOT)
- Illinois Statewide Mutual Aid Plan (Illinois Emergency Management Agency)
- Illinois Department of Natural Resources (DNR) Strategic Plan (Illinois DNR)
- Amber Alert Notification Plan (IDOT)

The Illinois DOT emphasizes coordination among planning efforts that contribute to the LRTP as depicted in Figure 3 below.

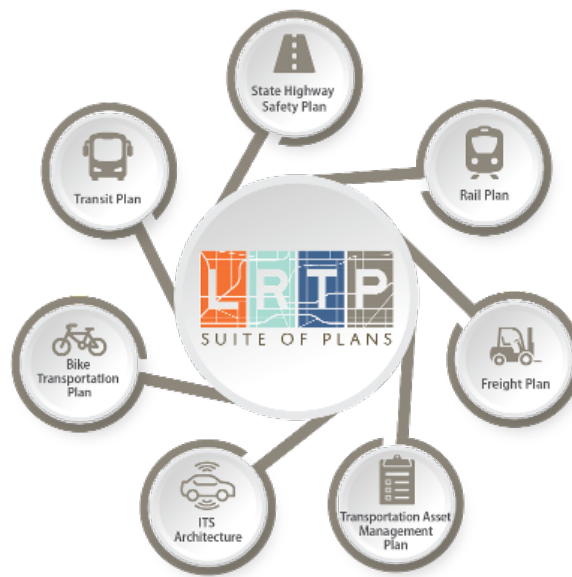


Figure 3 - Illinois LRTP Suite of Plans²

² IDOT LRTP: <http://www.idot.illinois.gov/transportation-system/transportation-management/planning/lrtp/index>

Statewide and Regional Plans

Illinois consists of 102 counties, which include 1,299 municipalities and 1,432 towns or townships, for a total of 2,731 sub-county divisions, the largest total of any state in the nation. In addition, the 2017 U.S. Census of Governments identified independent, special-purpose governments in Illinois that have transportation responsibilities, including 23 for highways, 31 for airports, nine (9) for other transportation, totaling an additional 63 public transit operators across the state³. Similarities among these agencies, whether in the challenges they face, their day-to-day activities, or their plans for future operations provide key opportunities for potential integration and sharing of funds. Many transportation agencies in Illinois use ITS in some manner, and many more have incorporated ITS solutions into their plans for the future.

The planning documents reviewed for ITS program elements and projects, vary in levels of detail in terms of goals, performance measures, mission/vision statements, technology, programs and projects. These documents address ITS at varying levels of detail in terms of goals, performance measures, mission/vision statements, technology, programs and projects. Some overall themes are as follows:

- ITS is recognized as integral to virtually all statewide planning efforts. Several advanced technologies are discussed including connected and automated vehicles.
- Transit goals and Illinois freight goals make use of ITS technologies. CAV technology figures prominently into freight planning, as well as grade crossing safety through ITS in railroad applications. Multimodal operations are highlighted as important to future transportation.
- Performance goals as promulgated through Federal MAP-21 and FAST Act legislation are key to achieving improved transportation. The goals include safety and security along with improved mobility through traffic management strategies and traveler information programs, economic development and livability.
- Several potential funding sources for ITS are mentioned, including Congestion Mitigation and Air Quality (CMAQ), Highway Safety Improvement Program (HSIP) and Infrastructure for Rebuilding America (INFRA). Innovative funding sources, such as managed lanes and mileage-based user fees are also discussed.

Regional Transportation Planning Process

In cooperation with key local agencies and the traveling public, IDOT is a key player in transportation planning in both urban and rural areas of Illinois. Metropolitan Planning Organizations (MPOs) in urban areas, and Regional Planning Commissions (RPCs) in rural settings, help to coordinate with local organizations during the planning process. These local agencies include elected officials, representatives from transit agencies, emergency services and law

³ US Census Bureau website: 2017 Census of Governments—Organization. Link: <https://www.census.gov/data/tables/2017/econ/gus/2017-governments.html>

enforcement personnel, and environmental groups. Through coordination with these local agencies and MPOs, the nine IDOT districts identify and prioritize candidate projects throughout the state. These potential projects then move to the IDOT Central Office in Springfield, where they are considered for inclusion in the State’s Multi-Year Highway Improvement Plan.

ITS planning in Illinois is carried out in each region by participating agencies. Figure 4 highlights how ITS Architecture relates to the regional Transportation Planning Process, showing key connections in the context of the Planning and Architecture processes.

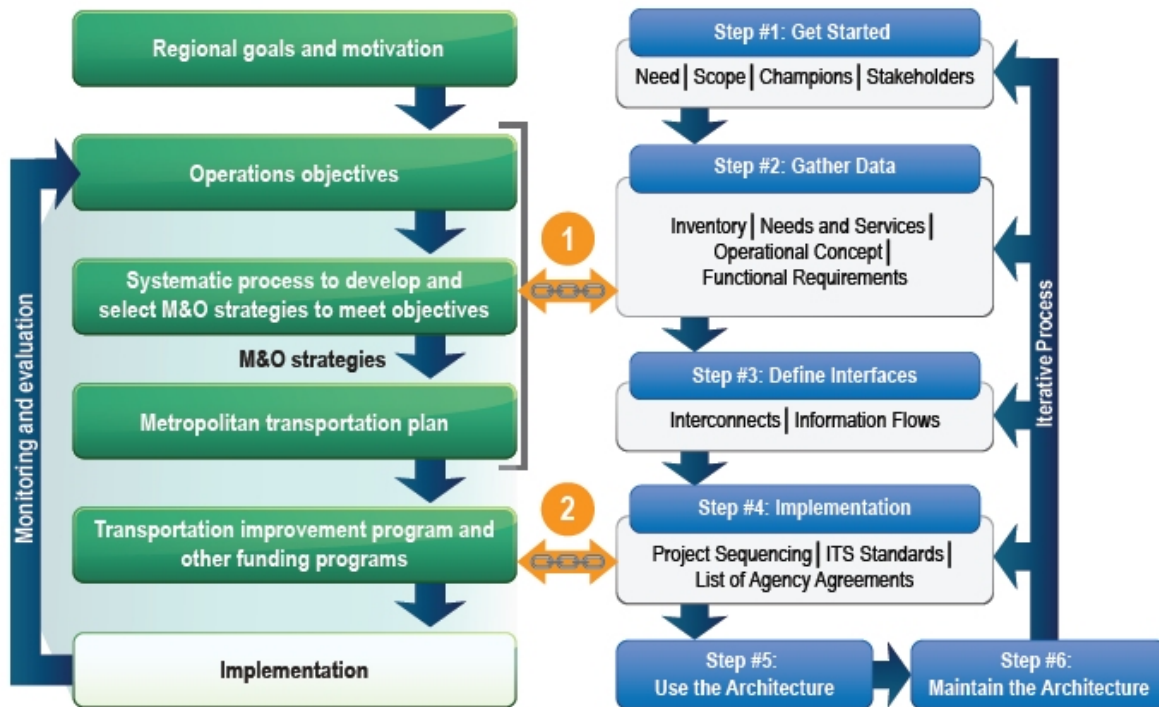


Figure 4: ITS Architecture and the Transportation Planning Process⁴

Figure 4 also illustrates how the use of an ITS Architecture enhances the transportation planning process. As a part of the process, stakeholders define the goals and objectives for the transportation network. In developing the “Long Range Transportation Plan” (LRTP), stakeholders define functions and services they must provide in order to meet the goals and objectives. Transportation planners then derive the requirements to provide the identified functions and services, and these requirements become the basis for individual projects. Using an ITS Architecture as a part of the transportation planning process leads to a more refined definition of needs and project requirements. This, in turn, helps streamline project implementation by reducing the risk of wasting resources or duplicating activities. These projects then become part of the Transportation Improvement Program which implements the LRTP goals and objectives.

⁴ USDOT Planning for Operations website: <https://ops.fhwa.dot.gov/publications/fhwahop12001/c4.htm>

Relationship to Regional Architecture Development

Each IDOT district has an ITS Coordinator, who is tasked with overseeing ITS activities. The district ITS coordinators work with the ITS Program Office, other district ITS coordinators, MPOs and RPCs, and local agencies to identify user needs and evaluate applications of technology that can address those needs.

Regional and project level architectures provide a concise project description and identify dependencies and relationships to other projects and activities. Based on these relationships, the project scope is refined to avoid duplication of effort, and to show the precedence of projects (e.g., Project B depends upon Project A, and thus Project B should be scheduled to occur after Project A is complete). Once projects are implemented, the Regional Architecture is updated to assure that new projects will account for completed projects in their planning and development.

Where identified functions may already be performed in a region, the Concept of Operations can be a reference for integrating capabilities and enhancing coordination. While IDOT Districts 1, 4 and 8 operate 24/7/365 Communications Centers, the other IDOT districts primarily operate 5 days per week, during business hours with on-call services for emergencies such as incidents, severe weather and major crashes. Station One coordinates reporting and response for circumstances such as hazmat crashes, emergency re-routing, AMBER and Endangered Missing Persons Alerts, and major weather events that have broader, statewide impacts. This Statewide operation also manages major evacuation activities, rest areas and weigh stations. During project outreach, there were numerous discussions regarding status of operations in non-24/7 districts.

The Concept of Operations is the first step in the systems engineering. While integral throughout the entire process, its most critical, and directly related, roles will be in the direct assistance to the generation of System Requirements, and in System Validation once it has entered an Operations and Maintenance phase.

Relationship to TSMO

Currently, formal Transportation Systems Management and Operations (TSMO) strategies are being developed nationally. TSMO involves the integration of passive and active management strategies, covering operation, demand management, and system expansion levels, including:

- **Planning, Partnering and Policy Development:** Land Use Planning, Policy Implementation, Traffic Corridor Planning, Data Sharing, Community Engagement;
- **ITS Improvements:** Ramp Metering, Weather Information System, Work Zone Management, Conflict Warning System, Online Truck Permitting;
- **Travel Demand Management:** Multi-Modal Development, Commute Trip Reduction, Managed Lanes, Fare Collection;
- **Cooperative Automated Transportation:** Truck Platooning, Autonomous Vehicles, Tolling Vehicle Occupancy Detection, Signal Communication to Vehicles;

- **Traditional Traffic Operations:** Signage, At-Grade Rail Crossing, Signal Optimization, Minor Geometric Modification.

TSMO also considers operations and maintenance (O&M) planning, a critical component of ITS projects. O&M planning helps traffic organizations ensure that installed ITS elements are properly operated and maintained, and detect early detection of equipment problems, leading to lower repair and replacement costs. Besides, due to relatively higher system maintenance costs and shorter anticipated useful lifespan compared to traditional infrastructure projects, confirming long-term needs is crucial to reduce the life-span total expense of a given ITS project. O&M planning helps develop the long-term resource requirements for an ITS project, including the total cost and required man-hours

In order to successfully manage TSMO at a statewide level, substantial work is needed to improve overall system performance. Applications of TSMO strategies offer the benefits of an improved transportation system performance level without the significantly increasing road infrastructure. TSMO provides practical solutions based on the combination of advanced technologies, traffic policies and the background knowledge of system optimization, while also considering safety and security issues. Typical TSMO principles include:

- Add an *operator* culture to complement existing *builder* culture
- Observe constraints on adding new capacity
- Need to *operate* the existing network to its fullest service potential
- Also apply TSMO to improve security, safety, capacity, and reliability

In general, application of TSMO not only includes typical ITS improvement strategies, but also promotes ITS project O&M planning, serving to reduce ITS project life cycle costs. This Concept of Operations references alignment with Statewide Transportation Systems Management and Operations (TSMO) concepts.

At a statewide level, the Central Operations Station One performs statewide coordination and communications for the transportation system. While the primary focus is on IDOT roadways and direct communication to District Communications Centers, Station One is the central communications focal point with Illinois State Police. As Figure 5 illustrates, Station One communicates directly with IEMA, IDPH, and IDOC. Cooperative agreements are in place for IDOT to provide resources in cases of critical operational issues, such as road and bridge failures, severe weather, evacuations due to hazardous materials including nuclear. Station One also coordinates directly with the commercial vehicle operators including Mid-West Truckers Association, and the Illinois Trucking Association to provide resources associated with disaster clean-up and transport of supplies to support major incident response.

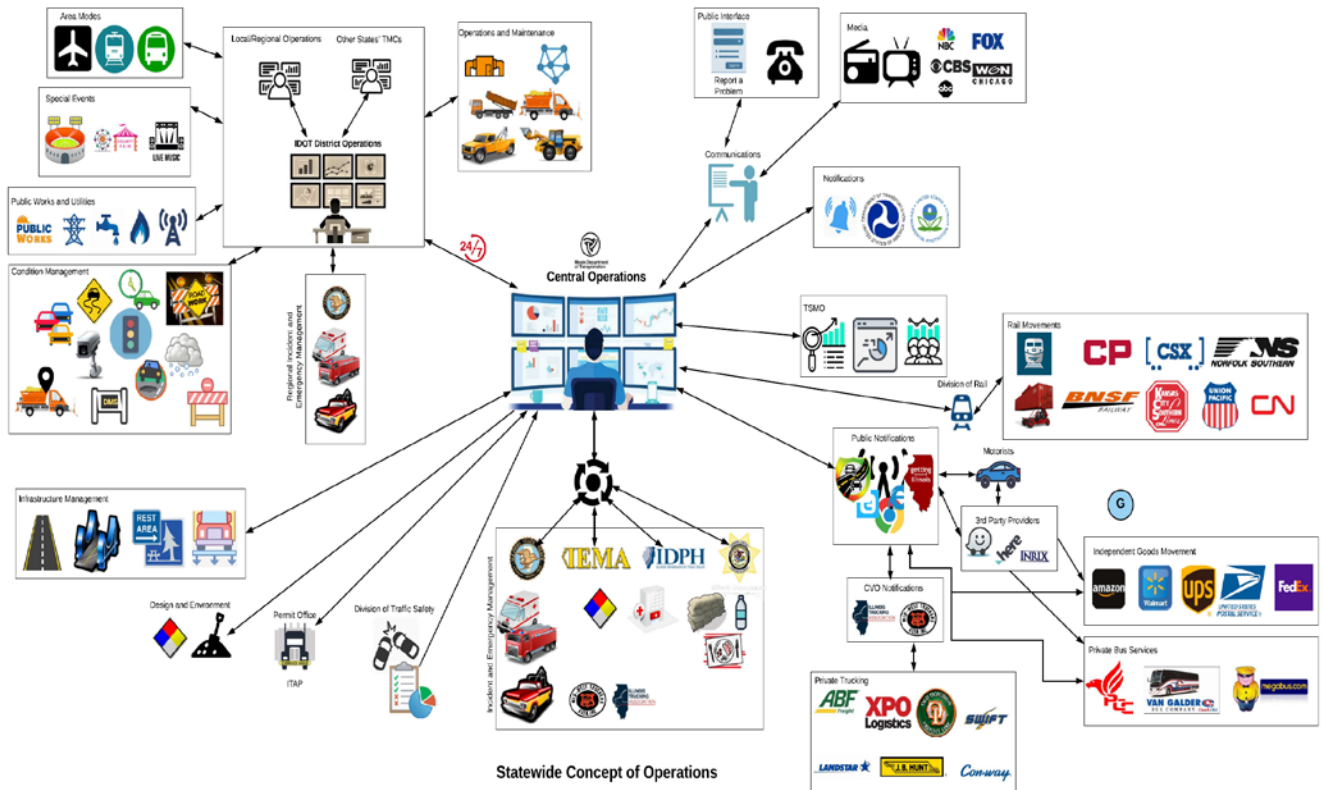


Figure 5: Illinois Statewide Operational Concept

While the Concept of Operations diagrams focus on operational entities, the Gateway Traveler Information System and www.travelmidwest.com is not explicitly called out. The GTIS is effectively serving multiple roles for Northeastern Illinois, the greater Lake Michigan Region, as well as statewide components. GTIS currently serves the following roles:

- Standardization platform for regional and northeastern Illinois traffic data including incidents, construction, travel times, and vehicle speed and volume data.
- Serves as a traveler information hub for the region.
- Serves as a data sharing center for agencies and with private sector and research institution activities.
- Provides a regional operation to validate real-time traffic conditions across the region.
- Provides archiving services that can support some TSMO component.

As part of the Statewide ATMS assessment project and even the Regional (IDOT Northeastern Illinois) Arterial ATMS assessment project, it is anticipated that strategies which consider the role of Gateway, Getting Around Illinois (GAI), and the recently added services with the Regional Integrated Transportation Information System (RITIS) will be updated. Topics of real-time services

and support level, statewide consistency (collecting, measuring, and archiving), and long-term support and viability will be necessary. These existing systems and the recent proliferation and broader acceptance of private sector data such as crowd-sourced speeds and incidents, may warrant modifications to the Gateway, GAI, and RITIS roles. As compared to the previous Concept of Operations, a centrally noted Transportation Systems Maintenance and Operations (TSMO) component has been added. Per USDOT, TSMO is defined as:

The U.S. Department of Transportation Organizing and Planning for Operations Program supports the integration of Transportation Systems Management and Operations strategies into the planning process and transportation organizations for the purpose of improving transportation system efficiency, reliability, and options. This program is led by the Office of Operations and Office of Planning, Environment, & Realty of the Federal Highway Administration (FHWA) in coordination with the Federal Transit Administration (FTA), which work with metropolitan planning organizations, State and local departments of transportation, transit agencies, and other organizations to maximize the performance of existing infrastructure through multimodal and multi-agency programs and projects⁵.

While IDOT currently maintains crash data with Illinois State Police, the approach to developing consistency statewide with regard to data reporting in support of TSMO is in the early stages of development. TSMO activities will require recognition of the different types of operations across the state, considering urban, suburban, and rural operations, along with varying differences in systems and overall data availability. For example, while Metro East and Northeastern Illinois have broad coverage of the interstate network with regard to volume and speed data collection, the vast majority of the state is only recently connected to third-party traffic data. Notably, IDOT has a relatively consistent and complete statewide construction information system.

Station One has developed an initial plan to improve overall operations. In this process, IDOT developed detailed workflows, system requirements, and plans for larger operating facilities including more advanced decision support systems and provisions for a more robust operating environment intended to bring more real-time transportation data in Station One. The goals also include utilization of Station One as a 24/7 back-up to regional/district operations.

At the regional level, IDOT District Communications Centers are the focus of state and interstate route operations and state route arterials. In parallel, local route operations and cooperative arrangements between IDOT and municipalities are in place for managing signal timing and maintaining traffic signals. In all districts, project activities are in place to expand signal interconnects with fiber optics. In some districts, IDOT personnel are working with DoIT and even private sector communications providers to further connect signals and centers. These efforts are typically utilizing the latest in Layer 2 and Layer 3 ethernet network connectivity. Within the Strategic Plan there is a recognized need to make communications access more efficient through improved agreements and inventory methodologies between IDOT, DoIT, and private sector

⁵ FHWA Transportation System Management and Operation (TSMO) Plans:
https://ops.fhwa.dot.gov/plan4ops/focus_areas/integrating/transportation_sys.htm

communications providers. On a statewide basis, IDOT can utilize the best practices and experiences in various districts to create a statewide methodology. It is recognized that improving these processes will require high level understanding and buy-in from the key decision makers at IDOT, DoIT and private partners. These efforts will also require detailed understanding and technical requirements to ensure network security.

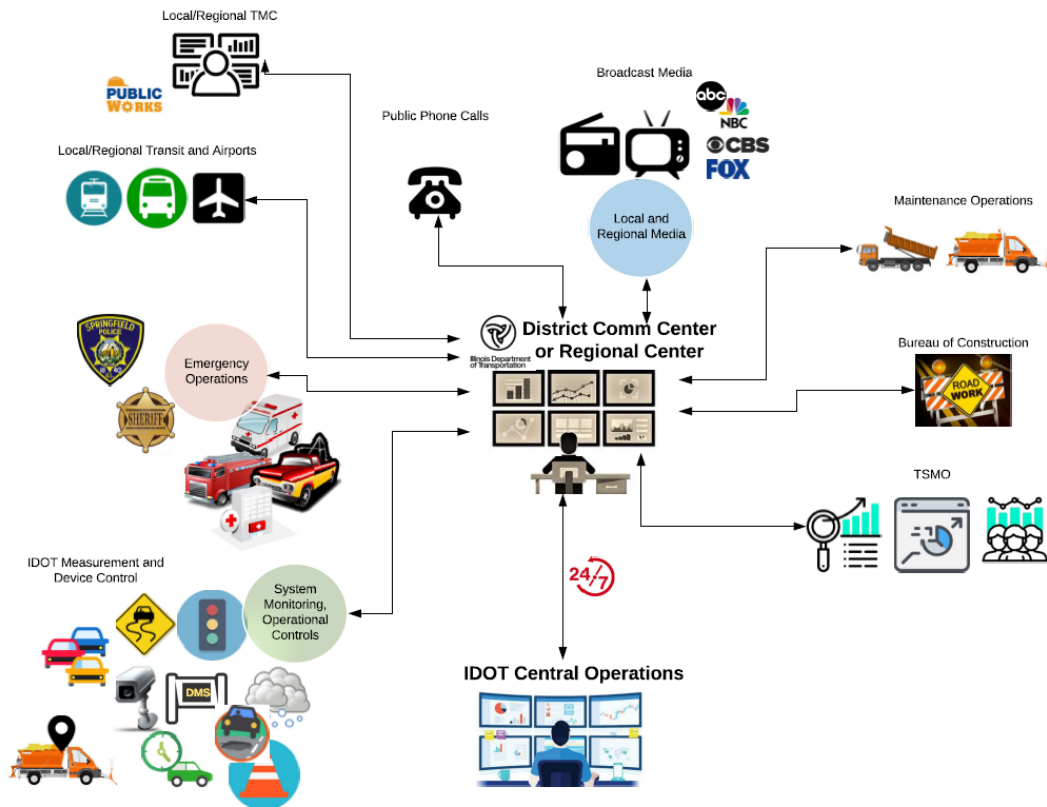


Figure 6: Illinois Statewide Regional Operational Concept

The Regional level tends to be multi-jurisdictional and collaborative in nature; pooling the resources from many jurisdictions to address select transportation issues common to the region. IDOT Communications Centers and regional centers depicted in Figure 6 handle day-to-day operations ranging from signal control to construction to congestion and incident response. As discussed earlier, major traffic events and natural disaster related operations currently are reported and coordinated via Station One (IDOT Central Operations).

The functional areas of ITS identified to meet the statewide needs are discussed in Chapters 4 through 15. For each functional area, the following information is presented to identify 'what' is necessary to complement and improve the State's existing ITS capabilities.

- Description and Examples
- Relationship to Statewide ITS Vision
- Identification of Issues
- Benefits
- ITS Architecture
- Findings and Recommendations.

Each of these is addressed at a high level to help identify functional requirements for the pending update to the Illinois ITS Strategic Plan. Of particular note, the ITS Architecture section deals with the primary ARC-IT service packages that pertain to each functional area. As projects are developed and detailed in the ITS Strategic Plan update, specific service packages associated with each will be identified through application of RAD-IT.

The Concept of Operations supports the design phase of the systems engineering process by providing the overall vision and objectives of the system to which designers can refer back during this phase.

4. Traveler Information

Description and Examples

Traveler Information service functions disseminate traveler information to all equipped travelers within range. They collect traffic conditions, advisories, general public transportation, toll and parking information, incident information, roadway maintenance and construction information, air quality and weather information, and broadcasts the information to travelers using technologies such as radio, cellular data broadcasts, and Internet streaming technologies.

At the statewide level, methods for disseminating traveler information include highway advisory radio (HAR), dynamic message signs (DMS), social media and websites such as GAI and Travel Midwest. These tools offer interactive mapping for users to search and display live traveler information on incidents, road conditions, closures, construction, congestion or weather. Travel Midwest covers the entire State of Illinois and several counties in Indiana, Wisconsin, Michigan, Minnesota, Ohio, and Iowa. This site is unique because it makes the traffic information data for the entire Midwest region available in one place. This can be advantageous, considering that sometimes construction or an accident impact can cross state lines.

For newly developed ridesharing modes and in preparation for connected vehicles applications, the most recent ITS reference architecture ARC-IT also includes Service Package TI06 Dynamic Ridesharing service and TI07 In-vehicle Signage.

Relationship to Statewide Vision

A robust Traveler Information system needs to be able to collect timely, accurate, and reliable traffic, transit, and other road conditions data from multiple sources in order to inform travelers of the latest conditions affecting their travel. A key component of the Illinois Statewide ITS Vision for ITS centers on the capability to provide real-time information.

The proliferation of private sector data through cell phone crowd sourcing, the advanced routing and planning systems for private sector transporters such as UPS, FedEx, Walmart, Amazon, and a large number of national carriers has grown rapidly. More data is being collected than ever before and the demands for data by public and private sector stakeholders has grown immensely. The most recent challenge has involved validation of the datasets and ensuring quality, density of data, and performance characteristics during a wide variety of traffic conditions. This effect will continue as the explosion of data sources continues.

Identification of Issues

Traveler information, especially under a statewide approach, presents a number of issues and choices. A starting point for traveler information on IDOT facilities is the website,

www.gettingaroundillinois.com/. The site includes links to travel condition maps for the Chicago, St. Louis and Peoria metro areas, plus bicycling, commercial vehicle and other travel information.

Traveler information is already a multimillion-dollar business nationally, and there are both public and private sector entities participating in the collection, estimation and dissemination of information. Going forward, IDOT can benefit from the private sector in providing more traveler information services to the traveling public, supplementing or replacing services that already exist. Traveler information is starting to evolve into a public-private partnership. There are several private vendors today who sell and provide third-party data for a variety of transportation purposes such as HERE (www.here.com/en) and Waze (www.waze.com). Data may be oriented to commercial freight companies, personal services or transportation agencies. Speed, travel time, volume and occupancy data are the most relevant data for transportation agencies to maintain safety and mobility of the transportation network. Some transportation agencies use these types of data from third-party providers to deliver traveler information, manage traffic, and conduct studies.

Benefits of Traveler Information

Traveler information systems help inform the public about current traffic conditions and expected travel times. Traveler information services, including traveler information flowing through in-vehicle navigation systems, allow users to make more informed decisions about trip departures, routes, and modes of travel. Benefits include:

- Informed public optimizing travel times and modes
- Traveler diversions around incidents and bottlenecks
- Improved quality of travel from reduced stress
- Increased transit usage
- Reduced emissions and fuel consumption.

Traveler information systems help inform the public about current traffic conditions and expected travel times including emerging in-vehicle navigation systems. Traveler information services allow users to make more informed decisions about trip departures, routes, and modes of travel.

The USDOT ITS Joint Program Office released the ITS Benefits, Costs, and Lessons Learned (BCLL) 2018 Update Report. The report provides information on industry experience with ITS deployment and operations, the associated costs, benefits and lessons learned. Associated USDOT fact sheets are available at:

- <https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/TravelerInformation/> and
- <https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/DriverAssistance1/>

Multimodal trip planners can be instrumental in encouraging individuals to use existing transit services. By incorporating information such as gas prices and transit fares, in addition to travel times, a multi-modal trip planning tool in northeastern Illinois helped newer residents establish

efficient transportation habits. As knowledge of local transportation options increased, residents are more likely to use transit for some trips. According to the ITS BCLL 2018 Update Report, nearly 40 percent of all respondents and 50 percent of suburban respondents reported using at least one transit service that they did not usually use as a result of using the trip planning tool.

The Washington State DOT (WSDOT) placed data collection devices on heavily-congested areas of SR 512 and I-5 in the Olympic Region. The data collected from those devices were displayed in two places on WSDOT's website, on the state's 511 system and through the mobile phone application that WSDOT supports. Eighty-four percent of survey respondents found traveler information provided by WSDOT useful, with 95 percent saying it should continue to collect and distribute travel congestion information.

SFPark, a smart parking systems (SPS) pilot program, works to provide San Francisco drivers with real-time information about available parking spaces. Sensors installed in the surface of each parking spot communicated with radio receptors about which spots were occupied. The information was then displayed to drivers via LED screens located outside of each lot and through the downloadable SFPark mobile app. Evaluation of the pilot indicated a 43 percent decrease in time spent looking for parking, as well as a 30 percent decrease in CO2 emissions during the parking task.

ITS Architecture

Traveler information is a statewide function, augmented by local capabilities. The Illinois Statewide Hub is the primary source that supports statewide traveler information. The Illinois Statewide Hub receives regional information from each Region's Lake Michigan Interstate Gateway Alliance (LMIGA) Hub previously called GCM (Gary-Chicago-Milwaukee) and the Central Gateway Hub that communicates with other states.

Various service packages exist currently in the national ITS Architecture that address traveler information in its many forms, primarily in the Traveler Information (TI) service package area (see Table 2). A key component of any of these service packages is the need for real-time, accurate data about the surface transportation network. A variety of interactive devices are used by travelers to access information prior to a trip and during including phone, kiosk, message boards and screens, personal computer, and a variety of in-vehicle devices.

At the most fundamental level, the Broadcast Traveler Information service package collects traffic conditions, advisories, general public transportation, toll and parking information, incident information, roadway maintenance and construction information, air quality and weather information, and broadly disseminates this information through existing infrastructures and low-cost user equipment (e.g., FM subcarrier, cellular data broadcast). The information gathered may be provided directly to travelers or provided to merchants and other traveler service providers so that they can better inform their customers of travel conditions. Note that this is not the same functionality that is in the Traffic Information Dissemination service package which provides

localized HAR and DMS information capabilities; Broadcast Traveler Information provides a wide area digital broadcast service. This package contains the core collection and processing capabilities in other TI packages and provides many of the traveler information functions in basic forms.

If providing tailored information in response to a traveler request is the service to be provided, then the Interactive Traveler Personalized Information service package is available within the National ITS Architecture for review and tailoring. In this instance, both real-time interactive request/response systems and information systems that "push" a tailored stream of information to the traveler based on a submitted profile are supported. The traveler can obtain current information regarding traffic conditions, roadway maintenance and construction, transit services, ride share/ride match, parking management, detours and pricing information. A range of two-way, wide-area wireless and fixed-point to fixed-point communications systems may be used to support the required data communications between the traveler and Information Service Provider (ISP). A variety of interactive devices may be used by the traveler to access information prior to a trip or in-route including phone, kiosk, Personal Digital Assistant, personal computer, and a variety of in-vehicle devices.

This service package also allows value-added resellers to collect transportation information that can be aggregated and be available to their personal devices or remote traveler systems to better inform their customers of transportation conditions. Successful deployment of this market package service relies on availability of real-time transportation data from roadway instrumentation, transit, probe vehicles or other means. A traveler may also input personal preferences and identification information via a "traveler card" that can convey information to the system about the traveler as well as receive updates from the system, so the card can be updated over time.

Dynamic Route Guidance is a market package service that offers advanced route planning and guidance that is responsive to current conditions. The package combines the autonomous route guidance user equipment with a digital receiver capable of receiving real-time traffic, transit, and road condition information, which is considered by the user equipment in provision of route guidance.

The most advanced traveler information service package is the Trip Based Infrastructure-Provided Planning and Route Guidance. At its essence is the ability to offer the user pre-trip route planning and turn-by-turn route guidance services. Routes may be based on static information or reflect real time network conditions. Unlike the Dynamic Route Guidance service packages where the user equipment determines the route, the route determination functions are performed in the ISP Subsystem element of the architecture in this service package. This approach simplifies the user equipment requirements and can provide the infrastructure better information on which to predict future traffic. The package includes two-way data communications and optionally also equips the vehicle with the databases, location determination capability, and display technology to support turn by turn route guidance.

The In-Vehicle Signage market service package supports distribution of traffic and travel advisory information to drivers through in-vehicle devices. It includes short range communications between roadside equipment and the vehicle and wireline connections to the Traffic Management Center (Subsystem) for coordination and control.

The Dynamic Ridesharing market and Shared Use Transportation service package is one to consider in larger metropolitan or the more heavily traveled corridors of Illinois. In this service package, dynamic ridesharing and shared use transportation/ride matching services are provided to travelers. This service could allow near real-time ridesharing reservations to be made through the same basic user equipment used for Personalized Traveler Information. This ridesharing/ride matching capability also includes arranging connections to transit or other multimodal services.

Findings and Recommendations for Traveler Information

In order to successfully integrate traveler information into its daily activities, IDOT should consider multiple simultaneous integration strategies, including the following:

- Continue providing coordination activities since traveler information systems are an inter-jurisdictional issue.
- Advocate a regional collaborative approach to determine recommendations on aspects of traveler information.
- Continued integration of traveler information throughout the state with a broad variety of content in collaboration with individual agencies and statewide plans.
 - Explore and refine roles of [Travel Midwest](#) and GAI websites and other traveler information services.
- Monitor and incorporate in CAVs development for future functionalities that may significantly improve sources of availability of traveler information.
- Continue public sector and private sector investment in improved accuracy and timeliness of data dissemination to the public.
- Multi-modal information and big data opportunities will present themselves, thus preparedness to look a new traveler information sources, and atypical sources should be continuously considered and evaluated relative to needs and usage requirements.

5. Freeway Management

Description and Examples

An excellent introduction to Freeway Management can be found in the Introduction of FHWA's *Freeway Management and Operations Handbook*:

Increased turbulence and increased vehicle demand lead to more conflicts and collisions, reducing safety. Today, the demand for freeway facilities is overwhelming, and problems have grown to an intolerable proportion in some metropolitan areas. A FHWA paper discussing TEA-21 Reauthorization states: "It has become widely acknowledged that providing effective highway-based transportation consists of three component parts:

- *Building the necessary infrastructure*
- *Preserving that infrastructure (e.g., maintenance & reconstruction), and*
- *Preserving its operating capacity by managing operations on a day-to- day basis.*

Highway transportation can thus be likened to a three-legged stool that cannot effectively serve customer needs if any of these three parts (legs) is missing or is underemphasized (too short) relative to the others." The focus of this document is the "operations leg."

Freeway traffic management and operations is the implementation of policies, strategies and technologies to improve freeway performance. The over-riding objectives of freeway management programs are to minimize congestion (and its side effects), improve safety, enhance overall mobility, and provide support to other agencies during emergencies. The TRB Freeway Operations Committee's Millennium Paper states: "Freeway operations, in its broadest context, entails a program to combat congestion and its damaging effects: user delay, inconvenience and frustration, reduced safety, and deteriorated air quality." Moreover, this "context" includes a vast array of freeway uses – the daily commute, commercial vehicle operations, personal and recreational trips, emergency service response, and evacuations during emergencies."

Illinois pioneered ITS for freeway management even before the term "ITS" was coined; here are just some examples of current freeway management systems:

- The IDOT Traffic Systems Center (TSC) in Oak Park provides volumes, speeds, and occupancy information, as well as ramp meter operations information, via a connection to the Gateway and www.travelmidwest.com. The TSC also shares a connection with the ComCenter located in Schaumburg that can allow monitoring of CCTV camera feeds and control of DMS messages.
- IDOT's Operations and Communications Center (ComCenter) in Schaumburg performs centralized incident and communications coordination 24/7/365. District One's mobile radio system utilizes multiple base stations and a mix of frequencies to cover northeastern Illinois. The

ComCenter monitors, dispatches, and assists the Emergency Traffic Patrol, IDOT Maintenance, and other field forces by coordinating information with the Illinois State Police, over 350 local police and fire departments, other agencies, contractors, the news media, and the general public. Direct dedicated telephone hotlines are used for immediate communications with key agencies. Maintenance and response activities managed by the ComCenter include several pump stations that prevent expressways from flooding, traffic surveillance, weigh stations, and other systems such as DMS, HAR, pavement sensors, weather radar, and storm warning and response systems. The ComCenter also operates the Kennedy Expressway Reversible Lane Control (REVLAC) system and the Roosevelt Road ramp control system on the Eisenhower Expressway. The ComCenter receives real-time expressway information from the TSC and provides monitoring and operational support for ramp metering and DMS. The ComCenter works closely and shares information with the Illinois State Police, TSC, and Gateway through the Chicago Gateway Hub. Traffic conditions are provided to the ComCenter through protected pages on the Gateway.

- Illinois Emergency Traffic Patrol (ETP) operates on Chicago area expressways, with a central facility located off the Dan Ryan Expressway in Chicago, and centralized dispatching from the ComCenter in Schaumburg. The mission of the ETP, which operates 24/7/365, is to restore traffic flow through rapid response to incidents. The ETP shares information with the Illinois State Police, TSC, and Gateway, in addition to the ComCenter through the Chicago Gateway Hub. Traffic conditions are provided to the ETP through protected pages on the Gateway.
- Illinois State Toll Highway Authority (ISTHA) operates a Traffic Management Center that controls an Active Traffic management (ATM) system on 22 miles of I-90, monitors DMS and CCTV cameras, provides data to calculate travel times, and provides construction, maintenance, and incident information to other affected agencies, such as IDOT and the Chicago Department of Transportation.
- Multi-State Agreements for Coordinated DMS Message Posting— IDOT prepared an Operations manual to assist IDOT, ISTHA and Indiana DOT (INDOT) in the usage of DMS for incidents on Interstates 80, 94 and 294. This manual identifies procedures and techniques for coordinating DMS message postings using primarily low-tech methods. Additional agreements are being developed to allow LMIGA traffic managers to more effectively respond to cross-border impacts of traffic incidents, thereby reducing congestion and delay, secondary accidents, and driver frustration associated with such incidents.
- Agreements for Multi-State Incident Response Teams in State Border Regions— Agreements and coordination procedures are in development to support new and existing multi-agency incident response teams at the Wisconsin-Illinois and Illinois- Indiana state border regions. The teams will be composed of individuals from agencies that deliver incident management services in the field (such as fire, police, DOT, and EMS), and traffic operations center staff.
- The Gateway Guide, the regional Intelligent Transportation System for the Bi-State St. Louis Metropolitan area, was developed through a partnership between:

- IDOT District 8,
 - Missouri Department of Transportation (MoDOT) District 6,
 - East-West Gateway Council of Governments (MPO), and
 - METRO (formerly Bi-State Development Agency).
- Iowa DOT current provides the 24/7 operational activities for the Quad Cities, with IDOT paying for CCTV, DMS and other ITS Equipment. While primarily an effective strategy, it is understood that the operational agreements and command and control strategies need further evaluation as statewide operational enhancements advance, particularly with Station One.

Relationship to Statewide Vision

A key component of the vision for ITS in the State of Illinois centers on mobility. When it comes to freeway management, drivers of any vehicle want to know what to expect. This knowledge is a key attribute of "mobility." Having accurate information about roadway performance significantly improves the perception of a trip because information allows motorists to make decisions that give them the perception of having more control over their life. Knowing the extent and duration of congestion not only gives the motorist better options, it removes a significant stress point, the unknown. Thus, the perception of the congestion improves significantly.

Identification of Issues

Typically, the greatest challenges with freeway management are institutional and human in nature, though some technical challenges remain. Core issues that need to be addressed include:

- An ever-increasing need for automation, standardization, and interoperability across the existing transportation network, and the need to strike the appropriate balance between construction, maintenance, and operation of infrastructure elements.
- A shift from responsive planning to predictive and preventive action plans.
- Integration of various information sources across the state to enable and encourage data sharing, in order to promote safer and more cost-effective operations.
- Upfront inclusion of operations and maintenance costs for ITS elements into freeway management projects in the context of life cycle cost-benefit analysis, particularly upgrades to the major roadway network where obvious alternate routes are not evident.
- Determination of the criteria for centralized versus decentralized freeway management operations, particularly in light of the interstate and cross county aspects of freight movement.
- Qualified staff to maintain and operate the ITS components, who also have the necessary background to understand the transportation and traffic environments.
- Anticipation and incorporation of developments with CAVs that will change the nature of freeway management.

Benefits of Freeway Management

Active Traffic Management (ATM) and Integrated Corridor Management (ICM) Strategies have been realizing benefits regionally (I-90 Smart Road) and nationally (SANDAG ICM). The appropriate use of shoulders for capacity and the more detailed integrated operations of arterial operations with transit and the expressway and tollway systems can provide substantially to the mobility and safety benefits of particular corridors. Benefits from day-to-day freeway operations focus directly on mitigating congestion and improving safety. Congestion – particularly unexpected congestion – and safety have very strong impacts on travelers' attitudes. Freeway management systems are designed to improve traffic flow, safety, accessibility, and reliability/predictability.

ITS technologies, such as surveillance and detection, center-to-center communications, data processing, archiving, and information dissemination enable transportation engineers to rapidly identify potential causes of congestion, unsafe conditions requiring maintenance and law enforcement, and environmental hazards. Appropriate strategies can then be implemented to mitigate their duration and impacts on travel. The benefits of freeway management systems are demonstrated in a diverse set of measures, for example: improved response time of an ambulance; more rapid dissemination of "AMBER and Endangered Missing Persons Alerts" via DMS along rural interstates and metropolitan freeways; and the State of Illinois website showing real-time traffic conditions and providing links to roadway condition information.

In San Diego, SANDAG as the metropolitan planning organization, coordinate the implementation of Integrated Corridor Management (ICM) along the I-15 corridor. This effort engaged area signal operators (municipalities), expressways, transit, parking and real-time conditions simulation and forecasting to assess and implement appropriate operational strategies. The program focused on assessment and performance scoring of multiple operational scenarios in real-time to predict performance benefits. The effort included command and control requests between the agencies, notification and escalation procedures, and traceability of operational activities and performance outcomes. Please visit the project website for more information at: <https://www.sandag.org/index.asp?projectid=429&fuseaction=projects.detail>.

The following are samples of cited benefits from the USDOT fact sheets are available at: <https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/FreewayMGT/> and <https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/FreewayICM/>.

- In Minneapolis- St. Paul, when link travel times posted on DMS are twice as long as typical travel times, drivers begin to favor alternate routes.
- Ninety-four percent of travelers took the action indicated by the DMSs in rural Missouri and drivers were very satisfied by the accuracy of the information provided.
- Regarding Integrated Corridor Management (ICM), Benefit/Cost Ratios of 7:1 to 25:1 are cited for ICM projects in San Diego, Dallas, Minneapolis and San Francisco.

ITS Architecture

The National ITS Architecture addresses freeway management with several service packages that come primarily from two of the 12 service package areas: Traffic Management (TM) and Maintenance and Construction (MC). More specifically, the focal point of each relevant service package is the Traffic Management Center physical object/subsystem. This subsystem controls and monitors traffic flow, the road network, the surrounding environmental conditions, and the status of ITS equipment in the field. Architecturally, this subsystem embodies the typical TMC that manages a broad range of transportation facilities, including freeway systems, rural and suburban highway systems, and urban and suburban traffic control systems. Other areas addressed in the core functionality of the TMC subsystem include:

- Incident detection, verification, response and dissemination
- Management of traffic and transportation resources to support allied agencies in responding to, and recovering from, incidents ranging from minor traffic incidents through major disasters including special traffic management strategies to support evacuation and re-entry.
- Coordination with maintenance and construction operations to maintain the road network and coordinate and adapt to maintenance activities, closures, and detours.
- HOV lane management and coordination, road pricing, and other demand management policies that can alleviate congestion and influence mode selection.
- Reversible lane facilities and barrier and safeguard systems management that control access to transportation infrastructure, along with ATM systems.
- Interagency coordination of traffic information and control strategies between neighboring jurisdictions.
- Rail operations coordination to support safer and more efficient highway traffic management at highway-rail intersections.
- Control over those devices utilized for CAV traffic and vehicle control.

ARC-IT outlines 23 Traffic Management (TM) service packages and 9 Maintenance and Construction (MC) service packages, many of which address freeway management-oriented services. As a starting point in developing Illinois' statewide architecture, the following key service packages have a strong freeway management focus:

Infrastructure-Based Traffic Surveillance is the foundational service package that enables traffic managers to monitor traffic and road conditions, identify and verify incidents, detect faults in indicator operations, and collect census data for traffic strategy development and long-range planning. Functionality includes traffic detectors, other surveillance equipment, the supporting field equipment, and fixed-point to fixed-point communications to transmit the collected data back to the Traffic Management Center. The derived data can be used locally, such as when traffic detectors are connected directly to a signal control system, or remotely (e.g., when a CCTV system sends data back).

An alternative to Infrastructure-Based Traffic Surveillance, or an adjunct, the Vehicle-Based Surveillance service package provides an alternative approach for surveillance of the roadway network.

Two general implementation paths are supported by this service package: the first approach leverages wide area communications equipment that may already be in the vehicle to support personal safety and advanced traveler information services, and the second approach utilizes vehicle equipment that supports toll collection, in-vehicle signing, and other short-range communications applications identified within the architecture. As of June 2019, the 5.9 GHz band assigned to Dedicated Short Range Communications for transportation safety is deployed through a series of US DOT funded projects and various national pilot projects. These projects are testing vehicle to vehicle, vehicle to infrastructure and vehicle to everything (V2X) applications. The service package enables traffic managers to monitor road conditions, identify incidents, analyze and reduce the collected data, and make it available to users and private information providers. Given the large volume of data collected by probes, data reduction techniques are required, such as the ability to identify and filter out-of-bounds or extreme data reports.

The Traffic Metering service package provides central monitoring and control, communications, and field equipment that support metering of traffic. It supports the complete range of metering strategies including ramp, interchange, and mainline metering. This package incorporates the instrumentation included in the Infrastructure-Based Traffic Surveillance service package (traffic sensors are used to measure traffic flow and queues) to support traffic monitoring so responsive and adaptive metering strategies can be implemented. Also included is configurable field equipment to provide information to drivers approaching a meter, such as advance warning of the meter, its operational status (whether it is current on or not, how many cars per green are followed, etc.), lane usage at the meter (including a bypass lane for HOVs) and existing queue at the meter.

HOV/HOT Lane Management manages high-occupancy vehicle (HOV) and high-occupancy toll (HOT) lanes by coordinating freeway ramp meters and connector signals with HOV lane usage signals. Preferential treatment is given to HOV lanes using special bypasses, reserved lanes, and exclusive rights-of-way that may vary by time of day. Vehicle occupancy can be detected to verify HOV compliance and to notify enforcement agencies of violations. For HOT lane configurations, tolls are collected for vehicles that do not meet the high-occupancy criteria for the lane.

Traffic Information Dissemination is a simple service package that addresses the need to provide drivers with information using DMS or HAR.

The Regional Traffic Management service package supports the need to share traffic information and control among TMCs to support a regional control strategy. This service package advances the Traffic Signal Control and Traffic Metering service packages by adding the communications links and integrated control strategies that enable integrated inter-jurisdictional traffic control. The nature of optimization and extent of information and control sharing are determined through working arrangements between jurisdictions.

Traffic Incident Management System is a broad service package that manages both unexpected incidents and planned events, so that the impact to the transportation network and traveler safety can be minimized. The service package includes incident detection capabilities through roadside surveillance devices (e.g., CCTV) and through regional coordination with other traffic management,

maintenance and construction management and emergency management centers, as well as rail operators and event promoters. Information from these diverse sources is collected and correlated to detect and verify incidents and implement an appropriate response. This service package supports traffic operations personnel in developing an appropriate response in coordination with emergency management, maintenance and construction management, and other incident response personnel to confirmed incidents. The roadside equipment used to detect and verify incidents also allows the operator to monitor incident status as the response unfolds. The coordination with emergency management might be through a CAD system, or through other communication with emergency field personnel. The coordination can also extend to tow trucks and other allied response agencies and field service personnel.

Integrated Decision Support and Demand Management service package recommends courses of action to transportation operators in a corridor, downtown area, or other heavily traveled area. Recommendations are based on an assessment of current and forecast transportation network performance and environmental conditions. Multi-modal transportation operational strategies are created that consider all modes and all roads in the travel area to correct network imbalances and effectively manage available capacity. As part of the operational strategies, this service package may also recommend lane restrictions, transit, parking, and toll strategies to influence traveler route and mode choices to support active demand management programs and policies managing both traffic and the environment. Operational strategies, including demand management recommendations, are coordinated to support operational decisions by each transportation operator that are consistent with the recommended strategy. All recommended operational strategies are based on historical evaluation, real-time assessment, and forecast of the roadway network performance based on predicted travel demand patterns. This service package also collects air quality, parking availability, transit usage, and vehicle occupancy data to support operational strategies that manage and balance capacity and demand.

Reversible Lane Management is a service package similar to HOV/HOT Lane Management. This service package provides for the management of reversible lane facilities and includes functionality to detect wrong-way vehicles and other special surveillance capabilities that mitigate safety hazards associated with reversible lanes. This service package also includes the equipment used to electronically reconfigure intersections and manage right-of-way to address dynamic demand changes and special events.

Speed Warning and Enforcement service packages supports the concept of monitoring vehicle speeds through a roadway system. If the speed is determined to be excessive, roadside equipment can suggest a safe driving speed. Environmental conditions may be monitored and factored into the safe speed advisories that are provided to the motorist. Besides monitoring vehicle speeds, this service package also enforces the speed limit while the variable speed limits service (covered in Variable Speed Limits service package) focuses on varying the posted speed limits to create more uniform speeds along a roadway, to promote safer driving during adverse conditions (such as fog) and/or to reduce air pollution.

The Drawbridge Management service package centers on the functionality necessary to manage drawbridges at rivers and canals and other multimodal crossings (other than railroad grade crossings, which are specifically covered by other service packages). The equipment managed by this service package includes control devices (e.g., gates, warning lights, DMS) at the drawbridge, as well as the information systems that are used to keep travelers apprised of current and forecasted drawbridge status.

Roadway Closure Management is a general service package whose primary goal is to close roadways to vehicular traffic when driving conditions are unsafe, maintenance must be performed or under other scenarios where access to the roadway must be prohibited. The service package includes automatic or remotely controlled gates or barriers that control access to roadway segments, including ramps and traffic lanes. Remote control systems allow the gates to be controlled from a central location, improving system efficiency and reducing personnel exposure to unsafe conditions during severe weather and other situations where roads must be closed. Surveillance systems allow operating personnel to visually verify the safe activation of the closure system and driver information systems (e.g., DMS) provide closure information to motorists in the vicinity of the closure. Note that this package covers general road closure applications; specific closure systems that are used at railroad grade crossings, drawbridges, reversible lanes, etc. are covered by other TM service packages. IDOT has deployed a statewide construction data entry system to support a unified approach. In parallel, via Gateway, IDOT routinely collects construction information from county and municipal operations folks to add to Gateway.

Weather Data Collection (WX01): This service package collects current road and weather conditions using environmental sensors deployed on and about the roadway or sensor systems located on maintenance vehicles and on-board sensors provided by auto manufacturers. Note that the collected environmental data is used by the Weather Information Processing and Distribution service package to process the information and make decisions on operations.

The Weather Information Processing and Distribution (WX02) service package encompasses all aspects of what it takes to distribute the environmental data collected from the Weather Data Collection service package. This service package uses the environmental data to detect environmental hazards, such as icy road conditions, high winds, dense fog, etc. so system operators and decision support systems can make decisions on corrective actions to take. The continuing updates can be used to more effectively deploy road maintenance resources, issue general traveler advisories, issue location-specific warnings to drivers (via the Traffic Information Dissemination service package), and aid operators in scheduling work activity.

Roadway Automated Treatment (MC03) is a service package of great interest in the more rural parts of Illinois. This service package automatically treats a roadway section, based on environmental or atmospheric conditions (e.g., fog dispersion, anti-icing chemicals, etc.) and warns drivers when the treatment system is applied (e.g., DMS).

The Winter Maintenance (MC04) service package supports winter road maintenance, including snow plow operations, roadway treatments (e.g., salt spraying and other anti-icing material applications),

and other snow and ice control activities.

The Roadway Maintenance and Construction (MC05) service package is a broad set of functionalities aimed at scheduled and unscheduled maintenance and construction activities along the roadway and/or right-of-way. Maintenance services would include landscape maintenance, hazard removal (roadway debris, dead animals), routine maintenance activities (roadway cleaning, grass cutting), and repair and maintenance of both ITS and non-ITS equipment on the roadway (e.g., signs, traffic controllers, traffic detectors, DMS, traffic signals, CCTV, etc.). Environmental conditions information is also received from various weather sources to aid in scheduling maintenance and construction activities.

The service package for Work Zone Management (MC06) directs activity in work zones, controlling traffic through portable DMS and informing other groups of activity (e.g., ISP, traffic management, other maintenance and construction centers) for better coordination management. Information on work zone speeds and anticipated delays are provided to the motorist prior to the work zones.

The Maintenance and Construction Activity Coordination (MC08) service package supports the dissemination of maintenance and construction activity information to centers that can utilize it as part of their operations, such as a traffic operations center that manages freeway operations.

Findings and Recommendations for Freeway Management

To improve freeway management, IDOT should consider multiple simultaneous strategies, including:

- Aggressively work with local and state law enforcement to gather real-time incident data in support of real-time operations to promote safe clearance and reduction of incident related congestion and secondary incidents.
- Expand freeway management activities beyond building and reconstructing conventional infrastructure. Transportation agencies, authorities and their staffs need tools to be more proactive in addressing potential problems, rather than merely reactive to existing conditions. This includes managing the elements of the network itself (e.g., asset management, maintenance, and IT support), not just the traffic flow.
- Support continued coordination between regional operating agencies responsible for freeway operations.
- Continue to increase the use and coordination of ITS technologies (detectors, video surveillance, DMS, HAR, ramp metering, roadway weather information systems, etc.) to provide information on current roadway conditions to and among the various agencies, as well as to the public.
- Continue to provide information on all aspects of the major roadway network (e.g., work zones, alternate routes, weather and roadway conditions).
- Monitor and incorporate CAV development for future functionalities that may significantly modify freeway management.
- Identify and Explore more advanced 24/7 operational relationships between the districts,

- other regional centers and Station One.
- Explore managed lanes concepts and hard shoulder running best practices.

6. Arterial Management

Description and Examples

Arterial management systems manage traffic along arterial roadways, employing traffic detectors, traffic signals, and various means of communicating information to travelers. These systems ultimately make use of traffic surveillance information to smooth the flow of traffic along travel corridors and it is this traffic signal progression that prevents unnecessary delays for motorists. Dissemination of information about travel conditions via technologies such as DMS or HAR is yet another means to inform the users of the surface roadway of current conditions.

In order to manage arterial roadways, data collection and management systems are needed, so that signal timing plans can be developed. These timing plans typically coordinate signals at intersections within a traffic management subsystem. In a more advanced implementation, this same system can integrate traffic flow information to predict future traffic conditions and assist in route planning.

Relationship to Statewide Vision

All IDOT regional communications centers utilize closed loop traffic signal systems or centralized signal control systems to monitor and manage arterial operations. State route signals are owned and maintained by IDOT, although many cooperative agreements are in place with local cities to update timing plans and ensure efficient operations. Jurisdictional agreements are in place or can be sought to cover geographic regions and boundaries for all type of maintenance operations from pavement patching to snow removal. Most coordination with local public works, utility companies, special event venues, and companies and organizations with high traffic volumes in and out of their facilities occurs on a regional or/local level.

Large-scale signal coordination efforts can not only provide traveler benefits, but can also substantially increased levels of inter-agency communication, which are key underpinnings of Illinois' statewide vision. Just as the Manual on Uniform Traffic Control Devices defines the signs, signals, and pavement markings that guide drivers along the nation's roadways, the statewide vision for arterial management should strive to provide a smooth and consistent traffic flow along surface streets. Furthermore, the same types of integration and interoperability benefits should be realized for all communities across the State of Illinois.

Identification of Issues

Northeastern Illinois is one of the five largest urban areas in the U.S., and it faces significant transportation challenges, including: worsening congestion, transportation delays, increased impacts from incidents, declining transit use, travelers with limited information, air quality concerns, limited availability of right-of-way, funding and resources. To varying degrees, the MPO/RPC agencies which plan for other Illinois urban areas, face similar issues. In the more rural counties of Illinois, limited funding and resources, transportation delays due to construction, maintenance or weather, and limited availability of traveler information also exist.

The underlying issue for arterial management is integration and communication. Integration is one of the factors in successful ITS deployments. An integrated system is often more effective than one in which all components function separately. A communications infrastructure allowing multiple agencies to share real-time traffic operations information (and update signal plans accordingly) allows the achievement of regional integration goals. Specific areas in which challenges have been identified for arterial management include:

- Cost of building out the fiber optic backbone
- Signal preemption / signal priority
- Continued and expanded signal coordination and detector coverage
- Enhanced transit system coordination and operations
- Frequency of optimization and appropriate maintenance funding
- Boundary effects on signal coordination, preemption, and transit priority effectiveness between adjacent coordinated sections
- Impacts of proprietary systems versus open standards
- Signal problem reporting system and public outreach
- Enforcement – red light running
- Management and Operations
 - Advanced traffic signal systems
 - Corridor signal coordination
 - Alternative devices
 - Varying timing philosophies between agencies
 - Transit / traffic interaction
 - Safety / spot problems
 - Pedestrian and bicycle issues
- Anticipation and incorporation of developments with CAVs that will change the nature of arterial management.

Benefits of Arterial Management

Traffic signal control systems address a number of objectives, primarily improving traffic flow and safety. Transit signal priority systems can ease the travel of buses or light-rail vehicles traveling arterial corridors and improve on-time performance. Signal preemption for emergency vehicles enhances the safety of emergency responders, reducing the likelihood of crashes, while improving response times.

Adaptive signal control systems coordinate traffic signals across metropolitan areas, adjusting signal timing based on prevailing traffic conditions. Advanced signal systems include coordinated signal operations across neighboring jurisdictions, as well as centralized control of traffic signals which may include some necessary technologies for the later development of adaptive signal control.

It is of note that the most important factor in achieving coordination within or across jurisdictional

boundaries is not the technical or equipment challenges. Rather, it is the prevalence of cooperation and communications among the agencies or departments involved. The benefits that can be achieved from signal coordination at any level (but particularly cross-jurisdictional), are not only seen in alleviating traffic congestion, and improving air quality and safety, but also in cost efficiencies for the purchase and installation of traffic control equipment.

Other less publicized areas include pedestrian detectors, specialized signal heads, and bicycle-actuated signals that can improve the safety and mobility of all road users at signalized intersections. Arterial management systems with unique operating schemes can also smooth traffic flow during special events.

A variety of techniques are available to manage available travel lanes on arterial roadways, and ITS applications can support many of these strategies. Examples include dynamic posting of high-occupancy vehicle (HOV) restrictions and the use of reversible flow lanes - opening more lanes in the peak direction of travel during rush hours. Parking management systems, most commonly deployed in urban centers or at modal transfer points such as airports, monitor the availability of parking and disseminate the information to drivers, reducing traveler frustration and congestion associated with searching for parking.

Any agency or organization operating ITS can (and should) share information with road users through technologies within the arterial network, such as DMS, HAR or over the internet, and with other agencies to help smooth traffic progression. Arterial management systems may also include automated enforcement programs that increase compliance with speed limits, traffic signals, or other traffic control devices. The Insurance Institute of Highway Safety (IIHS), reported that red light cameras in Chicago have reduced injury crashes by 10 percent and angle injury crashes by 19 percent. According to the report, researchers from Northwestern University examined 340 approaches at intersections across the city before and after the camera installation, also another 236 similar intersections without cameras were analyzed as control points.

The following are samples of cited benefits from USDOT fact sheets:

- A decentralized adaptive signal control system has an expected benefit-cost ratio of almost 20:1 after five years of operation, if deployed city-wide in Pittsburgh.
- The Traffic Light Synchronization program in Texas demonstrated a benefit-to-cost ratio of 62:1.
- Adaptive signal control, transit signal priority, and intersection improvements implemented during the Atlanta Smart Corridor project produced a benefit-to-cost ratio ranging from 23.2:1 to 28.2:1.

ITS Architecture

Architecturally speaking, the same high-level physical architecture entities as discussed in Section 5 (Freeway Management) come into play for arterial management. The service packages discussed previously are largely the same for arterial management functions - with a few notable exceptions.

As noted previously, the foundational service package for managing the surface roadway network is Infrastructure-Based Traffic Surveillance and its alternative, Vehicle-Based Traffic Surveillance. However, this is the first differentiation point between freeway and arterial management. Instead of the Traffic Metering service package, the Surface Street Control service package is geared toward providing the central control and monitoring equipment, communication links, and the signal control equipment that support local surface street control and/or arterial traffic management. A range of traffic signal control systems ranging from fixed- schedule control systems to fully responsive systems that dynamically adjust control plans and strategies based on current traffic conditions and priority requests are supported in this service package.

Additionally, general advisory and traffic control information can be provided to the driver while in-route. Such information is intra-jurisdictional; it does not rely on real-time communications between separate control systems to achieve area-wide traffic signal coordination. Systems that achieve coordination across jurisdictions by using a common time base or other strategy that do not require real-time coordination would be represented by this package. Those areas needing inter-jurisdictional coordination would use the Regional Traffic Management service package described in Section 5. As an aside, the transit-related Multi-modal Coordination and emergency responder-related Routing Support for Emergency Responders service packages are also involved with arterial management strategies when it comes to preemption signal priority.

The Traffic Incident Management System, Traffic Forecast and Demand Management, Emissions Monitoring, and Roadway Closure Management are also TM service packages that could be applied to Arterial Management. Construction-related service packages such as Weather Data Collection, Weather Information Processing and Distribution, Roadway Automated Treatment, Winter Maintenance, Roadway Maintenance and Construction, Maintenance and Construction Activity Coordination and Work Zone Management described in Section 5 can also be applied to arterial management.

Another important construction-related service package is Work Zone Safety Monitoring, which is more technologically advanced. Here, rather than simply “managing” the work zone, ITS systems improve work crew safety and reduce collisions between the motoring public and maintenance and construction vehicles by detecting vehicle intrusions in work zones. In turn, these systems warn crew workers and drivers of potential safety hazards.

Findings and Recommendations for Arterial Management

To improve arterial management, IDOT and local agencies should consider multiple strategies, including:

- Promote more cooperative purchases of arterial ITS systems. IDOT should work to develop guidelines – not specifications – for the most desired functions, to guide agencies and municipalities in formulating their own ITS plans, which will promote integration and inter-jurisdictional coordination once these arterial roadway systems are in place.
- Continue to evaluate and effectively utilize adaptive technologies and creative signal control opportunities such as transit signal priority in appropriate environments.
- Encourage agencies in the same region to interconnect their systems, creating corridors and working through any institutional issues through shared cooperative committees. Planning for different types of incidents can speed up on-scene management and reduce traffic disruptions. Planning and coordination are needed not only among the agencies within a jurisdiction, but also among various jurisdictions--in order to define authority and determine resources. Planning also requires carefully evaluating current policies and procedures.
- Encourage management and operations considerations in the planning process through the distribution of best practices information about how others are mining their ITS data to support operations analysis, incident/disaster response planning and construction/maintenance activities support.
- Encourage appropriate frequency of optimization and appropriate maintenance funding.
- Encourage hiring of sufficient technical staff and provide on-going training via staff who have implemented arterial management ITS projects, and can therefore serve as resources to other agencies undertaking similar ITS implementations.
- Encourage additional efforts to utilize national standards through development of a statewide, vendor-neutral signal specification that emphasizes performance measurement, as has been done in Indiana, Utah and a few other states.
- Expand coordination between arterial and freeway management centers and systems - particularly in the areas of incident management, emergency response, and construction and maintenance activities.
- Monitor progress in testing standards, and guide agencies in deciding which standards to adopt.
- Monitor and incorporate CAV development for future functionalities that may significantly modify arterial management in conjunction with freeway management.

7. Incident Management

Description and Examples

Major incidents may bring tremendous impacts to the flow of people and goods across statewide transportation networks. Without safe and efficient response including delivery of timely information to the public, an incident can literally result in the unnecessary additional loss of life and excessive traffic delay, fuel consumption, and air pollution - particularly during the long restoration period following major incident or during the recurring rush hour congestion at many locations in Illinois's metropolitan areas.

To get a better understanding of Incident Management, it is helpful to apply the familiar law of supply and demand. Traffic engineers measure a roadway's supply in terms of capacity (e.g., the maximum number of vehicles through a single lane per hour) while the demand is measured in terms of how many motorists wish to travel on that lane per hour. Sometimes an incident reduces network capacity by blocking or destroying roadway infrastructure. Effective Incident Management can minimize the duration that an incident reduces capacity and can also encourage the traffic volume (supply) to utilize alternate routes until capacity is restored.

Incident scope varies immensely, ranging from a single vehicle encountering debris to entire communities losing access to the transportation network. Such incidents include the bridge collapses in 2017 on I-85 in Atlanta and in 2007 on I-35 in Minneapolis. Impacts from these types of large scale infrastructure incidents include loss of life and excessive delays due to alternate routing and lack of multimodal travel options. All incidents have the potential to cause crashes, congestion, wasted fuel and pollutants increase. Incidents also have the tendency to self-propagate, causing additional incidents in their wake as traffic backups occur. In many cases, secondary incidents are more serious than the initial incident. In this document, an incident will be defined as: any circumstance that negatively reduces traffic flow for a significant amount of time. The term "traffic flow" is used to cover two conditions: reduced capacity and excessive demand. The term "significant" is relatively used according to local importance on a specific road segment. For heavily traveled areas such as the urban Interstates, this could be as little as 10 or 20 minutes. For a rural highway with low traffic demand, this could be several hours. Significance can be ranked by the negative impacts created by the incident, such as the man-hours of delay or the probability for a new crash to occur.

The following dot-points describe some typical incident types:

- **Traffic Crashes:** One significant characteristic of crashes is that they are usually very unpredictable with sudden, local consequences. They may also cause secondary incidents when they create localized backups, catching motorists off guard. Another significant aspect is that the subsequent congestion may block emergency crews, prolonging the problem and increasing the negative crash impact.

- **Weather Events:** While the weather is not often considered as an incident, it meets the criteria mentioned above – severe or inclement weather can reduce the transportation system capacity. Typically, the roadway network is more vulnerable to weather-related incidents than the rail or transit systems. Weather events can occur suddenly, but the ITS Architecture can improve circumstances by defining the information path that enables earlier warnings to unsuspecting motorists and more accurate and timely information for road maintenance staff.
- **Bridge or Roadway Failures:** The physical highway infrastructure itself can also cause incidents as it degrades. Pavement failures, bridge damage and rail crossings that become impassible could meet the criteria for an incident. They reduce the capacity of the network and would occur with little or no warning.
- **Construction Activity (“Planned Incidents”):** Construction activity is a "planned" incident. Advanced notification can help reduce the negative impact by diverting motorists to an alternate route if applicable. Other motorists can be informed of construction sites ahead.
- **Rush Hour Traffic:** Even though rush hour congestion is not planned in the system, it is recurring and fairly predictable, enabling some countermeasures in advance. Rush hour traffic management is part of the "demand" side, in the sense that available capacity is exceeded over a significant amount of time, leading to congestion. Similar to crashes, rush hour conditions also raise the potential for secondary incidents due to slow or queued vehicles.
- **Special Events:** Special event is another form of "planned" incident with the advantage of predictability. Like rush hour traffic, special events affect the demand side more than the supply side. ITS Architectures identify the ways to reconfigure the network for this increased demand.

Incident information is needed by motorists, operations personnel and others, who react and influence either the supply side or demand side of roadway capacity. Motorists can reroute themselves, thereby making the optimal use of remaining available capacity and reducing the demand on disabled links. Accurate and timely information also helps the emergency response personnel to know the best access routes, for them to accomplish important, time-sensitive work and minimize incident duration. Incident information provides detailed insights about roadway capacity and expected variations in demand, serving future improvements.

Relationship to Statewide Vision

Consistency of real-time traffic data on a statewide basis is partly limited in Illinois. While construction reporting, weather data including winter weather pavement condition reports are generally available statewide, there are gaps. Illinois State Police and IDOT share incident data for numerous purposes, while the exchange primarily occurs after the events are long over. Reporting and validation are focused on traffic safety applications and potential system improvements derived from the crash data. Real-time exchanges of crash data are primarily via radio monitoring and direct IDOT to Illinois State

Police interactions via phone, radio, and text. The notable exception is Illinois Tollway with ISP District 15 where real-time communications from dispatch to traffic operations are facilitated electronically. From a congestion and travel times perspective, several IDOT Districts are utilizing ITS equipment to measure speed and derive congestion and travel times. To enhance this capability statewide, IDOT is currently testing and evaluating private sector feeds of speed data on a statewide basis. IDOT District 1 is currently receiving CAD data from ISP and a project is underway to also facilitate video sharing with ISP. Similarly, District 4 receives CAD data from Tazewell County Sheriff and Peoria County to enable coordination of resources for Incident Management and response.

Identification of Issues

The individual agencies typically provide substantial commitment to safe response and management procedures, associated staffing, agreements and policies with private sector support staff, and frontline responders such as police, fire, and emergency medical services.

Advancement of statewide efforts to connect IDOT, Illinois State Police, and regional or local PSAPs is required. Often arrangements that share access to CCTV in real time with the responder agencies can serve as a valuable offering to law enforcement. There are numerous examples nationally and two local examples Lake County Passage, and Illinois Tollway TIMS, where data sharing issues have been resolved creating a more effective real-time incident management environment.

The primary challenges lie in (1) the ability to collect and track incidents in real-time, and (2) the ability to coordinate responses at a regional level. As examples, Computer Aided Dispatch integration projects in portions of the state, and the influence of private sector crowd-sourced data such as Waze have removed theoretical barriers to real-time incident data sharing. Generally, obtaining timely and actionable information regarding location, impact, lane blockage and basic event characteristics such as vehicle quantities and types and information on cargo debris, spills, and/or gaseous leaks are key to effective response. The ability to protect personal data in the information integration process is no longer a critical barrier.

From an agency coordination perspective, the connectivity of systems and ability to reasonably share information, supporting responses and coordination of resources from an area or regional perspective can often be addressed through operational procedures and agreements, but do require commitment executing those procedures and on-going training.

At a more detailed level the challenges distill into the following key items:

- Technological Incompatibilities between Legacy Systems:
- Internal Policies or Procedures that Impede Cooperation outside an Agency:
- Confidentiality Issues Relating to Data and Data Ownership: Will become even bigger thing. Accept it. Going to be data we collect and can't share. Use it, get it as service, available to be procured by anyone.
- Differences in Technological Sophistication between Agencies
- Differences in Resources

- Redundant Services

Benefits of Incident Management

Incident Management is one of the most valuable services that transportation agencies can perform because of the many benefits it affords. Study after study has clearly demonstrated that the return on the investment is extremely high. The list below briefly describes a few of these benefits.

- **Reduced Loss of Life and Property:** Fewer incidents and more rapid response efforts translate into a reduction in the loss of life and property.
- **Faster Notification of Incidents:** A comprehensive Incident Management program takes advantage of the ITS features to provide fast notification when anomalies in traffic flow occur. When the agencies become aware of these sudden changes from the normal flow of traffic, they immediately suspect that an incident has occurred, and their resources are made ready for mobilization. Making this information available to road users as soon as possible can result in alternative travel choices that can reduce congestion and improve incident response.
- **Reduction in the Overall Number of Incidents:** Incidents sometimes result in secondary incidents that can be more severe than the original. By aggressively responding to incidents and quickly clearing the obstructions to traffic flow, the likelihood of secondary incidents is greatly reduced.
- **Improved Overall System Reliability:** Implementing a comprehensive Incident Management Program, and thereby minimizing the number of hours each year that a roadway is restricted, can lead to the public perception of the system as more dependable.
- **Optimized Performance:** Reducing the number of secondary crashes and altering traffic management (like traffic signals and ATM devices) can dramatically improve system performance during an incident by adapting the available network to the changes in demand.
- **Lowered Cost of Response:** Critical information delivered to emergency responders in a timely manner can improve their choices as they initiate response actions. For example, a vehicle fire, an overturned truck spilling its cargo, and a pedestrian crash all require very different response strategies and equipment. If an emergency response agency gets critical information about the details of the incident at the time when they are first notified, it can deploy the appropriate equipment for the problem at hand. Rapid response to incidents, restoring traffic conditions to normal as quickly as possible, minimizes the potential for fatalities, injuries, and property damage. This translates into significantly lower operating costs for emergency response agencies.

The following are samples of cited benefits from the USDOT fact sheets:

- Michigan's traffic incident management-oriented ITS program cites a Benefit/Cost ratio of

3.2/1.

- In Portland, Oregon, an incident response program known as COMET has reduced 30 seconds per incident, resulting in a reduction of \$711,300 costs of delay, which is equivalent to the cost of operating the incident response program for a year.
- A multi-jurisdictional emergency response crew in the Phoenix metropolitan area provides services to six cities with a benefit-cost ratio of 6.4:1 by increasing responder safety and reducing the number of patrol officers necessary at each crash scene.

ITS Architecture

It has already been mentioned above that a Statewide ITS Architecture is highly relevant to Incident Management as it relates to reliability and availability of real-time information exchange facilitated by a communications infrastructure.

Given the importance of Incident Management and its effects on the surface transportation network, a large number of service packages exist in the National ITS Architecture that could be used in creating the statewide and regional ITS architectures in Illinois.

The *Traffic Incident Management System* service package manages both unexpected incidents and planned events so that the impact to the transportation network and traveler safety is minimized. The service package includes incident detection capabilities through roadside surveillance devices (e.g. CCTV) and through regional coordination with other traffic management, maintenance and construction management and emergency management centers, as well as rail operations and event promoters. Information from these diverse sources is collected and correlated by this service package to detect and verify Incidents and implement an appropriate response. This service package supports traffic operations personnel in developing an appropriate response in coordination with emergency management, maintenance and construction management, and other incident response personnel to confirmed incidents. Note that the response may include traffic control strategy modifications or resource coordination between center subsystems. Incident response also includes presentation of information to affected travelers using the Traffic Information Dissemination service package and dissemination of incident information to travelers through the Broadcast Traveler Information or Personalized Traveler Information service packages. These are described previously under the Travel Information section. The roadside equipment used to detect and verify incidents also allows the operator to monitor incident status as the response unfolds. The coordination with emergency management might be through a CAD system or through other communication with emergency field personnel. The coordination can also extend to tow trucks and other allied response agencies and field service personnel.

Emergency Call-Taking and Dispatch provides the functionality for basic public safety call-taking and dispatch services. It includes emergency vehicle equipment, equipment used to receive and route emergency calls, and wireless communications that enable safe and rapid deployment of appropriate resources to an emergency. Coordination between Emergency Management Centers supports emergency notification between agencies. Wide area wireless communications between the Emergency Management Center and an Emergency Vehicle supports dispatch and provision of

information to responding personnel.

Routing Support for Emergency Responders, the Emergency Vehicle Preemption and the Special Vehicle Alert service packages are a potentially huge time saver market when the ability to use automated vehicle location and dynamic routing of emergency vehicles is postulated or present. Traffic information, road conditions, and suggested routing information can be provided to enhance emergency vehicle routing. Special priority, preemption or other specific emergency traffic control strategies can be coordinated to improve the safety and time-efficiency of responding vehicle travel on the selected route(s). The Emergency Management Center provides the routing for the emergency fleet based on real-time conditions and has the option of requesting a route from the Traffic Management Center. The Emergency Vehicle may also be equipped with dedicated short-range communications for local signal preemption. The service provides for information exchange between care facilities and both the Emergency Management Center and emergency vehicles. Of note is that service package is an area of active private sector interest and public sector procurement since this service package leverages the same vehicle location, wide area digital communications, dispatch support, and in-vehicle interactive interface technologies that are instrumental to the related commercial and transit fleet support service packages. New standards are not required to support basic implementations. Progressive implementations which address more extensive inter-agency coordination in routing may be added as new standards become available and are adopted for the implementing region.

The *Mayday Notification* service package allows the user (driver or non-driver) to initiate a request for emergency assistance and enables the Emergency Management Center to locate the user, gather information about the incident, and determine the appropriate response. The request for assistance may be manually initiated or automated and linked to vehicle sensors. This service package also includes general surveillance capabilities that enable the Emergency Management Center to remotely monitor public areas (e.g., rest stops, parking lots) to improve security in these areas. The Emergency Management Center may be operated by the public sector or by a private sector telematics service provider.

In those areas of Illinois that are more rural in nature as opposed to metropolitan, this service package is applicable to a significant number of rural user needs with some augmentation for the rural environment. In general, the service package addresses the needs of the broad rural development track by the following: Allows agencies to automatically know the location of a vehicle calling in an incident, as travelers/users don't always know where they are. This type of service will further be enhanced as efforts in the E911 community continue. Another potential driver for inclusion of this service package is that it provides the ability to automatically transmit Mayday information from traveler personal devices and/or vehicles. For vehicle crashes, can include vehicle location and extent of crash damage. Finally, this service package also provides for the instance in which a user of the system (driver or non-driver) initiates a request for emergency assistance and the infrastructure is in place to enable the closest emergency management center to locate the user and determine the appropriate response.

Roadway Service Patrols: Supporting the concept of roadway service patrol vehicles that monitor roads that aid motorists, offering rapid response to minor incidents (flat tire, accidents, out of gas) to minimize disruption to the traffic stream is the thrust behind the Roadway Service Patrol service package. If problems are detected, the roadway service patrol vehicles will provide assistance to the motorist (e.g., push a vehicle to the shoulder or median). The service package monitors the service patrol vehicle locations and supports vehicle dispatch to identified incident locations. Incident information collected by the service patrol is shared with traffic, maintenance and construction, and traveler information systems.

Findings and Recommendations for Incident Management

- Improvements in incident reporting systems are needed at district levels, and in integration and data-sharing among all of the concerned parties. Automation of incident reporting systems is necessary to improve coordination between responders and in providing more timely and accurate traveler information.
- Progress toward additional efficiencies and real-time condition data integrated between Station One, IDOT District TMC's, IEMA, ESDAs and Illinois State Police can further advance efficient operations particularly during severe events where Station One relationships with responders is clearly required. Computer Aided Dispatch integration is viable on a broader scale enabling traffic incident management across regional boundaries.
- Incident Command for transportation professionals: The Incident Command System (ICS) is an incident response protocol that enables a variety of disparate players to arrive on scene and execute their roles within a chain of command that can be quickly established. Transportation agencies should continue to participate, and should provide training to their personnel, so that they can take advantage of the increased efficiency that this tool provides. For reference, see <https://www.fema.gov/incident-command-system-resources>.
- Performance Measures: Performance measures are useful for insuring consistent results. Incident Management performance measures include response times, clearance times, incident-related delays, and other metrics. This data can be used for planning and operational improvement purposes and should be archived in a readily accessible data warehouse for use to support operational improvements.
- Big Data: Crowdsourced data such as that available from Waze and other providers have become mainstream in many respects, thus the ability to effectively utilize these sources for incident detection in conjunction with traditional sources will be an on-going activity.
- Explore expansion of ETP to cover all Illinois interstates and major freeway networks. Increasing availability of resources for incident management, response and recovery, saves time, lives and money.

8. Electronic Fare/Toll Payment

Description and Examples

Electronic payment systems employ various communication and electronic technologies to facilitate commerce between travelers and transportation agencies. Agencies such as the Illinois State Toll Highway Association (ISTHA) uses automated electronic media for payment collection at toll plazas to increase the operational efficiency and convenience of toll collection. The IL Tollway system consist of five routes of multi-lane, limited-access facilities. Four of the five are part of the National Interstate System, while the fifth, IL 390, is an Illinois State Route built to the interstate standards. Between 2004 and 2016, the Tollway added 340 new lane miles to the system. Sections of the system were widened. The Tollway also built the South Extension of the I-355 Veterans Memorial and the western portion of IL 390. The South extension of the I-355 Veterans Memorial opened in November 2017 and added 74 new lane miles to the system. The wester portion of IL 390 opened on July 5, 2016 and added 13 new lane miles to the system. I-PASS is the Tollway's trademark name for its electronic toll collection (ETC) system. The Tollway has one of the highest ETC collection rates in the country. In 2016, about 87.0 percent of all Tollway transactions were paid with ETC. This compares to an average of 78.8 percent of transaction among E-Z Pass member agencies. The IL Tollway system has 131 "I-PASS Only" lanes and 193 Open Road Tolling (ORT) and Automated Electronic Toll (AET) Collection lanes.

The I-PASS transponder, available through the internet, toll plazas, and from selected retail stores (Jewel-Osco), contains a computer chip that stores a prepaid value of toll fares. Each time a driver passes through a designated I-PASS lane, radio signals communicate to the transponder and deduct the proper toll amount from the driver's balance.

Electronic transit fare and parking payment also come under the purview of Electronic Fare/Toll Payment. Current transit fare collection system in Chicago metropolitan area, Ventra, is a combination of RFID technologies and mobile app, which replaced previous magnetic stripe fare collection system Chicago Card in 2014. Transit users can purchase Metra mobile tickets using Ventra App, and pay for CTA and Pace rides when boarding or at any kiosk.

Ventra is designed to accept industry-standard, contactless payments. In addition to Ventra Cards, Ventra fare collection devices support RFID devices including smartphones and smartwatches (Apple Pay, Google Pay, Samsung Pay and Fitbit Pay), and bankcards with NFC chips. A more advanced combination with Apple Pay will be introduced in late 2019, to add virtual Ventra Card in Apple Wallet. The expansion of electronic payment systems will be useful for multimodal transportation applications in the future, including water taxis, scooters, bikes and tolls.

Ideally, all forms of electronic payment covering tolls, transit fares and parking are covered in an integrated multi-use payment system.

Relationship to Statewide Vision

In order to support such important goals as increased performance and customer satisfaction through improved mobility, electronic payment methodologies are an important tool for the transportation agency's use. Integrated payment systems support mobility and equity in services.

An underlying tenet for the success of the Statewide ITS vision is Integration. From both a technical and institutional perspective, electronic fare payment solutions are a complex undertaking, involving linkages across systems, modes, and functions. The State of Illinois has pioneered electronic payment in conjunction with the ISTHA. As increases in interoperability significantly eases integration of electronic payments across financial institutions, the consensus-driven standards development process for transportation will require more time to arrive at the same place nationally that the banking industry has reached today; that is true interoperability across different electronic fare payment solution that cross regional and state lines without the traveler needing different equipment for mode or state.

Identification of issues

Transportation is also being transformed by new smart transportation solutions that look to improve the mobility experience. Transportation infrastructure must smarten up, incorporating digital services like integrated apps and cashless payment as standard. The first issue surrounds the technology that addresses the different modes of service – public transit vs. parking vs. tollways. Existing proprietary revenue collection systems are limited in their ability to support an “open” architecture; therefore, a technology standard is needed to ensure compatibility and support reuse of the technology in the different modes.

As an example, Illinois Tollway I-PASS users can also use their transponders on the Chicago Skyway, the Indiana Toll Road and in 15 other states via the E-Z Pass system. However, there is not interoperability with other toll systems as in California (FasTrak), Texas (TxTag), and Florida (SunPass), which have their own pass systems. Per Federal MAP-21 legislation, interoperability was supposed to have been established by fall 2016, however, it now appears that timeline will extend (see <https://www.ibtta.org/ibtta-interoperability-committee-iop>). Since transactions are mostly going cashless, it is important to move to a fully interoperable tolling system that will accept the passes anywhere across the country.

In 2005, the Illinois Tollway began converting existing mainline toll plazas to full Open Road Tolling (ORT). Today the Tollway has 28 ORT plazas and is now gradually converting its system to an All Electronic Tolling (AET) system in which no cash is handled at toll plazas; all payments are via transponders, over the internet or in person at Tollway administrative facilities. In the interim, the Tollway has Electronic Toll Collection (ETC) at which I-PASS users are not stopped, but cash customers can deposit coins in toll collection bins or attendants or pay on-line. The Tollway encourages use of I-PASS transponders by heavily discounting toll rates for I-PASS users, such that I-PASS is now used for almost 90 percent of toll transactions. The biggest challenge with AET and ETC is the need to accurately read and interpret all license plates, a challenge that all license plate reading toll agencies

face across the US.

More broadly, across Illinois and the nation, there is a shortfall in available road improvement funds since the Federal gas tax has not been raised in over 20 years and vehicles have become more fuel efficient. This may translate into more widespread use of tolling over the next 20 years on current and future freeways. IDOT would likely then follow the ISTHA AET practice and have barrier-less mainlines for I-PASS users, with off-line payment cash patrons. The question then will be whether IDOT moves directly into tolling or hands off all tolling responsibilities to the Illinois Tollway. Despite the political sensitivity of the issue, technology plans must recognize that this approach may be a future requirement.

Project evaluations such as current I-55 and I-290 studies are exploring a variety of techniques to improve and sustain operational goals including the use of tolling. Congestion pricing for roadway combined with additional operational approaches on arterials, including transit, can support optimization of overall mobility in dense environments. As the term Smart Cities continues to influence program planning and capital development strategies, the integration of transportation safety and mobility, coupled with fee collection structures and technologies will be looked at holistically. More information is available at https://ops.fhwa.dot.gov/congestionpricing/cp_benefits.htm.

Benefits of Electronic Fare/Toll Payment

ETC and AET are successful ITS applications, with numerous benefits related to delay reduction, improved throughput, and reduced fuel consumption and vehicle emissions at toll plazas. These payment systems can reduce revenue collection and maintenance costs, increase security, and provide more detailed customer information.

Electronic transit fare and parking payment systems can provide increased convenience to customers and generate significant cost savings to agencies by increasing the efficiency of money-handling processes and improving administrative controls.

Multi-use payment (sometimes called Mobility as a Service), brings all means of travel together. It can combine options from different transport providers into a single mobile service, removing the hassle of planning and one-off payments. Payment for bus, rail, tolling, parking and other public or private sector goods and services can be made simply by passing a smart-card-sized device over an automated transaction point located at terminal gates, or at check-out counters other facilities. The overall benefit is time savings at payment locations and simplified administrative and accounting functions assuming a robust multi-agency payment system is included.

The following are samples of cited benefits for variable pricing projects

- The Minnesota UPA projects along the I-35W corridor in the Minneapolis-St. Paul metropolitan area included high-occupancy toll (HOT) lanes and a priced dynamic shoulder lane (PDSL), for a total benefit-cost ratio of 6:1.
- In the Seattle metropolitan area, the net benefits of a network wide variable tolling system

could exceed \$28 billion over a 30-year period resulting in a benefit-cost ratio of 6:1.

ITS Architecture

Unlike other areas such as Transit or Commercial Vehicle Operations in the National ITS Architecture, the area of electronic fare/toll payment is centered in the Payment Administration Center. The Payment Administration Center (Subsystem) provides general payment administration capabilities and supports the electronic transfer of authenticated funds from the customer to the transportation system operator or other service provider. Charges can be recorded for tolls, vehicle-mileage charging, congestion charging, or other goods and services. This subsystem supports traveler enrollment and collection of both pre-payment and post-payment transportation fees in coordination with the existing, and evolving financial infrastructure supporting electronic payment transactions. It supports communications with ITS Roadway Payment Equipment to support fee collection operations. As an alternative, a wide-area wireless interface can be used to communicate directly with vehicle equipment. The subsystem also sets and administers the pricing structures and includes the capability to implement road pricing policies in coordination with the Traffic Management Center (Subsystem).

The primary security consideration is related to the financial information collected from the field and exchanged between other agencies using common electronic payment media that needs to have a relatively high degree of confidentiality in order to safeguard it. The electronic financial transactions (in which this subsystem is an intermediary between the customer and the financial infrastructure) are generally cryptographically protected and authenticated to preserve privacy and ensure authenticity and auditability.

It is important to note that Payment Administration Center in the national ITS Architecture shares important interfaces with different Terminators or entities whose internal functionality is not governed or described by the surface transportation network. Among these Terminators are:

- DMV (registration and license requests)
- Enforcement Center (payment violation)
- Financial Center (payment request and transaction status)
- Other Authorizing Centers (payment coordination)
- Other Payment Administration Centers (payment coordination)
- Other Transit Management Centers (payment coordination)

The intrinsic features of electronic fare/toll payment methods are encompassed within three service packages and described as follows:

Transit Fare Collection Management – This service package manages passenger loading and fare payments on-board transit vehicles using electronic means. It allows transit users to use a traveler card or other electronic payment device. Sensors mounted on the vehicle permit the operator and central operations to determine vehicle loads, and readers located either in the infrastructure or on-board the transit vehicle allow electronic fare payment. Data is processed, stored, and displayed on the transit

vehicle and communicated as needed to the Transit Management Center (Subsystem).

Electronic Toll Collection is covered in a service package that describes functionality allowing toll operators to collect tolls electronically and detect and process violations. The fees that are collected may be adjusted to implement demand management strategies. Dedicated short range communication (DSRC) between the roadway equipment and the vehicle is required, as well as fixed-point to fixed-point interfaces between the toll collection equipment and transportation authorities and the financial infrastructure that supports fee collection. License plates of toll violators are read and electronically posted to vehicle owners. Standards, inter-agency coordination, and financial clearinghouse capabilities enable regional, and ultimately national, interoperability for these services.

The *Parking Space Management* service package covers enhanced monitoring and management of parking facilities.

The *Parking Electronic Payment* service package supports electronic collection of parking fees. It collects parking fees from in-vehicle equipment, contact or proximity cards, or any smart payment device. User accounts may be established to enhance services offered to frequent customers.

Findings and Recommendations for Electronic Fare/Toll Payment

Electronic payment (e-payment) systems provide an opportunity to partner with other agencies and integrate with other ITS technologies. One of the next steps in its evolution is for Illinois's various agencies to continue looking for other uses of e-payment, such as frequent trip discounts and senior discounts. Similarly, institutional arrangements whereby common e-payment solutions are used across modes (increasing customer service and ridership) should be explored.

- I-55 and I-290 corridor studies and the potential PPP programs that include tolling will continue to require consideration and implementation where investment costs and longer-term O&M costs must be addressed. In Northern Illinois the existing IPASS collection system for Illinois Tollway is already interoperable with the multi-state EZ-PASS program. In parallel, Kane County's Longmeadow Bridge construction is also considering tolling. As part of the program, Kane County continues to consider cash and transponder collection methodologies and fee considerations such as discounted tolling rates for residents. Integrated payment services and capitalization with existing fare and toll collection systems provide efficiencies to the agencies involved as well as being less intrusive on day-to-day mobility for customers.
- Expanded outreach to identify and address the diverse Illinois audiences who may become enrolled in the transit fare card or tollway transponder programs is needed. It is also important to speak to an individual's needs and should include those patrons who are not currently regular commuters. Marketing campaigns targeted to the commuting population only may, in fact, miss a significant portion of potential electronic payment customers.
- Illinois is a central delivery point for the country's shipping industry, both by rail and by road. Disparities between the various electronic payment systems need to be addressed and a statewide interoperable standard implemented across modes.
- In the Chicago area, e-payment agencies including CTA, Metra and ISTHA should investigate

and integrate their payment systems to make them as interoperable as possible.

- Monitor and incorporate CAV development for future functionalities that may significantly impact electronic fare payment.
- Explore potential applications for tolling on IDOT I-55 and I-290 projects that promote multimodal travel and payment options and also support first and last mile connections for travelers.

9. Transit Management

Descriptions and Examples

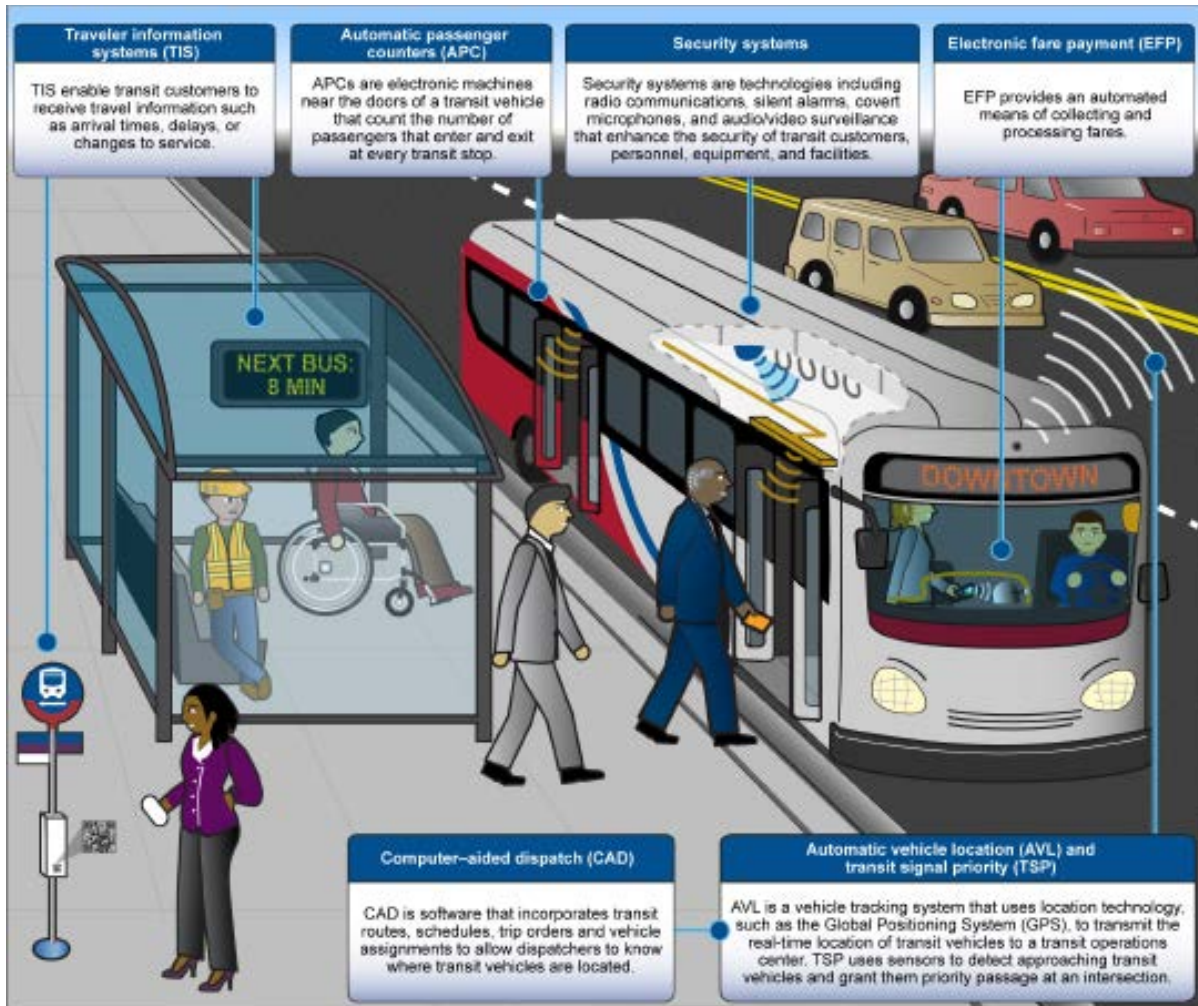
Transit ITS encompasses a broad range of wireless and wire line communications-based information and electronic technologies, for collecting, processing, and disseminating operational status. Transit service providers have experience deploying traveler information systems using websites, mobile applications, and electronic message signs at transit stops and stations to provide customers with information on routes, schedules, fares, and real-time information on vehicle arrival and departure times.

A 2015 Transit Cooperative Research Program (TCRP) open data survey found an increasing number of transit providers are making data available to the public from GIS, computer-aided dispatch (CAD), automatic vehicle location (AVL), and automatic passenger counters (APC). Between 2013 and 2016, the survey found that Transit providers implemented widespread ITS to enhance capabilities to provide real time, transit information and improvements to electronic fare payment systems.

In addition to sharing data with the public, the large and medium urban transit providers in our review reported that they share data with regional transportation stakeholders to support multimodal planning and management. An Integrated Corridor Management (ICM) approach, where transportation agencies operate transportation corridors in a coordinated and integrated manner, can include providing multimodal traveler information in-route in addition to pre-trip information as travel conditions change. Experience using ICM along a major road corridor combined with integrated data on real-time traffic conditions, transit, and parking availability has enabled travelers to make better travel decisions and reduced congestion on roadways.

In Region 1, transit service operating on bus-only shoulders has proven successful in increasing the reliability and attractiveness of public transportation. In 2011, Illinois State law was changed to allow bus-on-shoulder service on the Stevenson Expressway (I-55) in partnership with IDOT, the Illinois State Police, and RTA. Bus ridership on that corridor has increased more than 600%, and on-time performance—which averaged less than 70%—is now over 90%. Realizing the regional benefits, in 2014, the Illinois General Assembly enacted legislation permanently allowing bus-on-shoulder service and expanding that permission to all the region's expressways and tollways. Pace has expanded service along the I-55 corridor and in 2018, Pace and IDOT opened bus-on-shoulder service on the Edens Expressway (I-94). The statewide vision is positively impacted by demonstrated informed choices and improved operations for travelers.

Figure 7 of the Transit ITS Environment below illustrates how ITS technologies are used on a transit bus and how the public may interact with them when utilizing fixed-route bus service.



Source: GAO analysis of Department of Transportation documents. | GAO-16-636

Figure 7: Transit ITS Environment

Just as the settings for transit services in Illinois vary, so do the types of transit ITS applications planned or currently in operation in the state. In 2015, USDOT estimated that nearly 75 percent of small urban and rural transit providers use ITS through the deployment of security systems. The majority use closed circuit TV cameras and audio surveillance as well as silent alarms, object detection sensors, and covert microphones in transit vehicles and facility applications. Transit agencies were found to deploy (4) four primary ITS applications:

1. Security Systems
2. Automatic Vehicle Location (AVL)
3. Computer Aided Dispatching (CAD)
4. Geographical Information Systems (GIS)

RTA Regional Transit Signal Priority Integration Project: This ambitious RTA project seeks to foster regionwide adoption of transit signal priority, through a process of planning, analysis, and prioritization of corridors that will yield the highest payoff. Corridor demonstrations are in progress to learn more about frequency of TSP ‘calls’ and capabilities for controllers to service multiple transit agencies. The expected benefit is increased mobility for transit users, due to:

- Reduced congestion
- Improved reliability of service
- Reduced running times for buses through reduced intersection delays

Relationship to Statewide Vision

Transit ITS contributes to every element of the ITS vision enabling enhanced traveler information, incident management and safety. General Transit Feed Specification (GTFS) is the standard adopted by most transit providers and enables them to share static schedule information. Using GTFS-real-time, allows transit providers to format real-time vehicle information and service alterations. Several of the large and medium urban transit providers told us they use GTFS because it allows them to publish their data into Google transit maps. Two of the transit providers we interviewed told us that while they have not made their data open to the public, they have formatted their data into GTFS to allow it to be used for Google transit maps. Provision of real-time data by Transit operators is available via the internet and is incorporated with multimodal trip planning applications such as RTA Trip Planner and Google Maps.

The 2018-2023 Regional Transit Strategic Plan for Chicago and Northeastern Illinois includes several elements of ITS including an Information Technology initiative (\$170M), a New Control Center (\$150M) and Regional Transit Signal Priority (RTSP, \$10M). The Integrated Multi-Modal Electronic Payment service package provides electronic payment capability for transit fares, tolls, road use, parking, and other areas requiring electronic payments. More information is available at www.rtachicago.org/index.php/plans-programs/regional-transit-strategic-plan.html.

Identification of Issues

As planning and implementation of transit ITS proceeds around Illinois, a number of issues have arisen, or can be expected to arise. This section discusses some of these issues, along with their importance to the state’s travelers and transit agencies.

1. *Barriers to transit signal priority (TSP) adoption:* One barrier to full implementation of transit signal priority, is the large number of separate signal controller types and owners which can lead to long installation timeframes for TSP equipment and often compatible controllers. More importantly, there may be conflicts with emergency response agencies and traffic engineers about the impact of installing TSP devices. Finally, there is a technology issue. The variety of priority systems already installed for emergency vehicles means that regional transit agencies either need to install multiple signal priority technologies in their vehicles or forgo installation in what may be critical corridors.

2. Bus Rapid Transit (BRT) has emerged as a flexible, cost-effective solution to improve transit service and reduce congestion. Although, BRT systems are more successful along fully-developed areas, it is a challenge to balance the use of the right of way between general traffic, parking use and transit along these corridors.
3. Transit agencies need both funding levels and salary structures that will allow them to attract and retain sufficient staff with leading edge skills, to effectively exploit the cost, service, and revenue advantages available with ITS systems.
4. *Regional integration of electronic payment services:* As transit agencies in Illinois adopt electronic payment media such as magnetic stripe cards, contact, and contactless smart cards, they face challenges of establishing and maintaining these systems administratively, financially and technically. When multiple agencies share a common payment instrument, they must also establish a clearinghouse to receive and distribute revenue accordingly.

Fare collection smart phone applications have improved services and operational efficiency, and reduced delay in fare payment. This technology could increase the emphasis on integration and interoperability across transit modes, even across levels (local, regional or national) and across various services (parking, mass transit, tolling, taxi, etc.). This aspect also relates to discussion in Chapter 9 on Electronic Fare/Toll Payment. It is a major factor in increasing Mobility and equity in service for riders across modes and activities such as bike, scooter, parking, etc.

5. *Rural Services:* Rural Transit services are typically not fixed route and fill substantial needs to many areas in support of transportation for many folks without access to the passenger vehicle. Funding for these services is limited, but the needs remain.

Benefits of Transit Management

Elements of ITS Transit Management are being widely adopted in Illinois and across the U.S. because of the benefits they provide. Here are some of the key benefits:

Better operations and service: Transit CAD/AVL systems give dispatchers the tools to recognize developing service problems sooner, reducing fixed route bus bunching and improving the spacing of buses and trains along the route.

Improved real-time information: Transit CAD/AVL systems, as well as other third-party systems, can provide real time status information for transit services. Transit trip planning systems, such as the Regional Transportation Authority's Trip Planner presents transit alternatives for riders, making transit easier to use.

Improved safety and security: ITS technologies for transit help protect passengers, drivers, motorists, and pedestrians. They include on-board video cameras for security, silent alarm for the driver to summon help, and collision avoidance systems.

The following are samples of cited benefits for Transit Management.

- A comprehensive TCRP report from 2010 on TSP provides a set of benefit ranges that may be experienced by an agency deploying TSP based on case studies from a few dozen cities. Transit travel time savings experienced were between two (2) and 18 percent, with Los Angeles and Chicago seeing 7.5 and 15 percent decreases, respectively. Decrease in bus delay is heavily dependent on the priority guidelines set by the agencies, and thus has a wider range experienced by the cities examined for the report. Overall, agencies indicated that bus delay was reduced between 15 and 80 percent. Los Angeles had a 35 percent decrease in bus delay at intersections, while Oakland had a decrease of five (5) seconds per intersection.
- The San Antonio region's first bus rapid transit (BRT) line – the VIA Primo – became operational in 2012 and featured a TSP solution that earned the system a Transportation Achievement Award by ITE. The first of its kind in the U.S, the Primo BRT system's TSP element uses "virtual" GPS-based detection zones that do not require emitters at every intersection. Since its inception, the BRT system's TSP feature has helped the Primo vehicles adhere to their schedules and has reduced total travel times by 15-20 percent.

ITS Architecture

The National ITS Architecture includes transit functionality as part of the Transit Management Center. Several service packages - groupings of features that relate to commonly understood transit system functions include:

The *Transit Vehicle Tracking* service package represents AVL systems that track the location of transit vehicles, using GPS or fixed "beacons" to identify location. These systems forward location information to the Transit Management Center, where they are used to update the dispatch system, and to provide real-time location information to transit users.

Transit Fixed-Route Operations encompasses the functions of driver assignment, vehicle routing, and scheduling. It can also calculate transit schedule adherence in real-time. It supports dispatcher displays of system operations. Further, it forwards transit schedule and on-time status to Information Service Providers for use in their multimodal traveler planning and information systems.

The *Dynamic Transit Operations* service package addresses paratransit reservations, scheduling and dispatching functions, including the function of recommending/picking the best vehicle to take a new trip based on input from vehicle AVL systems. It provides displays for vehicle management to the paratransit dispatcher. It also allows for direct trip requests from travelers, as well as trip requests through a regional trip broker or multimodal trip planner.

Transit Passenger and Fare Management is a service package that encompasses two common transit ITS components: electronic fare payment and automatic passenger counters. The service package includes the collection and management of fares and fare transactions, as well as data on passenger boarding's and alighting's. It covers the interactions of travelers with remote payment systems, and

transit cards with fare boxes and turnstiles. Like a number of other service packages, it also addresses information coordination with other transit providers.

The *Transit Security* service package covers the physical security of bus riders and drivers, transit public areas such as stations and parking lots, transit facilities, and transit infrastructure. On board features include video and audio monitoring, threat sensors, motion detectors, and passenger alarms. Public facilities can be monitored and allow emergency reporting by travelers. Infrastructure can be monitored for structural health, threat sensors and structural integrity. It also supports remote vehicle shutdown in case of emergency, such as can be accomplished by OnStar™, and direct links to emergency management agencies.

The *Transit Fleet Management* service package covers supports automatic transit maintenance scheduling and monitoring. On-board condition sensors monitor system status and transmit critical status information to the Transit Management Center. The Transit Management Center processes this data and schedules preventative and corrective maintenance. The service package also supports the day to day management of the transit fleet inventory, including the assignment of specific transit vehicles to blocks and the assignment of transit vehicle operators to runs.

The Multi-modal Coordination service package covers coordination among transit agencies, and between transit agencies and traffic management centers. Transit inter- agency coordination incorporates schedule coordination and real-time connection protection, with the goal of seamless travel between different agency services. Coordination with traffic management centers includes transit agencies receiving real- time traffic information to support optimal routing, and roadside and center-based transit signal priority.

Transit Traveler Information is a service package that covers the provision of static and real-time transit information to travelers before, during, and at the end of their trip. It includes on-board information, such as audio and video announcements, as well as information delivered to signs at stations, kiosks, via the Internet, and through personal information devices. It also incorporates transit itinerary planning systems available to potential transit travelers.

In addition to these transit-oriented service packages, Transit Management takes advantage of other ITS subsystems and service packages, involving such functions as archived data, safety warnings, and traffic information.

Findings and Recommendations for Transit Management

In order to better integrate transit management into its daily activities, IDOT and others should consider multiple simultaneous integration strategies for transit:

- IDOT participation in Transit Corridor studies and planned transit ITS projects to allow proper allocation of funds and resources to meet multimodal mobility demands.
- IDOT should help facilitate more cooperative purchasing of transit ITS systems and work to

develop guidelines, not specifications, for the most desired TSP and smart intersection functions

- Agencies in the same region should explore interconnecting their systems and collaborating for service improvement.
- IDOT should facilitate the distribution of best practices information about how other agencies are analyzing their ITS data to support operations analysis and service planning.
- Monitor and incorporate CAV development for future functionalities that may significantly modify transit management.

10. Security and Disaster Response Management

Description and Examples

The following section describes the role that the ITS Architecture plays in the Illinois Security and Disaster Response Management initiatives. There are a number of similarities between this section and Section 7 (Incident Management). While both deal with events that impede traffic flow, the difference between the two is primarily one of scale. Security and Disaster Response Management initiatives deal with large-scale circumstances that have the potential for wholesale loss of life and property. Major weather disasters, terrorism, and industrial accidents are some categories of these situations - they would all have a great negative impact on the flow of goods and services. The Statewide ITS Architecture can be very useful toward the planning and implementation of countermeasures that mitigate the damage.

IDOT is a statewide agency with transportation resources that are well-positioned to respond to major incidents across the state. The Emergency Operations Manual provides roles and responsibilities for personnel in each district and for the Central Office, including a “District Emergency Coordinator” for each district, during a major disaster. The manual also stresses close coordination between IDOT and the “Disaster Control Group” at the Illinois Emergency Management Agency.

The ITS Architecture can be of great help to those who produce preparedness plans. Such planning is a difficult task, because the nature, location and magnitude of the disaster are not known in advance. This leaves the planners with no choice but to examine the most likely scenarios and conduct tabletop exercises of mock disasters. Illinois' anticipated major earthquake from the New Madrid Fault is one example that shows how the location and magnitude could make a huge difference in the level of damage that might occur. The Statewide ITS Architecture will also be useful during the aftermath of such an event, as the transportation networks are restored. During those times, the managing agencies would want to ensure that the ITS infrastructure is incorporated into the design plans and the ITS Architecture would aid in that process.

The following examples describe some typical circumstances that create a need for security and disaster response management efforts.

- Major Weather Disasters
- Terrorism - Active Shooter
- Large-scale Evacuation
- Public Unrest
- Large-scale Infrastructure Failures

Relationship to Statewide Vision

As previously stated in Section 7, a key component of the statewide vision for Illinois is to *provide* a flexible, adaptable, standards-based framework for the integration and coordination of transportation

technologies in Illinois. This vision of integrated systems becomes even more important when considering Security and Disaster Response Management systems, because it can lead to considerably lower fatality rates when major catastrophes occur. One of the main objectives of the Illinois Terrorism Task Force (ITTF) is to have rescue teams in place. This includes enforcement and medical personnel who can be deployed to any of the nearby homeland security regions. These teams will be assembled from agencies all over the state, and it is essential that their equipment be compatible. Almost every emergency situation of this magnitude will have a mobile command post established for the duration of the incident, and the ITS Architectures can be very useful for planning and setting these up.

Identification of Issues

The initiation of the Statewide ITS Architecture can be thought of as an effort to address the various agency interdependencies. The agencies have been around for a long time, and their processes are well established, but they often are narrowly focused on each agency's specific needs. Systems engineering looks at the interactions between the technology, the agencies, and the public, and helps identify how these components interact and influence each other. Because this project attempts to overlay the Statewide ITS Architecture on top of existing systems, it is almost certain that several issues will need to be addressed. The issues identified in Section 7 (Incident Management) can be applied to Security and Disaster Response Management. In addition, there are some other issues that also apply:

- Access to real-time road condition and restriction data is not readily integrated with disaster-based operations. IDOT and IEMA have well-coordinated plans for significant responses; however, the impacts of construction, road use restrictions, and other parallel events are not readily integrated into updating responses.

Benefits of Security and Disaster Response Management

Security and Disaster Response Management are essential functions of government. The benefits of these programs are derived in the form of reduced losses and increased resiliency when catastrophic events occur. Again, the benefits outlined in Section 7 (Incident Management) apply. The list below briefly describes a few additional benefits.

- **Faster Mobilization of Supporting Resources:** Rapid mobilization is a key to successful disaster response. Large numbers of personnel from different backgrounds, with varying transportation needs, must be deployed on a moment's notice. To be effective, the logistics for these activities must be worked out in advance. The ITS Architectures (both Statewide and Regional) provide a solid foundation on which to build the necessary deployment and readiness plans.
- **Faster Restoration to Normal Conditions:** In addition to the important work of dealing with the catastrophic incident itself, the recovery and restoration period following an event is equally critical to improving resiliency. The ITS Architectures can be used as a blueprint to guide the planners, designers and specification writers as they attempt to

bring conditions back to normal.

Following is a sample of cited benefits from the USDOT fact sheets is available at <https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/EmergencyManagement/>.

- A 2011 report provided results from research that tested the effects of transit signal priority on emergency evacuation clearance times and the results showed significant time savings.
- The study area was a 14-intersection corridor located in the Southeast corner of Central Washington, DC (NW 7th Street from SW E Street (South) to NW Pennsylvania Ave, West to NW 12 Street). The scenario was the detonation of a dirty bomb at L'Enfant Plaza, setting in motion the city's emergency evacuation response.
- The methodology used a microscopic traffic simulation of an evacuation environment merged with a transit operations and signal priority component. These models generated an evacuation origin destination (O-D) matrix to create a realistic emergency evacuation traffic model with measures of effectiveness (MOEs) including travel time, evacuation clearance time, and delay time.
- Allowing transit signal priority during the evacuation resulted in a 26 percent time savings for transit buses, meaning that three prioritized vehicles accomplish the same as four would without priority. The 26 percent time savings enables more transit units to make additional trips, resulting in shorter evacuation times. When transit signal priority is restricted to operate only on evacuation routes, evacuee travel and delay time decreases (in contrast to previous studies that found transit priority results in delays to vehicular traffic during high roadway demand).

ITS Architecture

In general, Emergency Management initiatives are larger, have more people involved, and expend greater amounts of public and private resources as compared to local Incident Management initiatives. This implies that it is extremely important that the pre-arranged processes, procedures, and resources are well established and kept up to date. Ideally, many of these services would be routinely exercised as part of the Incident Management program in day-to-day operations, and in standard training programs designed to prepare organizations to work together.

In addition to the service packages in Section 8.5, "ITS Architecture for Incident Management", the National ITS Architecture also has service packages that directly apply to Security and Disaster Response Management. The differences between Incident Management and Security and Disaster Response Management lie only in the urgency and magnitude of the circumstances.

The service package that includes the monitoring of transportation infrastructure for potential threats using sensors and surveillance equipment and barrier and safeguard systems to preclude an incident, control access during and after an incident or mitigate impact of an incident is the *Transportation Infrastructure Protection* service package. Threats can result from acts of nature (e.g., hurricanes, earthquakes), terrorist attacks or other incidents causing damage to the infrastructure (e.g., stray

barge hitting a bridge support). Infrastructure may be monitored with acoustic, environmental threat (such as nuclear, biological, chemical, and explosives), infrastructure condition and integrity, motion and object sensors and video and audio surveillance equipment. Data from such sensors and surveillance equipment may be processed in the field or sent to a center for processing. The data enables operators at the center to detect and verify threats. When a threat is detected, agencies are notified. Detected threats or advisories received from other agencies result in an increased level of system preparedness. In response to threats, barrier and safeguard systems may be activated by Traffic Management Centers to deter an incident, control access to an area or mitigate the impact of an incident. Barrier systems include gates, barriers and other automated and remotely controlled systems that manage entry to transportation infrastructure. Safeguard systems include blast shields, exhaust systems and other automated and remotely controlled systems that mitigate impact of an incident.

The *Wide-Area Alert* service package uses ITS driver and traveler information systems to alert the public in emergency situations such as child abductions, severe weather events, civil emergencies, and other situations that pose a threat to life and property. The alert includes information and instructions for transportation system operators and the traveling public, improving public safety and enlisting the public's help in some scenarios. The ITS technologies will supplement and support other emergency and homeland security alert systems such as the Emergency Alert System (EAS). When an emergency situation is reported and verified and the terms and conditions for system activation are satisfied, a designated agency broadcasts emergency information to traffic agencies, transit agencies, information service providers, toll operators, and others that operate ITS systems. The ITS systems, in turn, provide the alert information to transportation system operators and the traveling public using ITS technologies such as DMS, text messages, highway advisory radios, in-vehicle displays, transit displays, and traveler information web sites.

This *Early Warning System* service package monitors and detects potential, looming, and actual disasters including natural disasters (hurricanes, earthquakes, floods, winter storms, tsunamis, etc.) and technological and man-made disasters (hazardous materials incidents, nuclear power plant accidents, and acts of terrorism including nuclear, chemical, biological, and radiological weapons attacks). The service package monitors alerting and advisory systems, ITS sensors and surveillance systems, field reports, and emergency call-taking systems to identify emergencies and notifies all responding agencies of detected emergencies.

The *Disaster Response and Recovery* service package enhances the ability of the surface transportation system to respond to and recover from disasters. It addresses the most severe incidents that require an extraordinary response from outside the local community. All types of disasters are addressed including natural disasters (hurricanes, earthquakes, floods, winter storms, tsunamis, etc.) and technological and man-made disasters (hazardous materials incidents, nuclear power plant accidents, and national security emergencies such as nuclear, chemical, biological, and radiological weapons attacks).

The service package supports coordination of emergency response plans, including general plans developed before a disaster as well as specific tactical plans with short time horizons that are

developed as part of a disaster response. The service package provides enhanced access to the scene for response personnel and resources, provides better information about the transportation system in the vicinity of the disaster, and maintains situational awareness regarding the disaster itself. In addition, this service package tracks and coordinates the transportation resources - the transportation professionals, equipment, and materials - that constitute a portion of the disaster response. In Illinois, this is a key service package that should be considered.

The service package identifies the key points of integration between transportation systems and the public safety, emergency management, and other allied organizations that form the overall disaster response. In this service package, the Emergency Management Center Subsystem represents the federal, regional, state, and local Emergency Operations Centers and the Incident Commands that are established to respond to the disaster. The interface between the Emergency Management Center and the other center subsystems provides situational awareness and resource coordination among transportation and other allied response agencies. In its role, the Traffic Management Center implements special traffic control strategies and detours and restrictions to effectively manage traffic in and around the disaster. Maintenance and construction provide damage assessment of road network facilities and manages service restoration. The Transit Management Center (Subsystem) provides a similar assessment of status for transit facilities and modifies transit operations to meet the special demands of the disaster. As immediate public safety concerns are addressed and disaster response transitions into recovery, this service package supports transition back to normal transportation system operation, recovering resources, managing on-going transportation facility repair, supporting data collection and revised plan coordination, and other recovery activities.

To support evacuation of the general public from a disaster area and manage subsequent reentry to the disaster area, the National ITS Architecture has a service package entitled *Evacuation and Reentry Management*. The service package addresses evacuations for all types of disasters, including disasters like hurricanes that are anticipated and occur slowly, allowing a well-planned orderly evacuation, as well as disasters like terrorist acts that occur rapidly, without warning, and allow little or no time for preparation or public warning.

This service package supports coordination of evacuation plans among the federal, state, and local transportation, emergency, and law enforcement agencies that may be involved in a large-scale evacuation. All affected jurisdictions (e.g., states and counties) at the evacuation origin, evacuation destination, and along the evacuation route are informed of the plan. Information is shared with traffic management agencies to implement special traffic control strategies and to control evacuation traffic, including traffic on local streets and arterials as well as the major evacuation routes. Reversible lanes, shoulder use, closures, special signal control strategies, and other special strategies may be implemented to maximize capacity along the evacuation routes. Transit resources play an important role in an evacuation, removing many people from an evacuated area while making efficient use of limited capacity. Additional shared transit resources may be added and managed in evacuation scenarios. Resource requirements are forecast based on the evacuation plans, and the necessary resources are located, shared between agencies if necessary, and deployed at the right locations at the appropriate times.

Disaster Traveler Information is the service package that uses ITS to provide disaster-related traveler information to the general public, including evacuation and reentry information and other information concerning the operation of the transportation system during a disaster. Of note is that this is a building block service package as it augments the TI service packages that provide traveler information on a day-to-day basis for the surface transportation system. For this service package, the focus is on the special requirements for traveler information dissemination in disaster situations.

Information from multiple sources including traffic, transit, public safety, emergency management, shelter provider, and travel service provider organizations will be collected and processed so that real-time disaster and evacuation information using ITS traveler information systems can be utilized as broadly as possible.

A disaster will stress the surface transportation system since it may damage transportation facilities at the same time that it places unique demands on these facilities to support public evacuation and provide access for emergency responders. Similarly, a disaster may interrupt or degrade the operation of many traveler information systems at the same time that safety-critical information must be provided to the traveling public. This service package keeps the public informed in these scenarios, using all available means to provide information about the disaster area including damage to the transportation system, detours and closures in effect, special traffic restrictions and allowances, special transit schedules, and real-time information on traffic conditions and transit system performance in and around the disaster.

This service package also provides emergency information to assist the public with evacuations when necessary. Information on mandatory and voluntary evacuation zones, evacuation times, and instructions are provided. Available evacuation routes and destinations and current and anticipated travel conditions along those routes are provided so evacuees are prepared and know their destination and preferred evacuation route. Information on available transit services and traveler services (shelters, medical services, hotels, restaurants, gas stations, etc.) is also provided. In addition to general evacuation information, this service package provides specific evacuation trip planning information that is tailored for the evacuee based on origin, selected destination, and evacuee-specified evacuation requirements and route parameters.

Findings and Recommendations for Security and Disaster Response Management

Recommendations for Security and Disaster Response Management mirror the recommendations for Incident Management, with the differences being in the order of magnitude. Specific recommendations include:

- Improve radio communications interoperability.
- Take advantage of the coordinated relationships between IDOT (Station One), IEMA, ISP, IDPH, and IDOC – especially for training and the use of the statewide software currently being put in place for centralized control of emergency management across the various state and local agencies.
- Account for the differences in urban and rural environments.

- Continue to use incident command for transportation professionals.
- Use performance measures to quantify progress.
- Utilize the Statewide ATMS Study to fully plan enhanced Station One Operations, including coordination with Districts for real-time data access and utilization within the operations.
- Establish methods to better integrate road closure information across IDOT Regions, particularly for construction closures and also for emergency and evacuation planning.

11. Regional Communications Coordination

The ability for a transportation agency to communicate with its resources, as well as with other transportation organizations, is critical to the agency's success. This is especially true for transportation agencies that operate vehicles, such as transit, maintenance, and emergency and incident management services. Most of these agencies have some sort of communication link, in most cases telephone, radio or fax, both to contact their vehicle operators and to coordinate with other agencies. Not surprisingly, these agencies have also led the way in creating integrated and interoperable statewide and regional communications systems.

Description and Examples

Aside from standard telephone and fax communications, many different agencies in Illinois have developed integrated statewide and regional communications systems in an attempt to enhance their operations and to improve inter-jurisdictional coordination. The following sections describe some notable efforts.

- **Traffic Management / Maintenance Example:** Station One was established by IDOT to serve as a universal communications network between all nine IDOT districts. Station One is based at the IDOT Central Office in Springfield and is operated 24/7. Station One serves two primary purposes: emergency dispatch when the local district office is closed, and maintenance of traveler information, specifically road conditions, across the state. As such, it also acts as a central repository for such information, as collected by IDOT personnel and equipment across the state.
- **Emergency Management Examples:**
 - IWIN (Illinois Wireless Information Network) has developed into the primary means of communication between different law enforcement agencies. IWIN is a statewide communications system (CDPD through Verizon Wireless) set up by the Illinois State Police (ISP), Central Management Services (CMS), and the Illinois Criminal Justice Information Authority (ICJIA). It is linked to statewide/national databases like Law Enforcement Agency Data Service (LEADS), National Crime Information Center (NCIC), National Law Enforcement Telecommunications System (NLETS) and the Illinois Secretary of State databases. It can also be linked to an agency's CAD system or record management system. The Illinois State Police also have their own statewide communications channel, ISPERN (Illinois State Police Emergency Radio Network). As a means of secondary coordination, law enforcement officials around the state monitor the ISPERN frequency (155.475 MHz) to stay informed of ISP activities.
 - Fire departments, particularly those in the northern part of the state, also utilize dedicated communications channels to coordinate their operations. Started in the late 1960's, the Mutual Aid Box Alarm System (MABAS) allows hundreds of fire and emergency services personnel to coordinate their response to incidents. Today MABAS includes 38,000 of Illinois' 40,000 firefighters who staff emergency response units including more than 1,600

fire stations, 2,735 engine companies, 500 ladder trucks, 1,300 ambulances (many paramedic capable), 250 heavy rescue squads, and 1,000 water tenders. Fire/EMS reserve (back-up) units account for more than 1,000 additional emergency vehicles. Using a common radio frequency, Interagency Fire Emergency Radio Network (IFERN), MABAS agencies are activated for response through pre-designed "run" cards that each participating agency designs and tailors to meet their local risk need.

- **Transit Example:** Transit agencies across Illinois use a number of different systems to communicate between dispatch centers and transit vehicles. Some utilize trunked 800 MHz systems, others have VHF radio, while others rely on cellular communications. In at least one instance, transit agencies are also performing feasibility studies for inter-jurisdictional transit communications systems. For transit users in Chicago metropolitan area, CTA is now adding 4G wireless network to all Blue and Red Line subway stations and tunnels, and Metra has completed on-board Wi-Fi pilot project with expansion to 50 additional cars.

Relationship to Statewide Vision

The emergence of integrated, interoperable communications between transportation agencies is perhaps the most effective tool for addressing the elements of the Statewide Vision. Such communications systems promote the flexible, adaptable, standards-based approach to applying technology in transportation. Furthermore, these systems provide direct benefit to the traveling public, by providing more efficient transit options, improving emergency and incident response, and expanding the overall efficiency of the transportation system, as discussed in Section 12.4.

Identification of Issues- Communications Coordination

There are several issues that transportation agencies face when dealing with communications - primarily cost, coverage, reliability, and interoperability. Timing of project installations and knowledge of available communications bandwidth is not readily known or shared, limiting opportunities to leverage existing infrastructure. The lack of coordinated installations for communications has created gaps in connectivity that could be bridged with minimal investments an increased stakeholder coordination.

From an IDOT regional perspective, coordination with the Department of Innovation and Technology (DoIT) to identify and implement shared connectivity of fiber optic systems has proved successful in some districts.

Benefits of Communications Coordination

The ability of a transportation agency to communicate with its resources and its peers is perhaps the most important factor in determining the effectiveness of its services. Benefit areas include:

Traffic Management – Through various communications media, transportation data such as traffic

counts, weather conditions, and real-time video can be collected from devices in the field to help system operators more quickly detect an incident and determine the appropriate response.

Incident Management – Communications systems allow emergency dispatch facilities to contact and guide response vehicles in the field to an incident in the most direct and efficient manner, saving lives and reducing congestion.

Security and Disaster Response Management – Interagency communication during a major disaster allows response agencies to pool resources and coordinate activities, helping to lessen the adverse effects of the event and reducing the recovery period.

Traveler Information – Information collected and processed by traffic management agencies can be distributed to the traveling public using a number of communications mediums, reducing congestion and its impact on the environment.

Transit Management – Communications between transit vehicles and dispatch centers allow transit managers to locate the vehicles, determine if they are off schedule, and provide direction to transit operators to get them back on schedule, improving on-time arrivals and increasing ridership. Vehicle location and on-time performance can also be shared with transit users.

Commercial Vehicle Operations – Short-range communications between pre-cleared commercial vehicles and ITS field elements can allow truckers to legally bypass inspection facilities, reducing travel times and helping commercial vehicle drivers to meet their delivery times.

USDOT fact sheets for the functional areas above incorporate benefits of communications coordination. In addition, Transportation Management Center operations and benefits rely on communications coordination. See:

<https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/TransportationMgtCenters/> .

ITS Architecture

ARC-IT Version 8.2 organizes the standards into ‘Profiles’ that identify standards at each layer of the Open Systems Interconnection (OSI) communications stack and specifically includes standards that will support secure ITS communications. The combination of a profile that identifies the communications stack along with ITS information layer message and data dictionary standards are assembled into a communication ‘Solution’ for each information flow triple in the Physical View.

Physical Objects are defined to represent the major physical components of the ITS Architecture. Physical Objects that provide ITS functionality are referred to as subsystems (39 at present), whereas those that do not provide ITS functionality are called Terminators (76 at present). Both types of Physical Objects exchange information in order to provide ITS services.

Physical Objects in ARC-IT belong to one of 5 “classes”:

- Centers, such as a Traffic Management Center
- Field Equipment, such as a Traffic Signal Controller
- Vehicles, including specialized vehicles such as Transit Vehicles
- Traveler Devices, such as personal devices (smartphones)
- Support Systems; this class is new from previous versions and includes systems that provide non-operational use of ITS data (e.g., Archive Data Systems), and systems that provide support to a variety of services (e.g., Map Update System).

Among the Terminators in ARC-IT are the following ITS communications systems:

- Alerting and Advisory Systems - federal, state, and local systems that provide alerts and warnings about threats to the transportation system, including adverse weather, crashes, or other emergencies;
- Emergency Telecommunications Systems – wireline or wireless communications systems that connect emergency services with travelers in need;
- Government Reporting Systems – systems associated with the collection of transportation data, such as crash reports, highway performance, etc.; and
- Media – various public information outlets, including radio, telephone, and the Internet.

Communications are the backbone of any ITS, encompassing the equipment and capabilities necessary to exchange data between systems. While an ITS architecture does not identify specific technologies (e.g., fiber optic cable, 800 MHz, CDPD), it does provide technology types. Figure 8 depicts the National ITS Architecture Interconnect Diagram, a graphical representation of the Physical Architecture including communications links. The figure illustrates the 39 transportation subsystems of ARC-IT (organized by the 5 classes) and the general communication links used to exchange information between subsystems. Figure 8 represents the highest-level diagram of the Physical View.

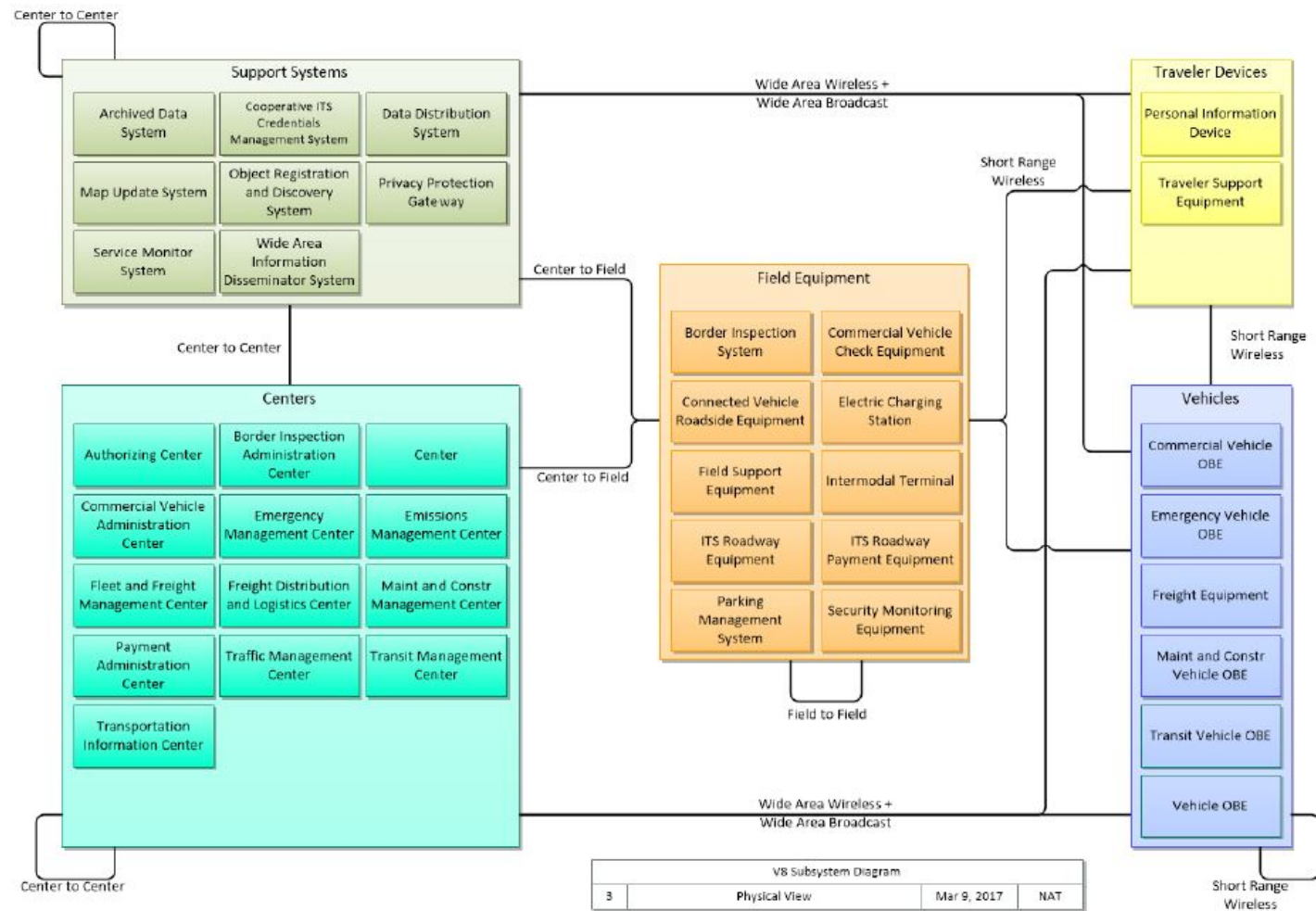


Figure 8: Physical View Interconnect Diagram

Findings and Recommendations for Communications Coordination

In order to perform better communications coordination, IDOT in coordination with others should promote the following strategies:

- Transportation agencies with internal communications systems like the Illinois State Police should take steps to ensure that their systems are accessible to similar transportation agencies.
- To the extent possible, universal communications systems for one group of similar transportation agencies should be made available to other transportation agencies.
- Competing universal interagency communications systems should be discouraged, in order to conserve resources and take better advantage of funding opportunities.
- Federal, state, and local funding options should be publicized to encourage transportation agencies to participate in universal interagency communications systems.
- Agencies should identify a set of agency technical staff who have implemented universal interagency communications systems and can serve as a resource to other agencies undertaking such implementations.
- Proceed with a formal statewide communications inventory.
- Develop policy templates and best practices statewide for the implementation of communications systems. These practices shall include IDOT, local and regional entities, DoIT and third-party providers to fulfill the broader interconnected vision.

12. Highway/Railroad Grade Crossings

Descriptions and Examples

The Highway/Railroad Grade Crossing component of ITS is focused upon increasing driver safety by providing information to the driver about oncoming trains. By integrating the newer ITS technologies into already existing warning systems for at-grade crossings, both safety effectiveness and operational efficiencies can be enhanced. At railroad grade crossings, these technologies are located both in-vehicle and along the roadside to ensure that train movements are coordinated with traffic signals and that drivers are alerted to approaching trains.

Typical components of an advanced rail crossing notification system can detect and measure terrain, train travel direction, estimated time of arrival, estimated duration of closure, and entrapped vehicles. When integrated with other traveler information (e.g. DMS) and traffic management systems (e.g. coordination with adjacent traffic signals) and emergency management systems (e.g. blocked vehicle alarm notification), the components collectively provide significant safety and travel efficiency benefits over the more conventional crossbuck sign warning travelers of a highway rail intersection.

The 2017 Illinois State Rail Plan Update cites the following ongoing efforts:

- The Illinois General Assembly created the Grade Crossing Protection Fund (GCPF) to help local jurisdictions (counties, townships and municipalities) pay for safety improvements at highway including railroad crossings on local roads and streets. This fund provides the GCPF with \$39 million annually to be used for safety improvements at highway-rail crossings on local roads and streets.
- IDOT and the Union Pacific Railroad (UP) are cooperating in the use of enhanced grade crossing warning devices targeting pedestrians near certain commuter rail stations on the Metra UP West Line in Chicago's western suburbs. Several projects are being implemented Grade crossing physical and warning signal safety improvements through the State's capital programs.
- Since 2013, IDOT and the Union Pacific Railroad (UP) have continued upgrading the Chicago-St. Louis high-speed rail corridor to expand the territory in which trains may run at 110 mph. These upgrades include roadway-rail grade crossing improvements. Railway-Highway Crossings (Title 23, U.S.C. Section 130) Program is a federal funding source used by IDOT for both state and local roads and provides funds for the elimination of hazards at railway-highway crossings. Funding for the Section 130 program in FY 2017 is \$10.7 million. Improvements include implementation of warning device improvements (flashing lights & gates, traffic signal interconnects, etc.) at several local and state grade crossings.

Relationship to Statewide Vision

Illinois Motorists suffer thousands of hours of delay on a typical weekday. As a major hub for the North American freight rail network, Illinois offers a safe and secure highway rail intersection system that

supports both highway and rail performance. Highway-rail grade crossings are instrumental in the provision of a safe, secure and seamless services in every community where pedestrians, buses, bikes, cars, trucks and trains all cross paths and interact.

Identification of Issues

As planning and implementation of advanced highway rail intersection technologies continues in Illinois, a number of issues have arisen, or can be expected to arise. This section discusses some of these issues, along with their importance to the state's travelers and various operational stakeholders.

Rail Operators typically operate in a vacuum. Outside of grade crossings and safety elements associated with traffic signal impacts, rarely are rail freight operators sharing real-time data. There is a need for frequent and better monitoring of train locations and schedules to provide information on freight train arrivals across the state. Freight traffic can severely impact commuter services and also cause lengthy delays for motorists at highway-rail grade crossings.

Agencies need competent technical staff for planning, implementation, operations and maintenance of ITS technologies: Many transportation management agencies have technical specialists on staff or on call for information technology, field devices and radio systems. However, the adoption of new ITS technologies may put a strain on those staff resources. While some of the functions can be contracted out as part of the ITS procurement, post-warranty maintenance will most likely need to be done in-house. This may require additional staff.

Another area where many agencies are strapped is in information technology or management information systems staff. Available staff are often substantially committed strictly for the maintenance of existing systems and applying upgrades. As agencies undertake systems integration between ITS subsystems and existing agency enterprise systems, experienced staff will be needed both to assure successful integration of real time and batch systems, but also to minimize the unintended consequences of modifying and interfacing to proprietary systems owned and operated by the railroad operators. Many transit agencies face challenges in hiring IT staff qualified to deal with state-of-the-art mobile technologies, Web-based systems, and complex integration issues. Agencies need both funding levels and salary structures that will allow them to attract and retain sufficient staff with leading edge skills, to effectively exploit the cost, service, and revenue advantages available with ITS systems.

Benefits of Highway/Railroad Grade Crossings

Here are some of the key benefits from Highway Rail Intersection Management:

Increase Transportation System Efficiency and Capacity: By augmenting passive warning systems and active warning devices with standard traffic control devices and interconnected with adjacent intersections, more efficient management of highway traffic at HRIs is achievable. Note that all of these capabilities can be implemented with today's technology, and without need for major new standardization efforts or institutional change.

Enhance Mobility: Strategic coordination between rail operations and traffic management centers enhances the quality of traveler information and offers the highest promise of both goods movement and efficient traveler mobility.

Reduce Energy Consumption and Environmental Costs: Technology solutions such as the installation of constant time warning devices at critical railroad grade crossing service to minimize unnecessary motorist and pedestrian delay relative to slow moving trains reduce fuel consumption and the resultant air pollutants from idling traffic.

Improved safety and security: Systems that manage HRIs by warning vehicle operators of train proximity and providing traffic control through barriers to prevent vehicle from entering rail/roadway help prevent accidents from occurring. HRI protection provides additional safety features to mitigate the risk associated with higher rail speeds. Data from the intersection is shared with the local traffic management agency and ITS field elements.

ITS Architecture

The National ITS Architecture includes both a standard and an advanced set of functionalities as part of the Traffic Management Center and Field Equipment Subsystems, as well as operational coordination planning under the heading Highway Rail Intersections. Core HRI features are encapsulated in three service Packages, groupings of features that relate to commonly understood railroad system functions:

The *Standard Railroad Grade Crossing* service package manages highway traffic at HRIs where operational requirements do not dictate more advanced features (e.g., where rail operational speeds are less than 80 miles per hour). Both passive (e.g., the crossbuck sign) and active warning systems (e.g., flashing lights and gates) are supported. These traditional HRI warning systems may also be augmented with other standard traffic management devices. The warning systems are activated on notification by interfaced wayside equipment of an approaching train. The equipment at the HRI may also be interconnected with adjacent signalized intersections so that local control can be adapted to HRI activities. Health monitoring of the HRI equipment and interfaces is performed, and detected abnormalities are reported to both highway and railroad officials through wayside interfaces and interfaces to the traffic management subsystem.

The *Advanced Railroad Grade Crossing* service package encompasses the functions at highway railroad grade crossings where operational requirements demand advanced features (e.g., where rail operational speeds are greater than 80 miles per hour). This service package includes all capabilities from the *Standard Railroad Grade Crossing* service package, and augments these with additional safety features to mitigate the risks associated with higher rail speeds. The active warning systems supported by this service package include positive barrier systems that preclude entrance into the intersection when the barriers are activated. HRI equipment is activated on notification by wayside interface equipment which detects or communicates with the approaching train. In this service package, the wayside equipment provides additional information about the arriving train so that the train's direction of travel, estimated time of arrival, and estimated duration of closure may be derived. This enhanced information may be conveyed to the driver prior to, or in context with, warning system

activation. This service package also includes additional detection capabilities that enable it to detect an entrapped or otherwise immobilized vehicle within the HRI and provide an immediate notification to highway and railroad officials.

The *Railroad Operations Coordination* service package provides an additional level of strategic coordination between freight rail operations and Traffic Management Centers. Rail operations provides train schedules, maintenance schedules, and any other forecast events that will result in highway-rail intersection (HRI) closures. This information is used to develop forecast HRI closure times and durations that may be used in advanced traffic control strategies or to enhance the quality of traveler information.

Findings and Recommendations for Highway/Railroad Grade Crossings

In order to address safety issues at highway/railroad grade crossings, IDOT and others should consider multiple simultaneous integration strategies, including:

- IDOT should help facilitate more cooperative purchasing of HRI ITS systems. It should work to develop guidelines, not specifications, for the most desired functions to guide agencies trying to formulate their ITS plans.
- Agencies throughout the state should explore interconnecting their systems and collaborating for service improvement.
- IDOT should monitor any new standards development in the HRI area, and guide agencies in deciding which new standards to adopt.
- Agencies should address the most problematic HRIs (measured by total hours of vehicle delay) with grade separation where feasible. Where this is not feasible due to physical constraints, IDOT should look at application of advanced functionality, including TMC interconnects, to allow traffic diversion when long crossing blockages are expected.
- IDOT should explore additional monitoring techniques, advanced traveler information and alternative routing services to address safety and mobility issues.
- Monitor and incorporate CAV development for future functionalities that may significantly impact HRIs.

13. Commercial Vehicle Operations

Description and Examples

The Commercial Vehicle Operations, or CVO, Management component of ITS is focused upon goods movement (primarily) and their operations (both private and public). Depending on the specific technologies deployed, electronic credentialing systems can receive driver and vehicle information that allows the motor carrier to pay for credentials, registration, and fuel taxes electronically, and request services or service information electronically. A safety information exchange system electronically records, stores and downloads vehicle inspection data, and issues citations as appropriate, and exchanges this safety data among agencies with a state and among other states. HAZMAT (Hazardous Materials) CVO needs extra services covering HAZMAT management and roadside HAZMAT security detection and mitigation.

Drivers can also ride more safely with advanced on-board concepts, such as collision warning systems and detection of pedestrians or other obstructions around the vehicle. Fleet and Freight operators can employ CAD systems with AVL to better manage vehicles and respond to operational or mechanical challenges that may arise. Non-fixed route deliverers can use location data to make scheduling more efficient and save valuable driver time by minimizing paperwork and voice radio connection delays. Operations planning can access historical data to improve routes and schedules, while maintenance can enhance its core software packages with vehicle health histories and tracking.

Currently, IDOT deploys PrePass, an electronic clearance system for commercial carriers at stations along the Illinois interstate highway network. In addition, Virtual Weigh-in-Motion (WIM) is used in conjunction with law enforcement authorities in Illinois. In Illinois, the agencies actively involved in performing administration functions to support credentials, tax, and safety regulations, and in issuing special oversize/overweight and HAZMAT permits are:

- Illinois Commerce Commission operates the electronic permitting systems called Single State Registration System (SSRS)
- Illinois Department of Revenue issues International Fuel Tax Agreement (IFTA) electronic permits and collects fuel taxes
- IDOT Bureau of Operations processes and issues special permits for Oversize/Overweight vehicles.
- Illinois Secretary of State issues International Registration Plan (IRP) permits and provides the electronic data from the IRP to the SAFER system, allowing a vehicle's safety records to be examined along with their registration fees.

Illinois bordering states must be included when considering commercial vehicles, because movement of goods is an interstate commerce activity. Much of the data collected by the State of Illinois is shared electronically with the Federal Motor Carriers Safety Administration (FMCSA), and ISP for CVO enforcement processes. Figure 9 presents the current integration environment for the range of

commercial vehicle systems. As of June 2019, IDOT is in the process of awarding a project to update the Illinois CVISN/CVIEW approach, as part of the federal Innovative Technology Deployment Program.

- Indiana Department of Revenue communicates with motor carriers conducting business in Indiana through an electronic permitting system (i.e., a “One-Stop Shop” for operators.)
- Wisconsin DOT Motor Carrier Services communicates with the IRP and the IFTA to process credentials applications and collect fuel, weight/distance, and other taxes and fees associated with commercial vehicle operations. It also receives application for, and issues special Oversize/Overweight and HAZMAT permits.

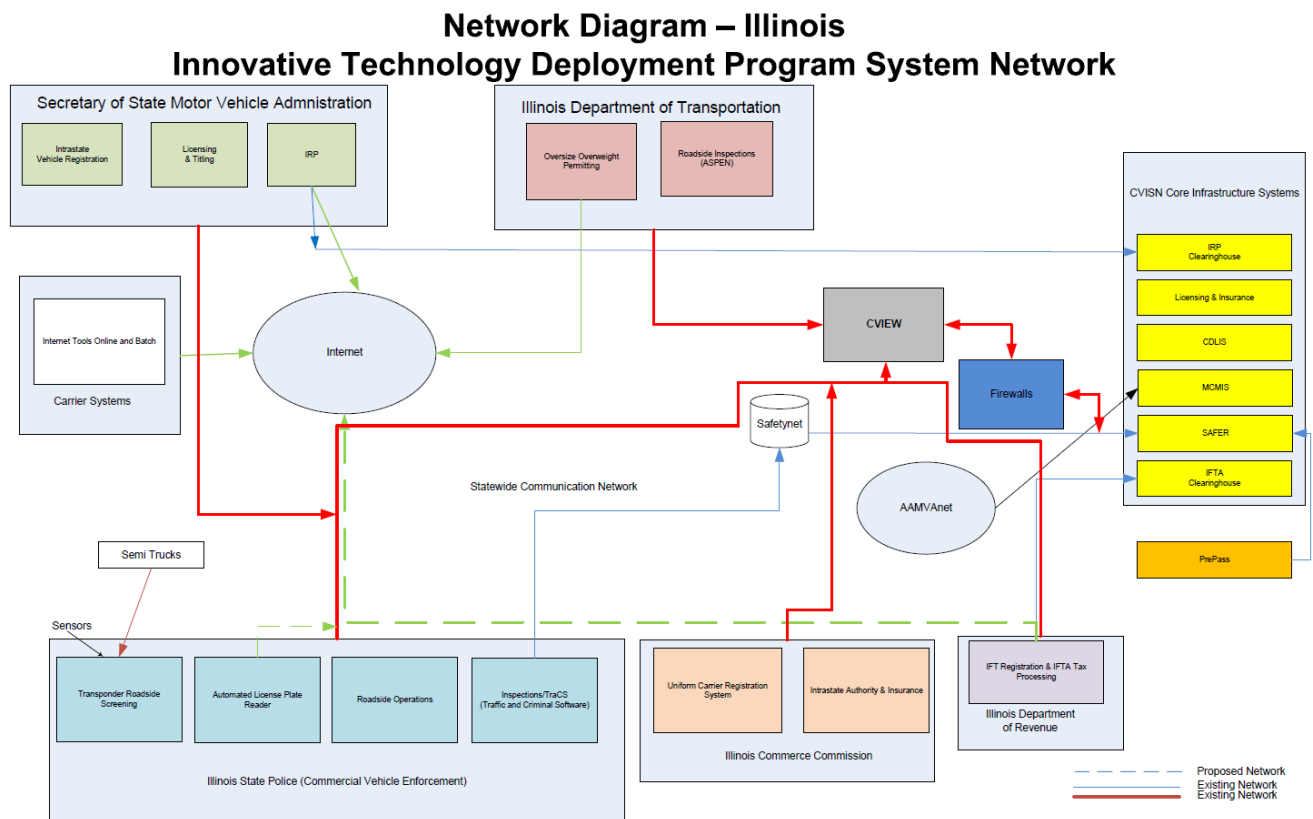


Figure 9: Level 2 Diagram for Commercial Vehicle Operations

Relationship to Statewide Vision

Commercial Vehicle Operations are primarily a statewide functional area involving the coordination of IDOT, Secretary of State, Illinois Commerce Commission, Illinois Department of Revenue, Illinois State

Police via multiple systems to ensure safe driver, trucks, and companies. This coordination also addresses enforcement, revenue collection, insurance and the permitting and coordination of oversize-overweight movements. Additionally, during emergency operations, IDOT manages the coordination and utilization private sector trucking to support operations. This coordination is through direct interaction of IDOT with Mid-West Truckers Association and the Illinois Trucking Association. These two associations then outreach to their constituencies to contract for supporting services to IDOT.

Among the areas that the statewide vision for ITS focuses on in terms of improving the transportation system are Performance and Safety. In the realm of CVO, moving freight efficiently is paramount, as goods movement via Commercial Vehicles is not only an important part of the state's transportation system – it is the vital lifeblood of the nation's economy. While there are challenges to the surface transportation network from these larger vehicles, CVO most certainly has a positive and pivotal role to play in the vision element:

Enhance Performance: Improved credentialing and clearance of trucks, improved weather, traffic, and parking information for truck dispatchers and operators, information support for intermodal freight facilities.

Enhance Safety: On-board vehicle security cameras are a proven deterrent to criminal acts and can help positively identify perpetrators in the event there is an incident on-board. These cameras have also been shown to substantially reduce agencies' claims due to crashes, fender-benders, abrupt stops, etc., by providing a photographic record of what really happened to/on the vehicle. Safety warning for lateral, front or rear obstacles, as well as intersections, will help drivers avoid crashes or pedestrian accidents. Other safety enhancements involve truck parking management with parking availability information, ramp speed warning systems, increased weight enforcement including WIM, truck safety inspection, and hours of service enforcement.

Identification of Issues

Commercial vehicle operators and regulating agencies face a number of issues in performing services and planning new projects:

- Despite general concerns toward trucks by the general public, trucking is a vital commercial activity supporting the state's economy. Thus, there is a need for expedited truck processing through loading and inspection facilities to optimize operations.
- Given the prevalence of online shopping services via Amazon and even Walmart and other traditional shopping methods, there is widely anticipated growth in the trucking industry, per Illinois Trucking Association.
- There is a constant need to monitor trucks for weight compliance and safety using inspection stations strategically located across the state. Weight enforcement is critical to protect pavements from overweight truck damage that shortens infrastructure life.
- CAV operations are under consideration in CVO for applications such as truck platooning in

exclusive lanes.

- The use of electronic logging devices (ELDs) is now mandated to keep track of legal driver hours of service, with full implementation by mid-December, 2019. The Federal Motor Carrier Safety Administration and Illinois counterparts need to assure that this occurs as required (see <https://www.fmcsa.dot.gov/hours-service/elds/implementation-timeline>).

Benefits of Commercial Vehicle Operations

ITS offers significant benefits to state motor carrier agencies, the motor carrier industry, and the traveling public. New and emerging technologies, information systems, and communications networks provide the framework for states, the Federal Government, and private stakeholders to electronically collect and exchange motor carrier safety and interstate registration and tax payment information. Use of these technologies supports initiatives by the state of Illinois and cognizant Federal agencies, in partnership with the motor carrier industry, to improve highway safety, simplify government administrative credentialing operations, enhance productivity, and reduce delays for safe and legal carriers.

By using the three main ITS technology areas designed for CVO applications (safety information exchange, electronic screening, and electronic credentialing), the Federal Motor Carrier Safety Administration aims to reduce commercial vehicle crashes and to reduce the number of persons injured in commercial vehicle crashes. As a result, the benefit of programs such as Pre-Pass implemented statewide provides enforcement personnel with access to up-to-date safety and credential information for motor carriers, as well as for individual vehicles. This access yields improved highway safety by allowing state and federal enforcement officials to concentrate their resources on high-risk carriers and vehicles.

Safety and Weight Inspection stations, strategically located and actively enforced, provide benefits in terms of preserving infrastructure (pavement and bridges) and reducing truck-involved crashes. Additional benefits are gained through use of unmanned VWIM sites to gauge truck use and determine the need for more active weight and safety enforcement.

The associated USDOT fact sheets are available at <https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/CVO/> and <https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/IntermodalFreight/>. Following is a sample of cited benefits.

- An evaluation of the national CVISN program found that electronic screening has a benefit-cost ratio of 1.9 to 7.5. Results varied depending on the system configuration, level of deployment, and the benefits of crash avoidance gained through increased compliance.
- Ninety-four (94) percent of motor carrier companies surveyed say that electronic credentialing is more convenient, 80 percent saw savings in staff labor time, and 58 percent achieved costs savings over manual methods.

In 2013, the Federal Highway Administration finalized an assessment of a drayage optimization application sponsored under the Cross-Town Improvement Project (C-TIP) in Memphis, Tennessee. A pre- and post-deployment analysis of 31 data points revealed the following benefits ([2014-00919](#)):

- Required fleet reduced by 21 percent
- Total miles reduced by 9 percent
- Average miles per truck increased by 14 percent
- Total bobtail miles reduced by 13 percent.

ITS Architecture

The National ITS Architecture includes a diverse set of functionalities as part of Commercial Vehicle Operations (CVO). Several service packages - groupings of features that relate to commonly understood commercial vehicle operations functions - encompass the fundamental management features:

Carrier Operations and Fleet Management service package manages a fleet of commercial vehicles. The Fleet and Freight Management Center monitors the vehicle fleet and can provide routes using either an in-house capability or an external provider. Routes generated by either approach are constrained by hazardous materials and other restrictions (such as height or weight). A route is electronically sent to the Commercial Vehicle with any appropriate dispatch instructions. The location of the Commercial Vehicle can be monitored by the Fleet and Freight Management Center and routing changes can be made depending on current road network conditions. This service package also supports maintenance of fleet vehicles with on-board monitoring equipment. Records of vehicle mileage, preventative maintenance and repairs are maintained.

Freight Administration is a service package that encompasses the movement of cargo and monitors the cargo condition. Interconnections are provided to intermodal freight shippers and intermodal freight depots for tracking of cargo from source to destination. In addition to the usual cargo monitoring required to ensure that cargo gets from origin to destination, the Fleet and Freight Management Center monitors shipments to make sure that no tampering or breach of security occurs to the cargo on commercial vehicles. Any such tampering is reported to the Fleet and Freight Management Center. In addition to exceptions (e.g., alerts) that are reported, on-going indications of the state of various freight equipment are reported to the Fleet and Freight Management Center. The commercial vehicle driver is also alerted of any tampering or breach of cargo security. Freight managers may decide to take further action on the alerts and/or provide responses that explain that the alerts are false alarms. If no explanation is received, the Fleet and Freight Management Center may notify the Emergency Management Center.

The *Electronic Clearance* service package provides for automated clearance at roadside check facilities. The roadside check facility communicates with the Commercial Vehicle Administration Center to retrieve infrastructure snapshots of critical carrier, vehicle, and driver data are used to sort passing vehicles. This allows a good driver/vehicle/carrier to pass roadside facilities at highway speeds using transponders and dedicated short-range communications to the roadside. Results of roadside

clearance activities are passed on to the Commercial Vehicle Administration Center. The roadside check facility may be equipped with Automated Vehicle Identification (AVI), weighing sensors, transponder read/write devices and computer workstations.

CV Administrative Processes is a service package that provides for electronic application, processing, fee collection, issuance, and distribution of CVO credential and tax filing. Through this process, carriers, drivers, and vehicles may be enrolled in the electronic clearance program provided by a separate service package, which allows commercial vehicles to be screened at mainline speeds at roadside check facilities. Through this enrollment process, current profile databases are maintained in the Commercial Vehicle Administration Center and snapshots of this database are made available to the roadside check facilities at the roadside to support the electronic clearance process.

Commercial Vehicle Administration Centers can share credential information with other Commercial Vehicle Administration Centers, so that it is possible for any Commercial Vehicle Administration Center to have access to all credentials, credential fees, credentials status and safety status information. In addition, it is possible for one Commercial Vehicle Administration Center to collect HAZMAT route restrictions information from other Commercial Vehicle Administration Centers and then act as a clearinghouse for this information for Information Service Providers, Map Update Providers, and Fleet and Freight Management Centers.

Roadside CVO Safety service package provides for automated roadside safety monitoring and reporting. It automates commercial vehicle safety inspections at roadside check locations. The basic option, directly supported by this service package, facilitates safety inspection of vehicles that have been pulled off the highway, perhaps as a result of the automated screening process provided by the *Electronic Clearance* service package.

The *Fleet and Freight Security Service Package* provides enhanced security for commercial vehicle fleets and freight. Internal and external alerts and advisories are monitored to identify potential threats to the safety and security of the fleet and freight. It provides for the planning and tracking of three aspects of commercial vehicle shipments. For each shipment, the commercial vehicle, the freight equipment, and the commercial vehicle driver are monitored for consistency with the planned assignment.

The *Electronic Clearance* service package covers high speed weigh-in-motion with or without AVI capabilities. This service package provides the roadside equipment that could be used as a stand-alone system.

International Border Electronic Clearance is a service package that covers the provision of automated clearance at international border crossings. This package augments the electronic clearance package by allowing interface with customs-related functions.

HAZMAT Management is a service package that integrates incident management capabilities with commercial vehicle tracking to assure effective treatment of HAZMAT material and incidents. The Fleet and Freight Management Center performs HAZMAT tracking. The Emergency Management Center Subsystem is notified by the Commercial Vehicle if an incident occurs and coordinates the response.

The response is tailored based on information that is provided as part of the original incident notification or derived from supplemental information provided by the Fleet and Freight Management Center. The latter information can be provided prior to the beginning of the trip or gathered following the incident depending on the selected policy and implementation.

Roadside HAZMAT Security Detection and Mitigation is the service package that provides the capability to detect and classify security sensitive HAZMAT on commercial vehicles using roadside sensing and imaging technology. Credentials information can be accessed to verify if the commercial driver, vehicle and carrier are permitted to transport the identified HAZMAT. If the credentials analysis and sensed HAZMAT information do not agree, the vehicle can be signaled to pull in, and if required, an alarm can be sent to an Emergency Management Center to request they monitor, traffic stop or disable the vehicle.

CV Driver Security Authentication provides the ability for the Fleet and Freight Management Center to detect when an unauthorized commercial vehicle driver attempts to drive their vehicle, based on stored driver identity information. If an unauthorized driver has been detected, Fleet and Freight Management Center can activate commands to safely disable the vehicle. Alarms sent to emergency management subsystems inform them of a potential commercial vehicle hijacking or theft and a potential hazardous situation. In addition, the Emergency Management Center can request the Fleet and Freight Management Center to disable a specific vehicle in their fleet.

In addition to these CVO-oriented service packages, Commercial Vehicle Operations take advantage of other ITS subsystems and service packages, involving such functions as data management, safety warnings, and traffic information.

Findings and Recommendations for Commercial Vehicle Operations

In order to improve support to commercial vehicle operations, IDOT should take advantage of the considerable amount of work that has been accomplished in CVO. The Department should perform the following activities to enhance commercial vehicle operations:

- Continue to support and implement Innovative Technology Deployments (ITD). Initiate and complete an Enhanced Program Plan and/or Top Level Design in order to define future CVO projects and programs, to establish eligibility for FMCSA funding.
- Strengthen partnerships with stakeholders such as Midwest Truckers and Illinois Trucking Associations for CVO monitoring, reporting and compliance
- Monitor and incorporate the latest developments in CVO ITS applications such as Electronic Screening
- Monitor and incorporate CAV development for future functionalities that may significantly modify CVO.

14. Connected and Autonomous Vehicles

Description and Examples – Connected and Automated Vehicles

Connected and Automated Vehicles (CAVs) are the emerging technology seeking to enable vehicles and transportation infrastructure to communicate, providing each other with detailed information: speed, location and bearing from vehicles, and regulations and control state from the infrastructure. Processing and synthesizing these sources can result in safety warnings, traffic and weather information and real-time performance measures. For example, cars on the highway could use short-range radio signals to communicate with each other so every vehicle on the road would be aware of where other nearby vehicles are. Drivers would receive notifications and alerts of dangerous situations, such as someone about to run a red light on an intersection approach, or an oncoming car out of sight beyond a curve, swerving into the opposing lane to avoid an object on the road. Connected vehicles could dramatically reduce the number of fatalities and serious injuries caused by accidents on our roads and highways.

An application example in Illinois is the Connected Vehicle (CV) Pilot Project that the IL Tollway is currently conducting. It features the early deployment of a small number of connected vehicle assets along 10-miles of I-90 from Arlington Heights Road to just east of Rte. 59, serving as a proof of the concept of using CV technology to collect useful traffic data directly from vehicles. This demonstration leverages the technology investment the agency has already made in the I-90 “Smart Road” by integrating CV technology into the roadway at a small incremental cost.

The ultimate goal of CAVs is completely autonomous vehicles that require no human driver; humans would just be passengers. This goal is several decades away, but initial work today is moving along this development path.

Relationship to Statewide Vision - Connected and Automated Vehicles

The State of Illinois via IDOT, Illinois Tollway, CDOT and private sector initiatives among others have recognized that CAV is here, although not all of the components related to security, policy, public-private partnerships, and technology details are not static. As this marketplace takes shape, a statewide communications network, ongoing and fostered relationships with the private sector, and explicit attention to communications standards will support preparedness for the CAV world. The Statewide Vision addresses access to real-time information from many sources to promote safe and a stable transportation system. Vehicles, Internet of Things (IoT), and numerous ‘smart’ technology opportunities will continue to emerge. To engage properly, acceptance of the high rate of technological changes and the ability to actively ‘procure to test’ will be required.

Identification of Issues - Connected and Automated Vehicles

Since CAVs are in an early stage of development, there are many challenges and issues to address. It is important to realize that there are many involved stakeholders, and there needs to be a good deal of

early dialogue and collaboration to push CAV development along. Among the challenges are the following:

- Collecting, integrating and communicating information on roadway condition will require investment in reporting systems, information management systems, and the development of relationships between public entities and private sector stakeholders to supply CAV's with important and timely data.
- Technology needs to develop further before allowing vehicles to operate with decreasing levels of human guidance.
- To provide vehicle-to-vehicle (V2V) and vehicle-to-infrastructure interactions (V2I), there needs to be a robust communications network that can handle an incredible amount of information. Current plans are to have vehicles sending detailed position, speed, bearing and other information 10 times a second, and the infrastructure and other vehicles must be able to process these data.
- Cybersecurity must be absolute so that vehicles cannot be taken over by malevolent hackers wishing to do harm.
- Privacy is an issue; people in CAVs must be assured they are not being tracked.
- CAV development will require the participation of vehicle manufacturers, all levels of government, communications system suppliers and others. Complex data processing and control will require national and even international standards. In the US, the USDOT and National Highway Traffic Safety Administration (NHTSA) need to develop standards from a "top-down" viewpoint.
- Legal liability presents a challenge; in case of a crash in which vehicle control software, for example, chooses to hit a pedestrian rather than another vehicle, who is legally responsible?
- The evolution to CAVs poses unique challenges as the driving environment changes from primarily human-based to machine-based. Hybrid environments of the two will inevitably raise conflicts that will need to be addressed.
- While numerous applications areas have been defined, the deployments are primarily in conceptual status or are only operating within pilot programs.
- Synergy between public and private sector activities is still in the infancy stage in most cases.
- While standards for Basic Safety Messages, Signal Phase and Timing, and MAP (intersection geometrics) data exist, the number vehicles on the roadway is limited, and very few vehicles from the OEMs are broadcasting or consuming the data.

There are several national initiatives to wrestle with these and other challenges. In 2018, the USDOT began conducting a national dialogue on highway automation to help chart a path forward through the many issues (see <https://ops.fhwa.dot.gov/automationdialogue/>).

Benefits of Connected and Automated Vehicles

NHTSA and the USDOT estimate that nearly all vehicle crashes could be eliminated through pervasive CAVs implementation (<https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/CVSAafety/>). Thus, the greatest benefit of CAVs is expected to lie in the safety field, saving lives and reducing injuries. This should be a major step forward as about 35,000 people are killed on highways in the US every year.

CAVs will use advanced communications and control techniques to reduce congestion and delays by 1) routing vehicles automatically on the optimum travel path and 2) allowing vehicles to operate at reduced headways, thus increasing road capacity and throughput. In a similar vein, as autonomous vehicles are phased in, vehicle travel should become less stressful and actually allow all passengers to engage in other activities such as reading, working and resting.

There are several associated USDOT fact sheets that serve as great example of the potential impacts. The fact sheets offer a wide range of estimated benefits, anticipated incrementally as CAVs move through levels of automation over several years.

Automated Vehicles:

<https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/Automation/>
<https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/TruckPlatooning/>
<https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/DriverAssistance2/> .

Connected Vehicles including In-vehicle navigation/guidance:

<https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/CVEnvironment/>
<https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/CVMobility/>
<https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/CVSAafety/>
<https://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/DriverAssistance1/>

ITS Architecture

ARC-IT includes now the architecture to support Connected Vehicle Applications that were defined in the Connected Vehicle Reference Implementation Architecture (CVRIA). Associated software packages establish the basis for the integration and standardization of connected vehicle technologies. The primary service packages addressed in ARC-IT relevant to IDOT's vision to support CAVs technology are in the Vehicle Safety area as presented in Table 6:

Table 2: Vehicle Safety Service Packages for CAVs

Name	Description
Autonomous Vehicle Safety Systems (VS01)	Improves vehicle safety using on-board sensors that monitor the driving environment surrounding the vehicle. All levels of driving automation are supported ranging from basic warning systems that warn the driver through full automation where the vehicle controls the steering and acceleration/deceleration in all scenarios and environments, without driver intervention. Unlike other Vehicle Safety service packages, this service package includes autonomous capabilities that rely only on on-board systems without communication with other vehicles or the infrastructure
V2V Basic Safety (VS02)	Exchanges basic safety messages with surrounding CVs to support and augment safety warning and control automation features identified in the Autonomous Vehicle Safety Systems service package. Exchanges support CV safety applications defined in SAE J2945/1: Emergency Electronic Brake Lights, Forward Crash Warning, Blind Spot Warning/Lane Change Warning, Intersection Movement Assist, Left Turn Assist, and Control Loss Warning; also supports Do Not Pass Warning, Motorcycle Approaching indication, Tailgating Advisory, Stationary Vehicle, and Pre-Crash Actions applications from CVRIA.
Situational Awareness (VS03)	Shares information about potentially hazardous road conditions or road hazards with other vehicles to support enhanced driver warnings and control automation. Vehicles broadcast relevant road condition information that is collected by the vehicle, such as fog or icy roads. It also supports the capability for CV to share situational awareness information even in areas where no roadside communications infrastructure exists. It can be useful to vehicles that are not fully equipped with sensors, or vehicles entering an area with hazardous conditions. Roadside communications infrastructure, if available, can extend the situational awareness range to cover wrong way vehicles where closing rates can require notification beyond DSRC communications range.

Name	Description
V2V Special Vehicle Alert (VS04)	Alerts the driver about the location of and the movement of public safety vehicles responding to an incident, slow moving vehicles, oversized vehicles, and other special vehicles that may require special attention from the driver. These public safety, commercial, and maintenance vehicles share their status and location with surrounding vehicles so that other drivers in the vicinity can avoid interfering with their actions and avoid collisions.
Curve Speed Warning (VS05)	Allows CV to receive information that it is approaching a curve along with the recommended speed for the curve. In addition, the vehicle can perform additional warning actions if the actual speed through the curve exceeds the recommended speed.
Stop Sign Gap Assist (VS06)	Intended to improve safety at non-signalized intersections where only the minor road has posted stop signs. It includes both onboard (for connected vehicles) and roadside signage warning systems (for non-equipped vehicles). The service package helps drivers on a minor road stopped at an intersection understand the state of activities associated with that intersection by providing a warning of unsafe gaps on the major road. The SSGA service package collects all available sensor information (major road, minor road, and median sensors) data and computes the dynamic state of the intersection to issue appropriate warnings and alerts.
Road Weather Motorist Alert and Warning (VS07)	Collects road weather data from CVs to develop short term warnings or advisories that can be provided to individual motorists. Information may come from either vehicle operated by the public and commercial entities or specialty vehicles and public fleet vehicles (such as snowplows, maintenance trucks, and other agency pool vehicles). Processed data will generate road segment-based data outputs and road weather motorist alerts algorithm for short time horizon alerts pushed to user systems and available to commercial service providers. Information can be combined with observations and forecasts from other sources to provide medium (next 2-12 hours) or long term (more than 12 hours) through interfaces such as web based and CV-based interfaces.

Name	Description
Queue Warning (VS08)	Utilizes CV technologies, including vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communications, to enable vehicles within the queue event to automatically broadcast their queued status information (e.g., rapid deceleration, disabled status, lane location) to nearby upstream vehicles and to centers (such as the TMC). The infrastructure will broadcast queue warnings to vehicles to minimize or prevent collisions. This service package will engage well in advance of any potential crash situation, providing messages and information to the driver to minimize the likelihood of his needing to take crash avoidance or mitigation actions later.
Reduced Speed Zone Warning/Lane Closure (VS09)	Provides CVs that are approaching a reduced speed zone with information on the zone's posted speed limit and/or if the configuration of the roadway is altered. The CV uses the revised speed limit and any applicable changed roadside configuration information to provide an alert or warning to the driver. Additionally, to provide warnings to non-equipped vehicles, infrastructure equipment measures the speed of the approaching vehicles and if greater than the reduced speed zone posted speed limit will provide warning signage.
Restricted Lane Warnings (VS10)	Provides the CV with restriction information about the travel lanes, such as if the lane is restricted to high occupancy vehicles (HOV), transit, or public safety vehicles only or has defined eco-lane criteria. A CV can use this information to determine if the vehicle is in a lane that has lane restrictions
Oversize Vehicle Warning (VS11)	Uses external measurements taken by the roadside infrastructure, and transmitted to the vehicle, to support in-vehicle determination of whether an alert/warning is necessary. The infrastructure data equipment detects and measures the approaching vehicle's height and width. Then transmits the vehicle measurements, along with bridge, overpass, or tunnel geometry, to the oversize vehicle. The vehicle application determines whether the vehicle can clear the bridge or tunnel. And, the driver is alerted to the impending low height and/or narrow horizontal clearance bridge or tunnel prior to a decision point, enabling the vehicle to reroute and avoid a collision. If the driver ignores the alert and continues along the route, the vehicle will generate a warning indicating an impending collision at a point near the bridge or tunnel approach. To support unequipped vehicles the infrastructure will display warning or reroute information when the measurements indicate that a vehicle does not have adequate height or width clearance. This service package can be expanded to consider weight.

Name	Description
Pedestrian and Cyclist Safety (VS12)	Supports the sensing and warning systems used to interact with pedestrians, cyclists, and other non-motorized users that operate on the main vehicle roadways that intersect the main vehicle roadways. These systems allow automated warning or active protection for this class of users. It integrates traffic, pedestrian, and cyclist information from roadside or intersection detectors and new forms of data from wirelessly connected, non-motorized traveler-carried mobile devices to request right-of-way or to inform non-motorized travelers when to cross and how to remain aligned with the crosswalk or pathway based on real-time Signal Phase and Timing (SPaT) and MAP information. In some cases, priority will be given to non-motorized travelers, such as persons with disabilities who need additional crossing time, or in special conditions (e.g., weather) where non-motorized travelers may warrant priority or additional crossing time. This service package will enable a service call to be routed to the traffic controller from a mobile device of a registered person with disabilities after confirming the direction and orientation of the roadway that the individual is intending to cross. It also provides warnings to the non-motorized user of possible infringement of the crossing or pathway by approaching vehicles
Intersection Safety Warning and Collision Avoidance (VS13)	Enables a connected vehicle approaching an instrumented signalized intersection to receive information from the infrastructure regarding its signal timing and the geometry. The vehicle uses its speed and acceleration profile, along with the signal timing and geometry information to determine if it is likely that the vehicle will be able to pass safely through the intersection without violating the signal or colliding with other vehicles. If the vehicle determines that proceeding through the intersection is unsafe, a warning is provided to the driver and/or collision avoidance actions are taken, depending on the automation level of the vehicle
Cooperative Adaptive Cruise Control (VS14)	Adds vehicle to vehicle (V2V) communications to adaptive cruise control (ACC) systems, which provides enhanced information so that groups or 'strings' of CACC-equipped vehicles can follow a lead vehicle with better accuracy, quicker response, and shorter time gaps, enhancing traffic flow stability. In ACC systems, sensors (e.g., radar or lidar) and longitudinal control automation are used to measure and maintain a safe distance from the lead vehicle. V2V communications enables direct communication between the vehicles so that acceleration and deceleration can be coordinated between vehicles in the string.

Name	Description
Infrastructure Enhanced Cooperative Adaptive Cruise Control (VS15)	<p>Adds Infrastructure to Vehicle (I2V) communications to Cooperative Adaptive Cruise Control systems so that strings of compatible CACC-equipped vehicles can be more efficiently formed and cooperating vehicles gain access to speed recommendations and traffic control status from the infrastructure, enhancing traffic flow stability and improving highway capacity and throughput. Speed recommendations provided by the infrastructure can stabilize traffic flow, reducing speed differentials and enhancing throughput along a route. Access to traffic control information such as signal phase and timing enables synchronized starts by adjacent CACC-equipped strings of vehicles, increasing intersection throughput. The infrastructure can also assist with broader coordination between CACC-equipped vehicles, enabling strings of vehicles to be more efficiently formed that share performance parameters and destinations</p>
Automated Vehicle Operations (VS16)	<p>Provides full vehicle automation, controlling both the steering and acceleration/deceleration on areas of the highway system that support full automation. Communications between vehicles and between the vehicles and supporting infrastructure equipment supports cooperative check-in to the automated portion of the system and transition to automated mode, coordination of maneuvers between vehicles in automated mode, and checkout from the automated system. This service package is distinguished from the most advanced CACC systems in that full longitudinal and lateral control automation are supported, enabling closely spaced, tightly coupled platoons of vehicles to operate with short fixed gaps, providing greatly enhanced highway capacity and throughput with enhanced efficiency since aerodynamic drag is reduced.</p>
Traffic Code Dissemination (VS17)	<p>Disseminates current local statutes, regulations, ordinances, and rules that have been adopted by local, state, and federal authorities that govern the safe, orderly operation of motor vehicles, bicycles, and pedestrians on public roads. The focus of this service package is electronic distribution to automated vehicles and their drivers so that automated vehicles can safely operate in compliance with the traffic or motor vehicle code for the current state and locality, though this information would also be useful to human drivers.</p>

Findings and Recommendations for Connected and Automated Vehicles

Given the transformative opportunities to improve safety and efficiency of our transportation system, IDOT and stakeholders across Illinois should continue to explore safe ongoing testing of CAV technologies. It is recognized that issues with regard to policy, technology, and maturity of CAV endeavors will continue to require substantial attention at the federal, state, and private sector levels. The private sector at the OEM level is proceeding from a global perspective with testing and pilot programs which will continue. In order to effectively engage in these activities and glean benefits, Illinois should proceed with needs focused engagement in private sector and public sector CAV initiatives. The Illinois Autonomous and Connected Track (I-ACT) program is a great example of public and private sector engagement. At the same time, it is recognized that development of these programs will be iterative and will be subject to potentially rapid changes at the stakeholder, technology and programming levels.

Figure 10 depicts the SAE Automation Levels explanation which frames the vehicle level components of automated driving.

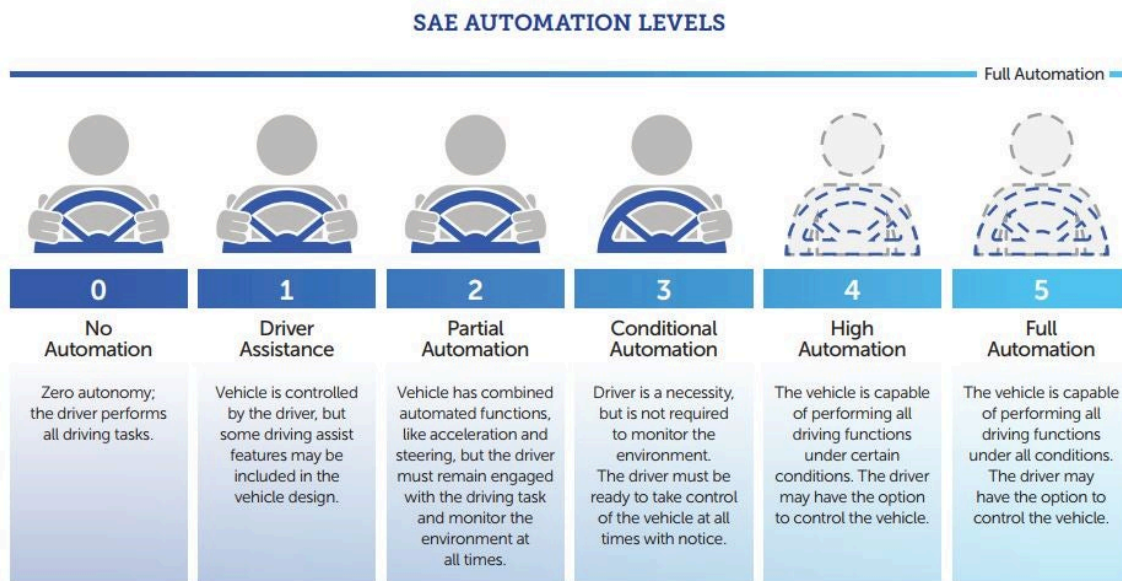


Figure 10 - SAE Automation Levels

It is fairly straightforward to demonstrate these levels at Levels 0-2 on the road today. Levels 4 and 5 are more easily demonstrated in controlled environments. As we observe on-going testing of the automation, the natural questions of reliability, security, interactions with roadways, pedestrians, bicycles, and environmental conditions will be answered in relatively discrete tests and projects in most cases.

The challenge will be for agencies to be flexible in procurement, tolerant of unexpected outcomes, and have the ability to educate each other and the public as a whole as these initiatives progress. The ability to focus on needs, and recognize that incremental steps will be normal in the safe and effective utilizations of the technology will be critical.

IDOT can provide a leadership role in coordination, facilitation, testing, and education for CAV in Illinois.

The CAV industry is rapidly evolving while simultaneously expanding into many areas of industry. As of this Concept of Operations, very few of the necessary elements including policy, liability, applications, inter-operability, communications and security standards, and widespread distribution of equipment via OEM vehicle have converged. Standards such as BSM and SPaT appear to be relatively stable, but the Security Credential Management System is not quite complete. In parallel, the private sector is forging ahead with a variety of tests in automation of data collection, safety, mobility, and fleet-based applications.

From a State of Illinois and IDOT perspective, the focus should be to engage, test, and work with public and private sector markets to test, modify, and re-test to remain 'in the game'. While there is an option to wait for the CAV world to mature, remaining on the sidelines until that maturity improves will leave stakeholders to catch up on the process to educate, design for, and implement the advantages of CAV moving forward. Those advantages impact safety, mobility and long-term economies for the state. IDOT should also focus and improve on its ability to collect, integrate and make available the necessary real-time traffic data which will be vital to develop the CAV environment.

Appendix A: ARC-IT Service Packages

Area	Short Name	Name
Commercial Vehicle Operations	CVO01	Carrier Operations and Fleet Management
	CVO02	Freight Administration
	CVO03	Electronic Clearance
	CVO04	CV Administrative process
	CVO05	International Border Electronic Clearance
	CVO06	Freight Signal Priority
	CVO07	Roadside CVO Safety
	CVO08	Smart Roadside and Virtual WIM
	CVO09	Freight-Specific Dynamic Travel Planning
	CVO10	Road Weather Information for Freight Carriers
	CVO11	Freight Drayage Optimization
	CVO12	HAZMAT Management
	CVO13	Roadside HAZMAT Security Detection and Mitigation
	CVO14	CV Driver Security Authentication
	CVO15	Fleet and Freight Security
	CVO16	Electronic Work Diaries
	CVO17	Intelligent Access Program
	CVO18	Intelligent Access Program-Weight Monitoring
	CVO19	Intelligent speed Compliance
Data Management	DM01	ITS Data Warehouse

Area	Short Name	Name
	DM02	Performance Monitoring
Maintenance and Construction	MC01	Maintenance and Construction Vehicle and Equipment Tracking
	MC02	Maintenance and Construction Vehicle Maintenance
	MC03	Roadway Automated Treatment
	MC04	Winter Maintenance
	MC05	Roadway Maintenance and Construction
	MC06	Work Zone Management
	MC07	Work Zone Safety Monitoring
	MC08	Maintenance and Construction Activity Coordination
	MC09	Infrastructure Monitoring
Parking Management	PM01	Parking Space Management
	PM02	Smart Park and Ride System
	PM03	Parking Electronic Payment
	PM04	Regional Parking Management
	PM05	Loading Zone Management
Public Safety	PS01	Emergency Call-Taking and Dispatch
	PS02	Routing Support for Emergency Responders
	PS03	Emergency Vehicle Preemption
	PS04	Mayday Notification
	PS05	Vehicle Emergency Response
	PS06	Incident Scene Pre-Arrival Staging Guidance for Emergency Responders

Area	Short Name	Name
	PS07	Incident Scene Safety Monitoring
	PS08	Roadway Service Patrols
	PS09	Transportation Infrastructure protection
	PS10	Wide-Area Alert
	PS11	Early Warning System
	PS12	Disaster Response and Recovery
	PS13	Evacuation and Reentry Management
	PS14	Disaster Traveler Information
Public Transportation	PT01	Transit Vehicle Tracking
	PT02	Transit Fixed-Routing Operations
	PT03	Dynamic Transit Operations
	PT04	Transit Fare Collection Management
	PT05	Transit Security
	PT06	Transit Fleet Management
	PT07	Transit Passenger Counting
	PT08	Transit Traveler Information
	PT09	Transit Signal Priority
	PT10	Intermittent Bus Lanes
	PT11	Transit Pedestrian Indication
	PT12	Transit Vehicle at Station/Stop Warnings
	PT13	Vehicle Turning Right in Front of a Transit Vehicle
	PT14	Multi-modal Coordination

Area	Short Name	Name
	PT15	Transit Stop Request
	PT16	Route ID for the Visually Impaired
	PT17	Transit Connection Problem
	PT18	Integrated Multi-modal Electronic Payment
Support	SU01	Connected Vehicle System Monitoring and Management
	SU02	Core Authorization
	SU03	Data Distribution
	SU04	Map Management
	SU05	Location and Time
	SU06	Object Registration and Discovery
	SU07	Privacy Protection
	SU08	Security and Credentials Management
	SU09	Center Maintenance
	SU10	Field Equipment Maintenance
	SU11	Vehicle Maintenance
	SU12	Traveler Device Maintenance
Sustainable Travel	ST01	Emissions Monitoring
	ST02	Eco-Traffic Signal Timing
	ST03	Eco-Traffic Metering
	ST04	Roadside Lighting
	ST05	Electric Charging Stations Management
	ST06	HOV/HOT Lane Management

Area	Short Name	Name
	ST07	Eco-Lanes Management
	ST08	Eco-Approach and Departure at Signalized Intersections
	ST09	Connected Eco-Driving
	ST10	Low Emissions Zone Management
Traffic Management	TM01	Infrastructure-Based Traffic Surveillance
	TM02	Vehicle-Based Traffic Surveillance
	TM03	Traffic Signal Control
	TM04	Connected Vehicle Traffic Signal System
	TM05	Traffic Metering
	TM06	Traffic Information Dissemination
	TM07	Regional Traffic Management
	TM08	Traffic Incident Management System
	TM09	Integrated Decision Support and Demand Management
	TM10	Electronic Toll Collection
	TM11	Road Use Charging
	TM12	Dynamic Roadway Warning
	TM13	Standard Railroad Grade Crossing
	TM14	Advanced Railroad Grade Crossing
TM15	Railroad Operations Coordination	
TM16	Reversible Lane Management	
TM17	Speed Warning and Enforcement	
TM18	Drawbridge Management	

Area	Short Name	Name
	TM19	Roadway Closure Management
	TM20	Variable Speed Limits
	TM21	Speed Harmonization
	TM22	Dynamic Lane Management and Shoulder Use
	TM23	Border Management Systems
Traveler Information	TI01	Broadcast Traveler Information
	TI02	Personalized Traveler Information
	TI03	Dynamic Route Guidance
	TI04	Infrastructure-Provided Trip Planning and Route Guidance
	TI05	Travel Services Information and Reservation
	TI06	Dynamic Ridesharing and Shared Use Transportation
	TI07	In-Vehicle Signage
Vehicle Safety	VS01	Autonomous Vehicle Safety Systems
	VS02	V2V Basic Safety
	VS03	Situational Awareness
	VS04	V2V Special Vehicle Alert
	VS05	Curve Speed Warning
	VS06	Stop Sign Gap Assist
	VS07	Road Weather Motorist Alert and Warning
	VS08	Queue Warning
	VS09	Reduced Speed Zone Warning/Lane Closure
	VS10	Restricted Lane Warnings

Area	Short Name	Name
	VS11	Oversize Vehicle Warning
	VS12	Pedestrian and Cyclist Safety
	VS13	Intersection Safety Warning and Collision Avoidance
	VS14	Cooperative Adaptive Cruise Control
	VS15	Infrastructure Enhanced Cooperative Adaptive Cruise Control
	VS16	Automated Vehicle Operations
	VS17	Traffic Code Dissemination
Weather	WX01	Weather Data Collection
	WX02	Weather Information Processing and Distribution
	WX03	Spot Weather Impact Warning

Appendix B: References

- Illinois Long Range Transportation Plan (LRTP)
<http://www.idot.illinois.gov/transportation-system/transportation-management/planning/lrtp/index>
- 2017 Strategic Highway Safety Plan
<http://www.idot.illinois.gov/transportation-system/transportation-management/planning/SHSP>
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<http://www.idot.illinois.gov/Assets/uploads/files/Transportation-System/Reports/OP&P/HIP/2018-2023/2018-23%20MYP%20Book.pdf>
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http://www.idot.illinois.gov/Assets/uploads/files/Transportation-System/Reports/OP&P/ILFreightPlan_FINAL.pdf
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