U.S. Department of Transportation
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INTEGRATED CORRIDOR MANAGEMENT AND THE SMART CITIES REVOLUTION: LEVERAGING SYNERGIES

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16. Abstract Because smart cities and integrated corridor management (ICM) are so fundamentally similar in terms of their requirements and objectives, this primer focuses on opportunities for co-deployment synergies and how approaches and lessons learned from one initiative can be translated to the other. The institutional relationships, operational processes, and technical methods developed as part of the successful ICM deployment may be extended across different regions and across different public service areas as part of a broader smart cities program. Both ICM and the smart cities philosophies share the same challenges inherent in coordinating among various stakeholders. This primer is intended to encourage these groups to think broadly about how to go about creating smart cities and how integrated corridor management can help achieve each stakeholder group's goals.			
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INTRODUCTION

"SMART CITIES"

The concept of "smart cities" is a relatively recent one, dating to the early 2000s as a response to growing urbanism and the return of population and commerce to cities. Its growth as a concept is due in no small part to technological advances that began replacing old style information "stove piping" with data sharing and improved communication. This in turn drove increased demand for more-accountable public services from cities that formerly had deteriorating infrastructure, inefficient systems, and limited public agency resources.

As a concept, smart cities is perhaps only slightly older than integrated corridor management (ICM), which is defined as a practical application of a smart cities objective, albeit within the defined cordon of a corridor, not necessarily city wide.

In 2014, as a means to position the emerging connected vehicle community of strategies into the concurrently emerging smart cities movement, the Federal Highway Administration (FHWA) Joint Program Office (JPO) defined a smart (or "connected") city as "a system of interconnected systems, including employment, health care, retail/entertainment, public services, residences, energy distribution, and not least, transportation. This 'system of systems' is tied together by information and communications technologies (ICT) that transmit and process data about all sorts of activities within the city."[1]

In many ways smart cities are still lagging in terms of technological maturity, primarily because smart cities initiatives must overcome decades of public service "culture" and overhaul a much wider breadth of services than ICM initiatives.

Who should read this primer?

The intended audience for this primer includes stakeholders from State and local transportation departments, metropolitan planning organizations, city agencies, and other organizations – public and private sector – that provide services within a city or metropolitan area and which are seeking to provide those services in a smarter, more efficient and sustainable way. It is intended to encourage these groups to think broadly about how to go about creating smart cities and how integrated corridor management can help achieve those goals.

INTEGRATED CORRIDOR MANAGEMENT FUNDAMENTALS

ICM exists as a complementary process under the tenets and precepts of a smart cities umbrella. In traditional urban transportation corridors, each transportation agency within the corridor typically would handle operations independently. While the operators may collaborate or interact

1 "The Smart/Connected City and Its Implications for Connected Transportation," FHWA-JPO-14-148 (Washington, DC: 2014). Available at: http://www.its.dot.gov/itspac/Dec2014/Smart_Connected_City_FINAL_111314.pdf.

to some extent to react to incidents or plan to manage pre-planned events, each agency mostly conducts day-to-day operations autonomously. When congestion and the number of incidents increases over time, this "reactionary" method of operation becomes less effective in meeting the transportation needs of the businesses and people that rely upon the corridor.

The vision of ICM is that transportation networks will realize significant improvements in the efficient movement of people and goods through aggressive, proactive integration of existing infrastructure along major corridors. ICM stakeholders include public transportation agencies, such as State and local departments of transportation (DOT), metropolitan planning organizations (MPO), and transit agencies. Through an ICM approach, transportation professionals manage the corridor as a multimodal system and make operational decisions for the benefit of the corridor as a whole. Smart cities seek to incorporate emerging information and communications technologies within existing infrastructure systems, such as transportation networks, in order to improve the efficiency and effectiveness of public sector services. As smart cities pilot programs kick off across the country, FHWA has a unique opportunity to integrate mature ICM strategies into smart cities solutions to address transportation challenges. Adding definition to the relationship between ICM and smart cities will improve the integration of stakeholders, issues, and solutions into ICM and broader smart cities transportation strategies.

This primer will:

- Examine how ICM can integrate smart cities strategies.
- Examine how existing ICM approaches can advance, inform, and even help lead smart cities initiatives.
- Explore opportunities to effectively integrate strategies institutionally, operationally, and technically, both by leveraging existing platforms and considering new options for coordination between ICM and smart cities stakeholders.
- Identify potential challenges to integrating ICM and smart cities, along with potential solutions.

The ICM approach is based on three fundamental concepts: a corridor-level operations "nexus"; agency integration through institutional, operational, and technical means; and active management of all available, and hopefully participating, corridor assets and facilities. Each of these concepts is described below.

Corridor-level focus on operations is one the fundamental elements of ICM. The United States Department of Transportation (USDOT) defines a corridor as a travel shed that serves a particular travel market or markets that are characterized by similar transportation needs and mobility issues. A combination of networks comprising facility types and modes provide complementary functions to meet those mobility needs. These networks may include freeways, limited access facilities, surface arterials, public transit, and bicycle and pedestrian facilities, among others. Cross-network connections permit travelers to seamlessly transfer between networks for a truly multimodal transportation experience.

Integration requires actively managing assets in a unified way so that actions can be taken to benefit the corridor as a whole, not just a particular piece of it. Integration occurs along three dimensions:

- **Institutional Integration** – Coordination and collaboration between various agencies and jurisdictions (i.e., transportation network owners) in support of ICM, including the distribution of specific operational responsibilities and the sharing of control functions in a manner that transcends institutional boundaries.
- **Operational Integration** – Implementation of multi-agency transportation management strategies, often in real-time, that promote information sharing and coordinated operations across the various transportation networks in the corridor and facilitate management of the total capacity and demand of the corridor.
- **Technical Integration** – The means by which affected agencies share and distribute information, system operations, and control functions among networks and their respective transportation management systems, and the means by which affected agencies can immediately view and evaluate the impacts of operational decisions. Examples include communication links between agencies, system interfaces, and associated standards. This cannot be accomplished without institutional and operational integration.

THE INTEGRATED CORRIDOR MANAGEMENT RESEARCH INITIATIVE

USDOT started the formal ICM Research Initiative in 2006 to explore and develop ICM concepts and approaches and to advance the deployment of ICM systems throughout the country. Initially, eight pioneer sites were selected to develop concepts of operations (ConOps) and system requirements for ICM on a congested corridor in their region. Three of these sites went on to conduct analysis, modeling, and simulation (AMS) of potential ICM response strategies on their corridor. In the final stage, two sites – the US-75 Corridor in Dallas, Texas, and the Interstate 15 (I-15) corridor in San Diego, California – were selected to design, deploy, and demonstrate their ICM systems.

The Dallas and San Diego demonstrations "went live" in the spring of 2013. Each demonstration has two phases: 1) design and deployment and 2) operations and maintenance. Both sites chose to develop a decision support system (DSS) as a technical tool to facilitate the application of institutional agreements and operational approaches that corridor stakeholders agreed to over a rigorous planning and design process.

In 2015, 13 other regional corridors were awarded grants to develop pre-implementation ICM foundations. Although the demonstration sites provide valuable insights into the necessary components of building an ICM system, they do not represent the *only* way to implement ICM. There is no "one-size-fits-all" approach to ICM, since the circumstances of a particular corridor will vary based on traffic patterns, agency dynamics, available assets, and a host of other factors. Thus, the FHWA is committed to raising awareness for ICM through their knowledge and technology transfer program, which advances the implementation and integration of ICM with other concepts.

PURPOSE OF THE PRIMER

Previously published ICM primers, including on traffic incident management (TIM) and transit operations, described how specific modal programs or activities could be integrated into ICM to provide additional operations and performance benefits to the ICM corridor. But because smart cities and ICM are so fundamentally similar in terms of their requirements and objectives, this primer will focus more on the opportunities for co-deployment synergies and how approaches and lessons learned from one can be translated to the other. For example, a community lacking a smart cities program but interested in developing one could start by implementing ICM on a particular corridor. The institutional relationships, operational processes, and technical methods developed as part of the successful ICM deployment could then be extended across different regions and across different public service areas as part of a broader smart cities program.

Who are smart city-philosophy stakeholders?

- Transportation (streets, transit, ports, bicycle).
- Water/wastewater utilities.
- Energy (electric and gas) utilities.
- City buildings/ facilities management.
- Public services (health services, waste management).
- Safety & security (fire and police).
- Parking providers (public and private).
- Private industry.
- End users: Private citizens; freight delivery services; taxi / car share services.

In many ways, a typical ICM corridor can be viewed as a "mini-city," albeit only in the transportation realm, with its mix of transportation-specific users, operators, and stakeholders, each with varying needs and objectives, and a unified need for cross-modal and cross-jurisdictional coordination in order to deliver the transportation services required by its users. Both ICM and the smart cities philosophies share the same challenges inherent in coordinating among various stakeholders. This primer examines the opportunities and challenges (institutional, technical, and operational) associated with integrating smart cities stakeholder groups and operations areas with ICM.

This primer also identifies many of the synergies (i.e., two-way benefits) of an integrated approach to ICM and smart cities. Such synergies include the exchange of information on planned and unplanned events (city wide vs. corridor-specific); coordinated response to events and incidents; better, data-driven decision making; and a broader measurement of system performance.

HOW DOES A "SMART CITY" OPERATE?

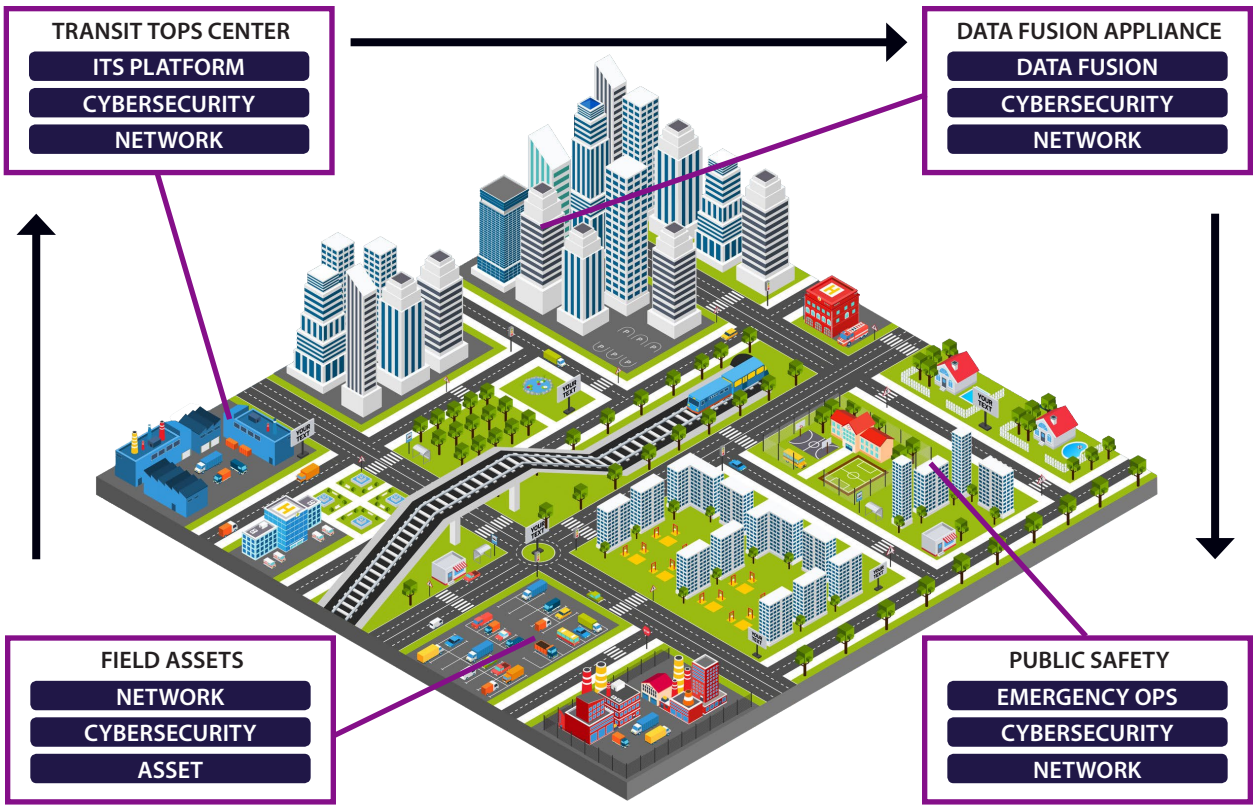
As the concept of smart cities began to take shape, it quickly focused on a few common themes seen in exemplary cities around the world. One of the most common was that the city became a "system of interconnected systems." The operational components of a city all work together to deliver the services its businesses and citizens require and expect. The main issue, of course, is how to make these systems work more efficiently. The simple answer is to integrate individual systems into a system of systems that can better share limited resources and data. For example, a city's assets may include local departments' information systems and the schools, libraries, transportation systems, hospitals, power plants, water supply networks, waste management, law enforcement, and other community services. Citizens now expect direct information on those services (e.g., trash pickup schedules, school status, hospital waiting times, bus schedules, etc.) from the convenience of their home computer or smartphone without having to contact or make a physical visit to a city facility for that information. That in turn makes city workers more productive and efficient, improving city processes. Information and communications technologies (ICT) also enable improved internal departmental efficiency via data manipulation and communication amongst different departments, the mayor's office, public utilities, and public safety agencies. In short, the goal of building a smart city is to improve quality of life for the citizens and to improve efficiency of government by using technology to better serve the public.

A fundamental aspect vital to the success of a smart city is ICT. Since the early 2000s, the advent of "big data" and improved communications due to smart phone applications and social media have allowed ICT to power smart cities and simultaneously make integrated corridor management (ICM) viable. "Big data" is associated with the ever-growing capability to collect huge amounts of data and then use that data to conduct research, analyze, and then disseminate information and services to the public (e.g., interactive communication with public agencies, and real-time updates of project and service status, etc.). The smart phone revolution has enabled the use of powerful applications and social media to make this real-time information available practically instantaneously and with increasing transparency. In layman's terms, both a smart city and an ICM process give users real-time information that allows them to make informed decisions and take decisive actions.

However, in many cities the integration of systems and ICT is often complicated by "silos," or vertical lines of business within the city that are not easily compatible or able to communicate with other silos and are typically surrounded by a virtual "wall" of opacity. This virtual wall can be characterized by institutional constraints, incompatible technologies, managerial parochialisms, or a combination of some or all of these factors. Building smart cities often requires breaking down these silos within cities and integrating people, systems, and processes, thus enabling data-driven decision making and improved efficiency.

Any number of smart cities proponents, from technology firms to market researchers to urban planners, have offered various definitions of smart cities and ways to depict a common platform or framework for real-time data sharing and operational governance within cities and communities. Figure 1 presents one such high-level integration platform that depicts how common elements across multiple agencies, such as networking and security, can be shared. This graphic represents only one of many possible frameworks for a smart city – it is an example, but not a recommended solution for every situation.

Integrating component systems—transportation, healthcare, utilities, education, public services, and buildings—will require cross-cutting services such as networks, cyber-security systems, weather intelligence, data sharing, and resource and performance monitoring to fully support integrated city management and citizen services.



Source: Leidos

Figure 1. Illustration. A shared services platform for smart cities can scale to integrate multiple agencies and devices.

U.S. DEPARTMENT OF TRANSPORTATION INITIATIVES

The approach taken by the U.S. Department of Transportation (USDOT) to improve the delivery and operational efficiency of the Nation's transportation system is embodied in its "Beyond Traffic 2045" framework. In the words of USDOT: "Beyond Traffic is an invitation to the American public—including the users, developers, owners, and operators of the transportation network and the policy officials who shape it—to have a frank conversation about the shape, size, and condition of that system and how it will meet the needs and goals of our nation for decades to come."[2] Beyond Traffic promotes five questions:

- How will we move (to build a better transportation network to serve the future)?
- How will we move freight (to meet increasing freight volumes vs. delay challenges)?
- How will we move better (to employ new technology, automation and travel information)?
- How will we adapt (to climate change and infrastructure deterioration)?
- How will we align decisions and dollars (to meet ever-declining revenue sources vs. construction costs)?

As part of the Beyond Traffic framework, the USDOT has initiated the "Smart City Challenge" which will award one city in 2016 with a substantial grant ($40 million in government funds plus contributions from the private sector) to implement smart cities technologies. In June 2016, the USDOT announced the winner of the Smart City Challenge, announcing that:

The USDOT Smart City Challenge

https://www.transportation.gov/smartcity

> "Columbus was selected as the winner because it put forward an impressive, holistic vision for how technology can help all of the city's residents to move more easily and to access opportunity. The city proposed to deploy three electric self-driving shuttles to link a new bus rapid transit center to a retail district, connecting more residents to jobs. Columbus also plans to use data analytics to improve health care access in a neighborhood that currently has an infant mortality rate four times that of the national average, allowing them to provide improved transportation options to those most in need of prenatal care."[3]

2 U.S. Department of Transportation, "Beyond Traffic: USDOT's 30 Year Framework for the Future" Web page. Available at: https://www.transportation.gov/BeyondTraffic.

3 U.S. Department of Transportation, "U.S. Department of Transportation Announces Columbus as Winner of Unprecedented $40 Million Smart City Challenge," DOT 73-16, June 23, 2016. Available at: https://www.transportation.gov/briefing-room/us-department-transportation-announces-columbus-winner-unprecedented-40-million-smart.

The size of the USDOT Smart City Challenge grant is one of the largest initiatives for smart cities deployment in North America. This approach recognizes the importance of the transportation system in facilitating and enabling many solutions to urban challenges.

OTHER EXAMPLES OF SMART CITIES INITIATIVES

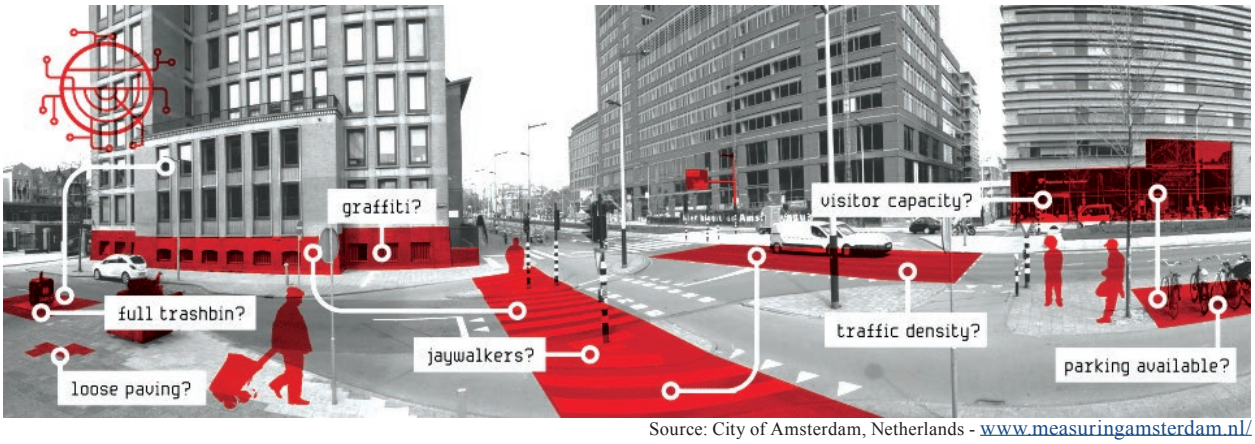
Several cities and communities around the world[4] have already begun the move to endorse smart cities concepts. In most cases, the initiatives have involved a much smaller level of investment than that intended for the USDOT challenge. In some cases, cities have undertaken pilot projects in one or more domains to show a proof of concept. Some cities have implemented a multi-year program to deploy inter-related projects and technologies so that each deployment builds upon a common framework, delivering synergistic benefits. Table 1 presents a partial list of cities that have been recognized as leaders in smart cities initiatives:

Table 1. Examples of smart cities and associated applications.

	Parking	Traffic Management	Transit Initiatives	Maintenance of Public Areas	Noise & Air Pollution	Energy Management	Street Lighting	Crime Analytics
San Francisco, CA, USA	✓		✓					
Santa Cruz, CA, USA								✓
San Diego, CA, USA		✓	✓					
Dallas, TX, USA	✓	✓	✓					
Barcelona, Spain	✓	✓	✓	✓			✓	
Santander, Spain		✓			✓			
Stockholm, Sweden		✓				✓		
Amsterdam, Netherlands	✓	✓	✓		✓	✓	✓	

4 There are many smart cities initiatives around the world that are being promoted or supported by governmental and non-governmental organizations (NGOs). See the Appendix for a list including Web site addresses.

The City of Amsterdam, Netherlands, has been implementing smart cities initiatives for many years. Figure 2 illustrates an important cross-cutting element of the city's initiative, "Measuring Amsterdam." Measuring Amsterdam provides a method for participatory open data collection that occurs periodically through a web application. Inputs are accepted regarding all of Amsterdam's infrastructure, environment, and services. The city publishes the collected data as open data, allowing developers to create visualizations or applications to provide new insights.



Source: City of Amsterdam, Netherlands - www.measuringamsterdam.nl/

Figure 2. Illustration. Measuring Amsterdam seeks citizen input on all aspects of the city's infrastructure, environment and services.

INTEGRATION: INSTITUTIONAL, OPERATIONAL, AND TECHNICAL

INSTITUTIONAL INTEGRATION

As mentioned earlier, almost all major urban areas are made up of a multitude of public agencies and governmental jurisdictions. The need for institutional integration is driven primarily by a set of common goals shared by many stakeholders.

Stakeholder Goals and Objectives

Each stakeholder group brings its own set of goals and mission objectives. Where it can be shown that many of these goals are shared across multiple stakeholders, there is a real opportunity to foster greater institutional integration. Some goals that are typically common across stakeholders in both ICM and smart cities include:

- Sustainable, reliable, safe, and efficient transportation and mobility services that are integrated across all modes all providers and which are ubiquitous throughout the urban area.
- Greater efficiency in providing citizen services, including new approaches to regulation, public safety initiatives, trash/snow removal, and health and human services.
- Improved quality of life for area residents through decreased pollution and more options for reliable mobility and sustainable lifestyles.
- Improved local/regional economic viability and competitiveness through improved transportation, citizen services, and quality of life.

Often, these shared goals are interconnected and complementary, building off of one another to advance local/regional operations.

Benefits of Institutional Integration

Shared goals should generate benefits to mutual stakeholders. Ideally, this is a two-way street. Figure 3 shows the sets of benefits from both integrated corridor management (ICM) and smart cities and where they may overlap. The following describes some of the benefits that are typically associated with ICM deployments, but which also may be accrued by smart cities deployments:

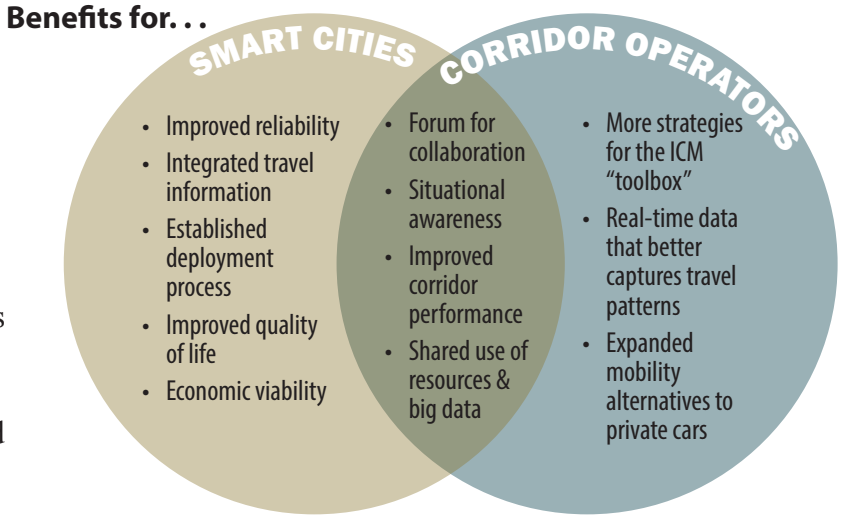


Figure 3. Diagram. Benefits of integrating smart cities and integrated corridor management.

- Improved reliability and resiliency of the transportation system, which supports key smart cities goals of economic improvements, efficient city services delivery, and increased quality of life.
- Enhanced data sharing and institutional cooperation (e.g., sharing of information on travel, weather, events), which supports smart cities goals of providing smarter city services.

Conversely, the following describes some of the benefits that are typically associated with smart cities deployments, but which also may be accrued by ICM deployments:

- Improved coordination with emergency responders, city utilities, etc. result from integrating more strategies into the ICM "toolbox."
- Clarified view of corridor or regional travel patterns provided by real-time data when that information is combined with additional data sources from related city services.
- Expanded mobility alternatives to private cars enables better coordination of shared ride services with changing corridor demand.

Opportunities for Institutional Integration

The special case for this primer is that ICM can inform and serve as the genesis of wider smart cities deployments. One example is simply building upon the success of a single ICM deployment in a single corridor to more corridors within the same urban area. Soon, as more ICM corridors overlap, the travel shed of multiple corridors will include the majority of travelers within the metropolitan area. In this case, the ICM becomes an "integrated network management" program, supporting integrated mobility options throughout the smart cities environment.

The potential for mutual benefits really drives opportunities for institutional integration. Whenever two or more agencies can save money, improve operations, or increase efficiency, there is motivation to overcome the inherent challenges of integration. Shared data offers some of the greatest promise, because it touches all city and ICM systems. Access to data and information via a common platform enables all manner of efficiencies. Big data analytics provide the most benefit when applied across multiple agencies' datasets. Efficiency increases where there is a centralized location to get information. Data-driven decision making is more effective with a holistic view and shared situational awareness.

Another opportunity for ICM to help with the deployment of smart cities projects is via the use of a structured systems engineering process. Smart cities deployments are only now beginning to be able to prove the value of standards and interoperability. The systems architecture and systems engineering processes developed for transportation technology over the last 20 years, and more recently for ICM, provides a roadmap for smart cities to follow. The emerging connected and automated vehicle technology program is also developing complementary reference architecture and related standards. These will serve as powerful opportunities that can be applied to many smart cities elements.

Challenges to Institutional Integration

Institutional issues have long been raised as one of the main obstacles for many programs that require the active participation (planning, funding, operations, and maintenance) of any system across multiple jurisdictions. Some specific challenges include:

- Lack of leadership or a champion with sufficient standing and authority in the organization to get things done.
- Absence of a coordinated vision across departments about issues such as open data requirements and interoperability standards.
- Laws that preclude some cities/agencies from legally entering into new contractual relationships (such as public private partnerships (P3)) or present difficulties in reforming procurement laws to attract innovation and new partnerships.
- Regulations (e.g., many cities are struggling to address regulatory issues around ride hailing providers such as Uber and Lyft).
- Reluctance among private sector entities to fully engage in public-sector-led activities; this is exacerbated by a lack of understanding within the public sector of private sector business models.
- Silos in city organizational structures around disciplines such as lighting, parking, signals, and streets; new business models must be defined by the desired outcomes (e.g., safety, efficiency, livability), not just outputs.
- Budgets for one initiative are often limited to the initial agency-specific scope of work, so even if a coordinated effort between agencies or departments could save the city significant money in the long run, the initiating agency often prefers to move forward in the context of its own limited scope.

OPERATIONAL INTEGRATION

Integrated Corridor Management Initiatives that can Inform Smart Cities Initiatives

Existing ICM initiatives have the opportunity to inform and provide lessons learned for emerging smart cities initiatives.

For example, ICM parking programs can support smart parking programs, especially those at transit park-and-ride facilities, by indicating real-time availability of parking spaces via online and other publicly accessible communications. This guidance serves to reduce congestion from drivers searching for a space and to increase transit mode-share.

Electric vehicle charging and sharing programs, especially those at transit park-and-ride facilities, can utilize ICM advances in providing real-time availability and usage statistics via online and other publicly accessible communications. In the future, this technology can also assist smart grids with the decision support necessary to serve special events and locations/time periods with recurring high demand for energy consumption as electric vehicle use grows.

Bike share programs can take advantage of ICM experience in the management and communication of options for last-mile solutions for transit. ICM decision support tools that coordinate supply and demand along a corridor could be adapted to manage existing supply and demand issues among bike share stations, especially for those at transit park-and-ride facilities.

Smart cities initiatives can adopt or use ICM initiatives in coordinated traffic management as a foundation for more advanced smart traffic management systems. Smart traffic management systems can learn from ICM experience, enabling better special event traffic management, incident response, resilience to catastrophes, and delivery of city services (e.g., waste management, snow plowing, coordinated emergency response).

Challenges to Operational Integration

As is often the case in technology deployments, considerations for operations and maintenance (O&M) receive relatively little attention. One approach to dealing with this challenge is the adoption of AASHTO's Capability Maturity Model (CMM) for Transportation Systems Management and Operation (TSMO). The CMM approach can be extended beyond the transportation realm and into the management of many city systems, including utilities and facilities management.

Limited funding for public projects of all types is a constant challenge for cities. This also makes it difficult to compare the relative benefits and priorities of transportation and smart cities initiatives. As planners look at ICM and smart cities projects, how do they compare economic impacts and societal benefits that will come from a smart grid project versus those resulting from a smart mobility project, for example? This challenge is best dealt with by the regional MPO, whose responsibility (under most regional governance models) and core competency is to balance priorities among all metro area transportation agencies (and often other government agencies). The MPO is also well suited for dealing with other city agencies and their corresponding governance panels and commissions.

Limited familiarity with cross-disciplinary issues and opportunities among agencies is also a significant challenge. The silos mentioned above are rarely intentionally created, but are typically due to a simple lack of understanding of each agency's challenges and the potential benefits of closer coordination and integration.

Finally, as cities look more and more to the private sector to help share the expense of operating many city systems, there is the challenge of incentivizing private sector participation in public sector-led initiatives. Privatized operation of public facilities can be challenging, but with the right mix of performance-based incentives and minimum service level agreements, this approach can be valuable for both ICM and smart cities programs.

TECHNICAL INTEGRATION

Once ICM and/or smart cities stakeholders are engaged and operational integration opportunities are identified, the systems engineering process can begin. Starting with a concept of operations (ConOps), system requirements and architecture, the details of design and implementation will define the technical integration of ICM and smart cities elements.

Opportunities for Technical Integration

Early in the systems engineering process, high level questions, such as "what is my vision?" and "what outcome do I expect?" help define the ConOps. Each stakeholder should then ask "what can I do with what I have and what do I need from one or more other stakeholders?" This conversation will help define potential data sources, existing or future, that will be necessary for a successful system. There are many possible data sources within an ICM corridor that will be valuable to related smart cities systems, including travel demand patterns, incident history, special events, etc.

In addition to data needs, there are resource needs. For example, the location and capacity of emergency responders is typically a resource that is evaluated for ICM incident response planning. These resources are also available to support other incidents, such as severe weather events and other natural disasters. There is also opportunity to share other resources, such as communications, sensors, etc. that can support both smart cities and ICM functions. For a typical ICM deployment, the technical infrastructure (communications networks for center to field and center to center connections) and the physical resources (emergency responder vehicles, maintenance equipment, etc.) needed to detect and monitor incidents and coordinate responses, requires extensive coordination between all stakeholders. This ICM coordination helps to create a more mature capability model within all affected agencies. This capability is reusable for smart cities deployments and provides multiple opportunities for mutual benefits to all stakeholders.

Challenges to Technical Integration

One of the most significant challenges facing smart cities initiatives is the lack of standards, protocols, and architectures for systems that have not previously been required to integrate or share data. The well-established approach used to develop standards and architectures for intelligent transportation systems (ITS) and programs such as ICM can be used as a model for smart cities. There are many benefits for establishing such standards, making it possible to share information across all city systems. Other ways to address the challenge of disparate data formats include the use of open data standards, big data, and data analytics technologies. These open data approaches actually reduce the need for complex integration between agency systems. With a common platform that enables secure and ubiquitous data sharing, city agencies can subscribe to data they need—with the applications they already have—to support more efficient operations.

CONCLUSION

Integrated corridor management (ICM) is a practical and logical evolutionary step in transportation operations. As congestion continues to grow and agencies' ability to expand the roadway network is limited by both space and resources, ICM provides operators with a tool to maximize the person-throughput of existing roadway infrastructure through active management of all assets along a corridor. It is this "active management" aspect that offers lessons to smart cities deployments.

Successful ICM deployments in Dallas and San Diego have shown that, in order to achieve the level of real-time, or even pro-active, transportation systems management necessary to optimize corridor operations and maximize the benefits of ICM, there is a need for both a shared vision and a shared view of the corridor between all stakeholders. The institutional issues addressed by ICM stakeholders are the same as those that smart cities planners will have to address.

The lessons learned by ICM deployment teams may be readily shared with smart cities implementers. For example, where there are shared goals between agencies, there are opportunities for shared benefits. Common goals for both ICM and smart cities implementations include safe, reliable, efficient transportation; greater efficiencies for the delivery of city services; and improved quality of life, including both economic vitality and a cleaner environment.

There are many opportunities for operational integration between ICM and smart cities operators. Smart cities initiatives can adopt or mimic ICM initiatives, such as coordinated traffic management and incident response. City-wide, smart traffic management systems can leverage the ICM experience, enabling better special event traffic management and proactive response to severe weather and natural disasters. This capability provides better system reliability and resilience, both of which are common goals for ICM and smart cities initiatives.

ICM deployments have been able to leverage existing and emerging technologies to meet project goals and objectives. This experience provides multiple examples and opportunities for smart cities initiative. Open data standards, big data, and data analytics technologies offer solutions to many technical challenges. ICM initiatives have been able to use these approaches to integrate and fuse real-time data from multiple sources, and disseminate information for use by multiple applications, including decision support systems and traveler information apps. Both ICM and smart cities initiatives benefit from a common platform that enables sharing data securely and ubiquitously across multiple city agencies to support more efficient operations.

APPENDIX
SMART CITIES RESOURCES – GOVERNMENTAL AND NON-GOVERNEMENT ORGANIZATIONS (NGOS)

Resource	Web Address
USDOT Beyond Traffic: Smart Connected Cities Program	www.transportation.gov/smartcity
Smart Cities Council	www.smartcitiescouncil.com
Smart Cities Association	www.smartcitiesassociation.org
European Innovation Partnership for Smart Cities & Communities	www.eu-smartcities.eu/
Smart City Advisory Group (Europe)	www.iurban-project.eu/the-consortium/smart-city-advisory-group.html
Russia The Smart City Project	http://en.isrussia.ru/visitors/events/bussines/smartcity/
India Smart Cities Challenge	www.smartcitieschallenge.in/
China Smart City (UK-China partnership	www.uk-chinasmartcities.com/
Meeting of the Minds	www.cityminded.org
IEEE Smart Cities Technical Community	http://smartcities.ieee.org
American Planning Association Smart Cities and Sustainability Task Force	www.planning.org/sustainingplaces/smartcities/
Global Smart City & Community Coalition (GSC3)	www.gsc3.city/news
National Science Foundation Smart & Connected Communities	www.nsf.gov/news/news_summ.jsp?cntn_id=136253

U.S. Department of Transportation
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U.S. Department of Transportation
Federal Highway Administration
Office of Operations
1200 New Jersey Avenue, SE
Washington, DC 20590
Toll-Free "Help Line" 866-367-7487
www.ops.fhwa.dot.gov

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