Planning and Implementing Multimodal, Integrated Corridor Management: Guidebook

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Contractor’s Guidebook for NCHRP Project 03-131
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Systematic, well-designed, and implementable research is the most effective way to solve many problems facing state departments of transportation (DOTs) administrators and engineers. Often, highway problems are of local or regional interest and can best be studied by state DOTs individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation results in increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

Recognizing this need, the leadership of the American Association of State Highway and Transportation Officials (AASHTO) in 1962 initiated an objective national highway research program using modern scientific techniques—the National Cooperative Highway Research Program (NCHRP). NCHRP is supported on a continuing basis by funds from participating member states of AASHTO and receives the full cooperation and support of the Federal Highway Administration (FHWA), United States Department of Transportation, under Agreement No. 693JJ31950003.

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<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
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<td>ADA</td>
<td>Americans with Disabilities Act</td>
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<tr>
<td>AMS</td>
<td>Analysis, Modeling, and Simulation</td>
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<tr>
<td>ATCMTD</td>
<td>Advanced Transportation and Congestion Management Technologies Deployment</td>
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<tr>
<td>ATIS</td>
<td>Advanced Traveler Information System</td>
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<td>ATMS</td>
<td>Advanced Transportation Management System</td>
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<td>AVL</td>
<td>Automatic Vehicle Location</td>
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<td>AWIS</td>
<td>Automated Work Zone Information System</td>
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<td>BoM</td>
<td>Bill of Materials</td>
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<td>BRT</td>
<td>Bus Rapid Transit</td>
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<td>BUILD</td>
<td>Infrastructure for Rebuilding America</td>
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<td>C2C</td>
<td>Center-to-Center</td>
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<td>CAD</td>
<td>Computer Aided Dispatch</td>
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<td>CCTV</td>
<td>Closed-Circuit Television</td>
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<td>CMAQ</td>
<td>Congestion Mitigation and Air Quality (Program)</td>
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<td>CMM</td>
<td>Capability Maturity Model</td>
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<td>CMS</td>
<td>Changeable Message Sign</td>
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<td>CO</td>
<td>Carbon Monoxide</td>
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<td>ConOps</td>
<td>Concept of Operations</td>
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<td>DART</td>
<td>Dallas Area Rapid Transit</td>
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<td>DMS</td>
<td>Dynamic Message Sign</td>
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<td>DOT</td>
<td>Department of Transportation</td>
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<td>DSS</td>
<td>Decision Support System</td>
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<td>EV</td>
<td>Emergency Vehicle</td>
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<td>FDOT</td>
<td>Florida Department of Transportation</td>
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<td>FHWA</td>
<td>Federal Highway Administration</td>
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<td>FTA</td>
<td>Federal Transit Administration</td>
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<td>FTE</td>
<td>Full-Time Equivalent</td>
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<td>GIS</td>
<td>Geographic Information Systems</td>
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<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
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<td>HAZMAT</td>
<td>Hazardous Materials</td>
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<td>High-Occupancy Vehicle</td>
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<td>ICM</td>
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<td>ICT</td>
<td>Information and Communications Technologies</td>
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<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers</td>
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<td>IGA</td>
<td>Intergovernmental Agreement</td>
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<td>Intermodal Transportation Management System</td>
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<td>Internet of Things</td>
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<td>ITS</td>
<td>Intelligent Transportation System</td>
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<tr>
<td>KSA</td>
<td>Knowledge, Skills, and Abilities</td>
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<td>MaaS</td>
<td>Mobility-as-a-Service</td>
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<tr>
<td>MOU</td>
<td>Memorandum of Understanding</td>
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<td>MPO</td>
<td>Metropolitan Planning Organization</td>
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<td>NCHRP</td>
<td>National Cooperative Highway Research Program</td>
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<td>NOx</td>
<td>Nitrous Oxide</td>
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<td>NPS</td>
<td>Network Prediction System</td>
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<td>NTCIP</td>
<td>National Transportation Communications for Intelligent Transportation System Protocol</td>
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<td>O&amp;M</td>
<td>Operations and Maintenance</td>
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<td>PDR</td>
<td>Preliminary Design Review</td>
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<td>PIO</td>
<td>Public Information Officer</td>
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<td>Project Management Plan</td>
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<td>Requirements Traceability Matrix</td>
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<td>Transportation Research Board</td>
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<td>TSMO</td>
<td>Transportation Systems Management and Operations</td>
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<td>TSP</td>
<td>Transit Signal Priority</td>
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<td>TxDOT</td>
<td>Texas Department of Transportation</td>
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<td>USDOT</td>
<td>United States Department of Transportation</td>
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<td>VOC</td>
<td>Volatile Organic Compounds</td>
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<td>VSL</td>
<td>Variable Speed Limit</td>
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<td>XML</td>
<td>Extensible Markup Language</td>
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Chapter 1 - Getting Started: Using the Guidance Document

Introduction

Most jurisdictions have recognized the importance of managing their systems through interjurisdictional coordination with emergency responders, incident response, transit, mobility services, and maintenance and construction management as well as timely notification to the public. Many agencies use traffic operations strategies for the reduction of recurring and nonrecurring congestion. Many jurisdictions have implemented a variety of strategies for maximizing flow on facilities by using all available pavement, transportation services, and managing their facilities using new technologies and better operations techniques. However, actively integrating strategies such as transit rerouting, mobility-on-demand services, multimodal trip-making, arterial coordination, detour planning, and managing lanes in real-time requires planning and coordination among many stakeholders. Pulling this all together through integrated corridor management (ICM) is essential to successful transportation system management. Additionally, new challenges in staffing and funding are present due to the new institutional, technical, and operational integration required for ICM.

What is ICM?

Integrated corridor management (ICM) is an approach to improving transportation that considers all elements in a corridor, including highways, arterial roads, and transit systems. ICM takes an integrated, multimodal/multiagency approach to congestion management. ICM uses technology and operational strategies as tools for transportation operators to address recurring and nonrecurring congestion and optimizes performance of the transportation infrastructure. Rather than address the shortcomings of the separate roadways and modes in isolation, ICM treats the individual transportation components (highways and roads, transit, parking lots, bicycle and pedestrian trails, etc.) as elements of an interrelated transportation corridor. ICM also promotes interjurisdictional coordination and the use of a broad toolbox of transportation system management and operations (TSMO) strategies to optimally detect, monitor, and respond to events and changing conditions. General benefits include improved mobility, reliability, and safety, and reductions in fuel consumption and emissions.

By optimizing the use of existing infrastructure assets through coordinated transportation management techniques, transportation investments can go farther. There are many corridors in the country with underused capacity (in the form of arterials, freeway travel lanes, and parallel transit capacity – e.g., bus, rail, bus rapid transit, etc.) that could benefit from ICM. The maturation of intelligent transportation system (ITS) technologies, availability of supporting data, and emerging multiagency institutional frameworks make ICM practical and feasible. There are a significant number of freeways, arterial, and transit optimization strategies that are already in widespread use across the United States. Many of these strategies are managed locally by individual agencies, often independently. Even those managed regionally are sometimes managed in isolation (asset-by-asset), rather than in an integrated fashion across a transportation corridor.

Why consider ICM?

Currently, many agencies operate their transportation networks well, but do not consider the overall operation of a corridor or region to improve the throughput of travelers through the corridor. ICM focuses on the operational, institutional, and technical coordination of multiple transportation networks and cross-network connections comprising a corridor. Moreover, ICM can encompass several activities that address the concerns and needs of agencies in a region (e.g., integrated policy among stakeholders, communications
among network operators and stakeholders, improving the efficiency of cross-network junctions and interfaces, real-time traffic and transit monitoring, real-time information distribution, congestion management, incident management, public awareness programs, and transportation pricing and payment).

According to the United States Department of Transportation (USDOT), “The vision of Integrated Corridor Management (ICM) is that transportation networks will realize significant improvements in the efficient movement of people and goods through institutional collaboration and aggressive, proactive integration of existing infrastructure along major corridors. Through an ICM approach, transportation professionals manage the corridor as a multimodal system and make operational decisions for the benefit of the corridor.”

Who should use this Guidebook?

The intended audience of this document is public agency staff and consultants involved in planning, designing, implementing, operating, managing, and maintaining ICM systems to improve the operations of their transportation networks by using a multiagency, multimodal approach. This document should help readers to appreciate how ICM planning fits into the current planning process and learn key lessons from other metropolitan areas who have planned and, in some cases, implemented ICM systems. Readers are assumed to have a general awareness of ITS technologies and transportation management principles.

How should this Guidebook be used?

This guidebook provides an overview of current recommended practices and outlines critical components for the planning, design and development, and operations and maintenance of an ICM system. It was written and organized to describe the overarching planning process at the various systems engineering stages of a technology deployment project.

The study team collected the information in this report through literature searches on existing ICM research, deployments, planning grants, the tools used in the development of ICM in the transportation industry, and other resources for transportation agencies (e.g., the Federal Highway Administration [FHWA] ITS Program). The remaining chapters in this document are summarized in Table 1.

Table 1. Where to Find ICM Information in this Guidebook

<table>
<thead>
<tr>
<th>Desired Information</th>
<th>Guidebook Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Definition of ICM</td>
<td>Chapter 2 – Overview of ICM</td>
</tr>
<tr>
<td>• Overview of the approach in planning for ICM</td>
<td>Chapter 3 – Pre-Assessing ICM</td>
</tr>
<tr>
<td>• Assessment process to determine the utility of ICM to address the agency’s issues</td>
<td>Chapter 4 – Planning for ICM</td>
</tr>
<tr>
<td>• Planning process for ICM</td>
<td>Chapter 5 – Planning for the Technical Integration of ICM</td>
</tr>
<tr>
<td>• Understanding how ICM fits into the systems engineering process</td>
<td></td>
</tr>
<tr>
<td>• Process for developing the technical components of an ICM system</td>
<td></td>
</tr>
<tr>
<td>• The development processes to consider when developing an ICM system, including identifying system gaps</td>
<td></td>
</tr>
<tr>
<td>• Operational planning needed for ICM operations</td>
<td>Chapter 6 – Planning for Operations and Maintenance of ICM</td>
</tr>
<tr>
<td>• Understanding needs for ongoing funding for operations &amp; maintenance of the ICM program</td>
<td></td>
</tr>
</tbody>
</table>
How was this Guidebook developed?

The information and recommendations presented within this guidebook were developed through the National Cooperative Highway Research Program (NCHRP) Project No. 03-131. A literature review and stakeholder surveys and interviews were used to identify issues, needs, and best practices for ICM planning, development, deployment, and operations and maintenance.

Research Objectives

The objective of this research was to develop guidance for agencies planning and implementing multimodal, integrated corridor (or area) management, while featuring multiple real-world examples drawn from a variety of contexts and an appropriate range of agency capabilities. It endeavors to address the topic areas listed in Table 2, which also provides the Guidebook chapter that discusses each topic.

Table 2. Topic Areas and Corresponding Guidebook Chapters

<table>
<thead>
<tr>
<th>#</th>
<th>Topic Areas</th>
<th>Guidebook Chapter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Defining the purpose and need of the integrated traffic management approach.</td>
<td>Chapter 2, Chapter 3</td>
</tr>
<tr>
<td>2</td>
<td>Demonstrating the value of the integrated approach to agency administrators and policy makers (including alignment with agency directions in a broader geographical area).</td>
<td>Chapter 2, Chapter 3</td>
</tr>
<tr>
<td>3</td>
<td>Identifying and engaging needed partner agencies and defining their respective roles.</td>
<td>Chapter 3</td>
</tr>
<tr>
<td>4</td>
<td>Deciding which scenarios will be cooperatively managed (e.g., crashes, special events, evacuation, adverse weather).</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>5</td>
<td>Determining viable strategies for managing traffic during those scenarios, including multimodal approaches.</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>6</td>
<td>Developing memoranda of understanding or other policies (internal and cross-agency) to support the traffic management system(s) and facilitate those strategies.</td>
<td>Chapter 4, Chapter 6</td>
</tr>
<tr>
<td>7</td>
<td>Setting performance metrics and targets.</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>8</td>
<td>Identifying data and information that should be shared between agencies and viable architectures for the sharing.</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>9</td>
<td>Inventorying the ICM infrastructure (e.g., traffic management field and central elements, communications, software) and identifying needed improvements.</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>10</td>
<td>Developing an appropriate staffing model, including hiring, training, and outsourcing.</td>
<td>Chapter 6</td>
</tr>
<tr>
<td>11</td>
<td>Developing a plan for ICM maintenance, sustainability, and continuous improvement.</td>
<td>Chapter 6</td>
</tr>
<tr>
<td>#</td>
<td>Topic Areas</td>
<td>Guidebook Chapter</td>
</tr>
<tr>
<td>----</td>
<td>------------------------------------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>12</td>
<td>Identifying decision support tools, ranging from simple heuristics to complex approaches with embedded simulation models (the typical daily operation should be included as an option).</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>13</td>
<td>Identifying ways to report the performance of the traffic management system(s) (e.g., dashboards) and measure (or estimate) the benefits of the actions taken.</td>
<td>Chapter 4, Chapter 6</td>
</tr>
<tr>
<td>14</td>
<td>Developing and implementing a deployment plan for the traffic management system(s).</td>
<td>Chapter 4, Chapter 5</td>
</tr>
</tbody>
</table>
Overview

Along many congested urban transportation corridors, transportation agencies (e.g., state and local departments of transportation, bus operators, light rail operators, etc.) manage operations independently. Recurring and nonrecurring congestion across any component of the transportation system can have widespread congestion consequences across the corridor and its users. Agencies recognize that non-coordinated operations of corridor assets are inefficient for managing events and optimizing travel throughput.

ICM is an operational concept that seeks to reduce congestion and improve performance by maximizing the use of available multimodal capacity across a corridor, including highways, arterial roads, and transit systems. ICM promotes cooperative and collaborative traffic management across the agencies that manage various transportation system components (i.e., freeways, arterials, signals, transit, parking systems, tollways, etc.) in a congested corridor. The purpose of this chapter is to introduce the concept of ICM and provide a case for the benefits of implementing ICM in transportation planning.

Although it is common to think about ICM as a system or solution, ICM is first and foremost an operational philosophy, aiming to increase agencies’ coordination and collaboration. This section provides deeper insight into operational philosophy and then describes what is more commonly referred to as ICM systems.

ICM Operational Philosophy

The term “Integrated” in ICM refers to the institutional, operational, and technical integration (as described in Table 3) of key agencies that manage corridor assets. Creating an environment of collaborative and cooperative traffic management requires that agencies be willing to break down silos and barriers that have historically kept agency operations isolated.

Table 3. Levels of Integration

<table>
<thead>
<tr>
<th></th>
<th>Definition</th>
<th>No Integration</th>
<th>Ideal Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutional</td>
<td>Coordination and collaboration between various agencies and jurisdictions that transcend institutional boundaries</td>
<td>Agencies have no working agreements and do not share funding</td>
<td>Interagency agreements and cooperatively funding deployment and operations</td>
</tr>
<tr>
<td>Operational</td>
<td>Multiagency and cross-network operational strategies to manage the total capacity and demand of the corridor</td>
<td>Agencies operate their networks independently</td>
<td>Centralized operations with cooperative management across agencies. System resources managed in real-time based on corridor needs</td>
</tr>
<tr>
<td>Technical</td>
<td>Sharing and distribution of information and system operations and control functions to support the</td>
<td>Siloed software applications and field infrastructure managing</td>
<td>Tightly coupled systems with multimodal and multisource fused data and event response</td>
</tr>
</tbody>
</table>

5
<table>
<thead>
<tr>
<th>Definition</th>
<th>No Integration</th>
<th>Ideal Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>immediate analysis of</td>
<td>specific segments of the</td>
<td></td>
</tr>
<tr>
<td>and response to events</td>
<td>network</td>
<td></td>
</tr>
<tr>
<td>within a corridor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 and Figure 1 present examples and requirements for cross-agency integration adopted from the NCHRP Project 20-68A U.S. Domestic Scan Program Scan 12-02 Advances in Strategies for Implementing Integrated Corridor Management (ICM) final report. These are the key attributes that jurisdictions will need to implement a successful ICM program.
Institutional Integration

- Established institutional partnership among operating agencies
- Agreements/memorandums of understanding/policies focused on joint operations and information sharing
- Identified funding of initial and sustained operations
- Identified champion
- Executive buy-in and commitment
- Documented organizational structure
- Defined roles and responsibilities
- Involvement of all modes and stakeholders in the corridor
- External and internal marketing, outreach, and education

Technical Integration

- ITS infrastructure and technological integration
- ITS infrastructure (existing or funding for new), to include field infrastructure for monitoring, information dissemination, and operations center systems (i.e., traffic management, traffic signal control, and transit management systems)
- Analytics/performance measures were available for analytics, modeling, travel information, and decision support systems
- Traveler information dissemination, including 511 systems, roadside devices, and feeds to the media
- ITS standards for easier integration of systems (e.g., regional ITS architecture, center-to-center, National Transportation Communications for ITS Protocol, and Traffic Management Data Dictionary)
- A common linear reference system to integrate multiple sources of data
- Various levels of a decision support system (i.e., a basic response plan book to full performance-based model used to generate responses)

Operational Integration

- Cooperative operational mindset among agencies
- An interagency concept of operations defined and supported by all agencies
- Interagency data and information sharing
- Integrated transportation management center operations (multiagency/multimode)
- Traffic incident management program/collaboration
- Traffic signal coordination, data integration, and emergency notification

Figure 1. Levels of Integration
Background on Planning for ICM

The “V-Diagram” Systems Engineering Process

The “V-Diagram” Systems Engineering Process shown in Figure 2 has been used in the last 20 years to guide the planning, design, and deployment of all types of ITS including the early stages of ICM. In this framework, there are five phases. The first, the Planning and Concept Phase, includes Needs Assessment, Concept Selection, Project Planning, Systems Engineering Management Planning, and development of the Concept of Operations.

![V-Diagram Systems Engineering Process](Source: FHWA ICM Implementation Guide)

**Figure 2. “V-Diagram” Guidance Approach**

ICM Planning and Deployment Framework

More recently, the FHWA *Integrated Corridor Management: Implementation Guide and Lessons Learned* report tailors the traditional systems engineering process using experiences documented from the ICM Pioneer Sites to create a seven phase ICM Implementation Process, as shown in Figure 3. The ICM Implementation Process is generally representative of the systems engineering process followed by the ICM Pioneer Sites.
Figure 3. Integrated Corridor Management Implementation Process Phases

Table 4. ICM Implementation Process Activities for the Planning and Concept Phase

<table>
<thead>
<tr>
<th>Systems Engineering V-Diagram Phase</th>
<th>ICM Implementation Process Phase</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needs Assessment</td>
<td>1. Get Started</td>
<td>Foster champions and organize stakeholders</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coordinate with planning process</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interface with the regional ITS architecture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Develop and approve project charter</td>
</tr>
<tr>
<td>Concept Selection</td>
<td>2. Establish Goals</td>
<td>Explore the ICM Concept</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Develop goals, measurable objectives, and data collection needs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Analyze system problems and identify system (user) needs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conduct Feasibility Assessment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Identify development support resources</td>
</tr>
<tr>
<td>Project Planning</td>
<td>3. Plan for Success</td>
<td>Assess project management activities</td>
</tr>
<tr>
<td></td>
<td>3.1 Project Management Plan (PMP)</td>
<td>Determine roles and responsibilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Initial procurement discussions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prepare Project Management Plan and supporting plans (as needed)</td>
</tr>
<tr>
<td>Systems Engineering V-Diagram Phase</td>
<td>ICM Implementation Process Phase</td>
<td>Activities</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>---------------------------------</td>
<td>------------</td>
</tr>
</tbody>
</table>
| Systems Engineering Management Planning | 3.2 Systems Engineering Management Plan (SEMP) | Assess project management activities and technical tasks  
Transition critical technologies  
Define needed systems engineering processes and resources  
Make procurement decisions and specify integration activities  
Prepare SEMP |
| Concept of Operations | 3.3 Concept of Operations (ConOps) | Define/refine project vision, goals, and objectives  
Explore project concepts  
Develop Operational Scenarios  
Develop and document Project Concept of Operations  
Define system boundaries |
| 3.4 Analysis Plan | Research analysis needs of the ICM alternatives and develop a sound analysis approach based on the operational conditions and the planned objectives of the ICM strategies  
Conduct analysis, modeling, and simulation iteratively to assess the feasibility of the proposed ICM strategies  
Identify the most promising strategies  
Identify the operational conditions under which the ICMS would be most effective |
| 3.5 Stakeholders | Identify stakeholders  
Identify roles and responsibilities  
Research and identify stakeholder agreements |

Additional guidance was added to the planning and concept phase of this ICM Guide regarding crosscutting activities such as stakeholder engagement, stakeholder agreements, asset management, and staffing and governance models, including:

- Specific stakeholder constraints, interests, priorities, preferences, and capabilities in the contexts of: (1) coordination of planning and operations activities with other agencies; (2) sharing of resources and data with partners (including available and desired data); and (3) adjusting operations when corridor conditions warrant it.
- The agencies and organizations they currently collaborate with or are seeking to partner with, and the nature, structure, and motivation for those partnerships.
- Operational challenges and situations they currently encounter that could be addressed or mitigated through ICM strategies and/or improved interagency coordination.
- Performance metrics and benefit measures typically collected or tracked.
- Various types of agreements that can be used to institutionalize or formalize ICM and a discussion their strengths and weaknesses. It will include the typical stages of agreements, the areas that are covered, and how they can be defined and implemented. It will also discuss the emergence of the private sector and how agreements with private agencies can be structured.
- Identification of the process the agencies need to use to identify ICM infrastructure. That includes identifying the existing conditions, the stakeholders’ needs, and the gaps between the existing conditions and the needs. It will discuss project sequencing, identifying early winner projects, and logical antecedents for ICM strategies.
Identification of different staffing and governance models and the pros and cons of each. It will identify the knowledge, skills, and abilities (KSAs) needed to support ICM planning, implementation, and operations and maintenance. This will also include training courses tied to the KSAs and guidance for when to outsource.

Systems Engineering Management Plan

USDOT requires all ITS projects funded with highway trust funds to be based on a system engineering process (refer to Figure 2.). To comply with this requirement, the SEMP is generally developed early in the project process; it is not uncommon for the SEMP to be developed before or in parallel with the ConOps. The purpose of a SEMP is to document a system engineering process that all stakeholders agree upon, to facilitate a successful project implementation. The SEMP helps to improve control of the project and common terminology, expectations, and understanding of the work being performed from planning all the way through operations and maintenance. The SEMP also helps to inform stakeholders about key project milestones and what role they will play in the success of those milestones (e.g., performing tasks or reviewing task outputs). Additionally, the SEMP identifies decision gates for the project, which require agreement from all project stakeholders for the project to move forward.

The SEMP is a living document and should be updated as additional information is learned about the system and its environment. According to FHWA’s Integrated Corridor Management: Implementation Guide and Lessons Learned report¹, the major items that should be included in the SEMP include:

- **Task Identification** – Identify tasks that must be performed and the task completion criteria (Note: tasks may be included as a work breakdown structure [WBS] which organizes tasks into a hierarchical structure and manages tasks and subtasks by name, budget, team roles and responsibilities, etc.).
- **Technical Planning and Control Processes** – Establish the technical program planning and control processes included in technical reviews, walkthroughs, and decision gates.
- **Risk Management** – Introduce the risk management plan to initiate a formal process for stakeholders to manage project risks.
- **Engineering Program Integration** – Provide guidance on how the various engineering teams (communications, design, information technology, multimodal, etc.) will work together to support the project development.
- **Systems Engineering Process** – Provide details of the systems engineering process that will be used to define the ICMS including the specific methodologies to be used for the ConOps, architecture, requirements, design, and testing.
- **Specialty Engineering Plans and Procedures** – Determine which specialty plans (human factors, system safety, system security, etc.) and procedures will be needed for the project.
- **Configuration Management** – Provide the configuration management plan that will facilitate control of changes to the ICMS and its artifacts including the ConOps, architecture, requirements, and design iterations.
- **Performance Monitoring** – Initiate system performance monitoring processes to determine which improvements may be needed for ICMS and external systems. Schedule periodic performance reviews to assess future system needs and operational improvements.

The proposed SEMP outline according to IEEE 1362² contains the following sections:

• **Section 1, Purpose of Document**, provides a brief statement of the purpose of the document and the plan for the systems engineering activities with special emphasis on the engineering challenges of the ICM system to be built.

• **Section 2, Scope of Project**, describes the planned project and the purpose of the system to be built, with special emphasis on the project’s complexities and challenges that must be addressed by the systems engineering efforts and the environment in which the project will operate.

• **Section 3, Technical Planning and Control**, lays out the plan for the systems engineering activities. The set of activities/plans to be included in this section should cover the successful management of the project as well as any plans designed to address specific areas of the systems engineering activities.

• **Section 4, Systems Engineering Process**, describes the intended execution of the systems engineering processes used to develop the system (i.e., each step of the “V-diagram” life cycle technical development model) in enough detail to guide the work of the systems engineering and development teams.

• **Section 5, Transitioning Critical Technologies**, describes the methods and processes to be used to identify, evaluate, select, and incorporate critical technologies into the system design.

• **Section 6, Integration of the System**, describes the methods to be used to integrate the developed components into a functional system that meets the system requirements and is operationally supportable.

• **Section 7, Integration of the Systems Engineering Effort**, addresses the integration of the multi-disciplinary organizations or teams that will be performing the systems engineering activities.

ICM SEMPs that can be used for reference include the following:


Chapter 3 - Pre-Assessing Integrated Corridor Management

Overview

This chapter emphasizes the pre-planning, foundational activities that will set the stage for the ICM planning process. It offers a set of optional, up-front steps that practitioners can step through to (1) quickly determine whether ICM is potentially a reasonable solution to their circumstances, and (2) sketch out the general contours of a prospective ICM project. It allows for initial pre-assessment before extensive time and resources are invested in more comprehensive ICM planning.

Some practitioners will find the pre-assessment useful, while others may choose to proceed immediately with the planning process described in Chapters 4-6. Those who do perform the pre-assessment will, of course, be able to carry the findings forward into the subsequent planning activities.

Steps in the Pre-Assessment

The following steps – with corresponding details and questions – offer guidance on the suggested sequence and content of the ICM pre-planning activities. These steps and activities can be tailored to practitioners’ targeted circumstances, as appropriate. Skip over those activities that do not pertain to your situation. Cover only the detail necessary to arrive at an informed judgment about ICM in your corridor.

Step 1 – Broadly Identify the Project Corridor

- Begin by thinking about the roadways and transit systems that might possibly be included in the ICM project.
- Is there an interstate highway or highways that would be a common-sense focal point for the corridor?
- What are the major arterials that feed into and parallel the interstate route?
- Identify the predominant origin and destination points for travelers. For example, do commuters travel daily from suburbia to a downtown urban setting?
- What are the transit services that support the origin/destination travels? Where are the transit routes and key transfer points?
- Are there logical interrelationships among the interstate, arterial, and transit services identified above? Do the different components tend to work together systemically? Do some of the components appear to exist in a “symbiotic” relationship, that is, do conditions on one component typically impact circumstances on another? Can the individual components of the transportation network be thought about as an interdependent, integrated system?
- Using a map, sketch out these preliminary thoughts on the potential project corridor; this will serve as your “baseline corridor.” Do not worry at this juncture about being precise on the locations of the corridor boundaries.

Step 2 – ICM Reality Check: Determine Whether ICM is a Candidate Solution for the Corridor

The reality check will assist in determining the suitability of ICM as a potentially effective corridor management strategy.

- Begin characterizing the major issues or problems to be solved in the baseline corridor and consider whether ICM is a potential solution.
- Think about the ICM definition/concepts presented in Chapter 2 and ask whether those concepts are applicable here.
• Do the general characteristics of the baseline corridor broadly line up with the previously identified ICM concepts? For example, ICM strategies will not increase capacity in a corridor; however, ICM strategies, appropriately applied, may help to optimize performance in the corridor given capacity limitations.
• What are the dimensions of the problems in the corridor? Do these problems inhibit mobility in the corridor? Is congestion predominantly recurring, nonrecurring, or both? What conditions or factors might explain this congestion? From your understanding of the concepts presented in Chapter 2, are these conditions/factors potentially addressable through ICM?
• Are there pockets of underutilized capacity in the baseline corridor? For instance, is the interstate overloaded, but some arterial routes are underused? Is there underutilized capacity on the transit system or bus routes? Are commuter parking lots underused? The answers to these types of questions may suggest opportunities for “load balancing.”
• Are there opportunities for technical, operational, and institutional integration?
• Consider the institutional dimensions of the corridor: Is there likelihood for collaboration among the partner agencies in the corridor? Are these agencies open to working collaboratively and aggressively towards the common goal of an integrated, multimodal infrastructure?
• Regarding operational integration: Would it make sense to approach incident management in the corridor collaboratively? What would that look like? At a high level, how would it work?
• How will “success” in the corridor be measured?

Step 3 – Identify Regional Partners and Stakeholders

ICM depends on regional collaboration and cannot succeed if ongoing, sustainable collaboration is not established. Consequently, it is essential that the ability to cooperate and collaborate be achievable from the outset. “Stakeholders” generally refer to those entities not serving as regional partners who have an interest in the ICM activities and outcomes. Some corridor agencies choose to involve public agencies only in the planning process; others invite both public and private organizations to participate. It is not necessary to engage with stakeholders as part of this preliminary activity – however, it is helpful to start identifying them.

• Building on Steps 1 and 2, above, identify candidate ICM partners in the corridor. Those partners typically include the transportation agency/agencies responsible for operating the roadways in the corridor, the principal transit agencies operating in the corridor, the metropolitan planning organization (MPO), etc.
• Sketch out some of the high-level roles that the candidate partners might potentially perform on the prospective ICM project.
• Consider approaching the candidate partners, explaining the early concepts and preliminary ideas, and inviting their inputs and insights. Provide opportunities for them to engage in the planning process and to assume co-ownership for the potential ICM initiative. Begin thinking about which partner would best make sense as the lead agency for the ICM initiative.
• Seek out and identify one or more regional “Champions” to spearhead ICM project planning and deployment. The Champion(s) will advocate for the project (both inside and outside his/her agency), engage partners and stakeholders, and organize important project planning and deployment activities. Public agency Champions have played indispensable roles in most ICM projects to date.

Step 4 – Begin Profiling the Project Corridor

• Begin documenting physical conditions and circumstances in the baseline project corridor. The objective here is to capture basic information now (enough information to support a decision on whether to move forward with the ICM project). The corridor profiling activity will continue beyond the pre-
assessments need to be completed to provide the necessary data and information. This will include gathering and capturing more comprehensive and detailed data during the planning process.

- Using an ad hoc corridor map, identify key transportation networks and technology assets in the corridor.
- Gather readily available data about the corridor – e.g., average daily traffic (ADT), vehicle miles traveled (VMT), transit ridership, etc.
- Identify some or all of the safety performance issues and congestion bottlenecks in the corridor.

**Step 5 – Conduct a Preliminary Maturity Capability Assessment for the Corridor**

- Recharacterize the key issues and problems identified in Step 2, above, as potential “actionable elements” in the corridor. Examples of actionable elements could be “Monitoring of Conditions,” “Incident and Emergency Management,” or “Information-Exchange Among Regional Partners.”
- For each actionable element, identify state-of-play. The state-of-play is a summary description of how things function now. For example, for “Monitoring of Conditions,” the state-of-play might be: “We have cameras over much of the interstate system, but we still have ‘blind spots.’ On arterials, we have very little real-time knowledge about conditions. Regarding transit, we currently do not know the real-time locations of buses traveling the roadways and how they are performing in relation to their route schedules.”
- Next, identify the targeted capability for the selected actionable elements. The targeted capability is an aspirational description of how things ought to function in the future. For instance, for the “Monitoring of Conditions” the targeted capability could be: “We will have real-time situational awareness on traffic, incident, and performance conditions across the corridor, including interstates, arterials, and transit.”
- Finally, specify a high-level action plan for the selected elements. This plan specifies the broad-based actions necessary to progress from state-of-play to targeted capability. Again, for the “Monitoring of Conditions,” the action plan might be something like: “Install cameras at ‘blind spot’ locations on the interstate system. Add cameras or other sensing equipment at key intersections along arterials. Gain access to automatic vehicle location (AVL) system data for transit buses.”

**Step 6 – Determine Whether to Move Forward with the ICM Project**

- Document and review the outputs from Steps 1-5, particularly the ICM Reality Check completed in Step 2 and the action plans prepared in Step 5. Make a preliminary determination as to whether an ICM project is conducive to the problems in, and characteristics of, this corridor.

In the event it is determined that an ICM approach is supported by this pre-assessment review, the outputs from the review should be carried forward to the more formalized planning activities described in Chapters 4-6. As the planning process progresses towards more structured assessments and more focused stakeholder guidance, the preliminary findings should, of course, be vetted and refined.

**Benchmarking Costs**

As part of the pre-assessment process, practitioners may find it instructive to begin thinking about how much their candidate ICM projects will cost. Although actual costs will vary by circumstances and not all projects will involve all elements, Table 5 presents some high-level cost benchmarks by type of ICM activity. You should adapt these benchmarks to your specific circumstances and continue to refine your cost projections as the planning process progresses.
Table 5. ICM Benchmark Cost Guidance

<table>
<thead>
<tr>
<th>ICM Element</th>
<th>Cost Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICM Planning (Concept of Operations and Requirements)</td>
<td>$250K - $1M</td>
</tr>
<tr>
<td>Preliminary Design and Procurement Documents</td>
<td>$150K - $500K</td>
</tr>
<tr>
<td>Agency Coordination Platform</td>
<td></td>
</tr>
<tr>
<td>License</td>
<td>$125K - $200K</td>
</tr>
<tr>
<td>Customization</td>
<td>$100K - $200K</td>
</tr>
<tr>
<td>Data Integration</td>
<td>$50K - $100K (per interface)</td>
</tr>
<tr>
<td>Traffic Signal NTCIP Integration</td>
<td>$250K (per vendor interface)</td>
</tr>
<tr>
<td>Hardware, commercial off the shelf software (COTS)</td>
<td>$125K - $500K</td>
</tr>
<tr>
<td>Decision Support System</td>
<td></td>
</tr>
<tr>
<td>Online Model Software</td>
<td>$400K - $600K</td>
</tr>
<tr>
<td>Online Model Development</td>
<td>$500K - $1M</td>
</tr>
<tr>
<td>Response Plan Development</td>
<td>$100K - $250K</td>
</tr>
<tr>
<td>Rules Engine (Configuration of Open-Source Tools and Rules Development)</td>
<td>$50K - $100K</td>
</tr>
<tr>
<td>Integration of Data</td>
<td>$50K - $100K (per interface)</td>
</tr>
<tr>
<td>Hardware, COTS, and Networking (Depends on Subsystem and Whether Host Environment is Existing or New)</td>
<td>$150K - $1M</td>
</tr>
<tr>
<td>Additional Implementation Costs (Project Management/Coordination, Deployment of Field Components, etc.)</td>
<td>$50K - $750K</td>
</tr>
<tr>
<td>Maintenance and Operations (ICM Coordinator, Maintenance of Technical Components)</td>
<td>10% - 15% (of total deployment costs)</td>
</tr>
</tbody>
</table>

“Reality Check” – A Process for Confirming that a Corridor Is Ready for ICM

A new process will be developed for confirming that all intended elements in the phase have been accomplished:

1. Stakeholders – Stakeholders have been engaged and roles and responsibilities have been identified.
2. Analysis – ICM strategies considered have been analyzed and simulated and eliminated based on lack of feasibility or lack of performance improvements.
3. Funding – Initial funding sources have been secured and additional funding sources have been identified.

To complete the “reality check” process, the Pre-Assessment Task Checklist, shown in Table 6, assures an agency that they have put into place the building blocks to begin ICM.

Table 6. Pre-Assessment Task Checklist

<table>
<thead>
<tr>
<th>Task</th>
<th>Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Identify and Diagnose Problem</td>
<td>- Qualitatively characterize the system dynamics of potential ICM corridors.</td>
</tr>
<tr>
<td></td>
<td>- Define logical boundaries for potential ICM corridors.</td>
</tr>
<tr>
<td></td>
<td>- Identify whether existing problems along each corridor can be addressed using ICM.</td>
</tr>
<tr>
<td></td>
<td>- Set priorities among candidate corridors.</td>
</tr>
<tr>
<td>2. Determine Potential Partners</td>
<td>- Compile a list of potential partners, agencies, and organizations by type of decision maker.</td>
</tr>
</tbody>
</table>
### Task Checklist

<table>
<thead>
<tr>
<th>Task</th>
<th>Checklist</th>
</tr>
</thead>
</table>
| Task 3. Engage Potential Partners | • Convince potential partners of the value of ICM.  
• Detail the potential benefits of ICM participation in terms of your audience’s goals.  
• Understand stated concerns from stakeholders and develop strategies to work around or mitigate operational constraints.  
• Establish communication channels with participating stakeholder groups for information sharing. |
| Task 4. Planning Funds       | • Identify funds needed for the initial planning stage of the project.  
• Coordinate with stakeholders to receive their buy-in to participate. |
| Task 5. Initiate Formal Agreements | • Determine whether there is a need for formal or informal agreements for the ICM planning phase.  
• Discuss agreement terms with stakeholders (roles and responsibilities). |
Chapter 4 - Planning for Integrated Corridor Management

Overview

This chapter describes a comprehensive approach to be followed in developing the concept and planning for an ICM project.

The objectives of the planning phase are to coordinate across project partners and stakeholders and gather information necessary to define the desired ICM capabilities, corridor resources, and available corridor data to help inform the corridor boundaries and project needs assessment. This in turn helps project stakeholders to gain a clear understanding of where ICM may be beneficial so that they can define the high-level ICM project goals and objectives. The four major product outputs using the systems engineering process are the Project Management Plan, Systems Engineering Management Plan, Concept of Operations, and the Analysis Plan, including preliminary feasibility assessment of the proposed ICM system (ICMS).

Figure 4 provides definitions for these planning and concept phase tasks and Table 7. Planning and Concept Phase Task Checklist presents a checklist of activities included in the conduct of these tasks. The checklist can be used as a resource by agencies looking to implement ICM in their region.

Please note: These planning and concept phase tasks apply to ICM planning activities. The steps presented in Section 3.2 apply to ICM pre-assessment activities.
Figure 4. Planning and Concept Phase Main Tasks

(Source: NCHRP report 899 - Broadening Integrated Corridor Management Stakeholders)
Table 7. Planning and Concept Phase Task Checklist

<table>
<thead>
<tr>
<th>Task</th>
<th>Checklist</th>
</tr>
</thead>
</table>
| 1. Identify and Diagnose Problem                                     | • Qualitatively characterize the system dynamics of potential ICM corridors.  
                                                                 | • Define logical boundaries for potential ICM corridors.  
                                                                 | • Identify whether existing problems along each corridor can be addressed using ICM.  
                                                                 | • Set priorities among candidate corridors.  |
| 2. Establish ICM Objectives and Scale                               | • Identify main goals for the potential ICM project.  
                                                                 | • Establish objectives to meet each goal.  
                                                                 | • Explore realistic tiered ICM implementation options.  |
| 3. Determine Potential Partners                                      | • Compile a list of potential partners, agencies, and organizations by type of decision maker.  
                                                                 | • Create a stakeholder engagement plan, which details specific agencies and organizations to reach out to and when each type of decision maker should be engaged.  |
| 4. Engage Potential Partners                                         | • Convince potential partners of the value of ICM.  
                                                                 | • Detail the potential benefits of ICM participation in terms of your audience’s goals.  
                                                                 | • Understand stated concerns from stakeholders and develop strategies to work around or mitigate operational constraints.  
                                                                 | • Establish communication channels with participating stakeholder groups for information sharing.  |
| 5. Assess Potential Partners’ Needs                                  | • Compile and understand the main objectives of each participating stakeholder group.  
                                                                 | • Identify strategies to mitigate stated stakeholder concerns.  
                                                                 | • Short-list high priority stakeholder needs for inclusion in the ICM concept.  |
| 6. Develop ICM Concept of Operations                                 | • Develop a list of high-interest ICM strategies that address stated user needs.  
                                                                 | • Identify incoming and outgoing data needs and sources for each data need.  
                                                                 | • Identify and fill data gaps.  
                                                                 | • Develop a high-level architecture diagram that shows the key systems of the ICM system.  
                                                                 | • Develop operational scenarios that describe in detail how the ICM system is anticipated to operate in each scenario.  
                                                                 | • Define roles and responsibilities for each participating ICM entity/stakeholder through response plans.  
                                                                 | • Develop a Concept of Operations document.  |
| 7. Designate Performance Metrics                                     | • Identify performance metrics that are in line with the project objectives.  
                                                                 | • Identify data elements needed to evaluate each performance metric.  
                                                                 | • Identify potential data sources for selected performance metrics.  |
Task 8 – Assess Benefits of the Planned ICM Deployment

- Determine ICM analysis methodology.
- Develop an analysis work plan.
- Identify data requirements for analysis.
- Estimate ICM benefits and costs.
- Begin the process of adding the ICM project to the STIP and TIP.

Task 9 – Initiate Formal Agreements

- Determine whether there is a need for formal or informal agreements for this ICM project.
- Identify what types of agreements (institutional, operational, or technical) are necessary.
- Discuss agreement terms with stakeholders (roles and responsibilities).
- Develop a plan for long-term agreement management.

Task 10 – Develop Plan for Implementation

- Identify dependencies between ICMS projects to come up with an optimal project sequence.
- Explore Federal-aid, State, and local agency funding opportunities.
- Obtain funding commitments from as many sources as needed.
- Determine which ICMS project(s) will require procurement.
- Develop documentation needed to solicit development and deployment services needed.
- Document an agreed upon systems engineering process in a SEMP.
- Document remaining implementation strategies and plans into an implementation plan.

The remainder of this chapter provides detailed information on tasks that should be completed in the planning and concept phase. The tasks presented do not necessarily need to be done in the order listed, but each task is critical to ensuring the future success of an ICM project.

**Task 1 – Identify and Diagnose Problem**

In this initial stage, the ICM team needs to first identify the transportation problem that the corridor is experiencing and diagnose the underlying causes of the problem.

**Major Issues and Challenges**

Often, agencies are enthusiastic about embarking on an ICM project in their region and want to skip several critical steps and jump directly into concept development. Based on their experience with the corridors in their region, many believe that they have a good understanding of the issues that need to be addressed. Without quantitatively characterizing the system dynamics of potential ICM corridors, it is difficult to determine the main problems that need to be addressed, logical boundaries for an ICM corridor, and whether those problems identified are suitable for ICM. Multiple corridors may be designated as potential candidates for ICM, but funding constraints may force public agencies to set priorities among the candidate corridors.
Potential Solutions

Transportation System Dynamics

A typical pitfall for ICM projects is that the underlying nature of the problem is not well known until the project under development. Often, only near the end of the project does the ICM team focus on which specific system is being managed and optimized. An ICM project may be presented as a pure freeway merge/weave analysis, but it may turn out that signal timing on nearby arterials produces dense platooning on the on-ramps that essentially creates the merge/weave issue. The “system” here is the combined freeway-arterial roadway system, not just the freeway. An analysis of the freeway alone misses the essential point of the dynamics of the combined system. This example is quite tactical, but there are similar examples regarding individual elements of integrated multimodal corridors.

The system is the collection of facilities, fleets, infrastructure, and trip-making users for which the system manager is responsible plus all interacting systems that influence the performance of the system for which the manager is responsible. When defining the system, it can be useful to examine several boundaries:

- **Geographic** – Any transportation system is always influenced by its neighbors. There is no such thing as treating a subset of the transportation system as an independent element.
- **Temporal** – Under specific conditions or at times associated with events, many stakeholders may be trying to improve the performance of the transportation system.
- **Jurisdictional** – Even within a geographic boundary, many organizations may play a critical role in influencing the transportation system.
- **Functional** – The system can also be defined by where and when managers have functional control – as well as by the limitations of these controls. Functional boundaries can also be identified considering how data flows to and from entities associated with a transportation system. In some cases, data-related boundaries may limit the capability of the system manager to understand the state of the system, or neighboring systems.
- **Modal** – A transportation system may contain interacting subsystems associated with different transportation modes (e.g., transit, freight, HOV lanes, pedestrian networks, and bike lanes). A systems definition must recognize the interactions among these transportation modes.

Significance of Bad Traffic Days

A busy modern transportation system is inherently a dynamic entity. It never exists in pure equilibrium and is in a state of perpetual change at multiple temporal wavelengths: minute-to-minute, hour-to-hour, peak-to-non-peak, day-to-day, seasonally, and year-to-year. A time-dynamic view of the network informs a fundamental element of transportation systems management, namely, that system management is essentially a task of managing change.

With the advent of more continuous data available, the ability to characterize dynamic corridor performance has improved. These conditions can be within a day (e.g., the rise and fall of congestion in a peak period) or over many days (e.g., the variation in travel times between a specific origin and destination departing at a specific time each day over a full year). Likewise, there is a fundamental need to develop more effective condition-specific corridor management responses. For ICM to be successful, vague notions of recurrent and nonrecurrent congestion (convenient in a relatively data-scarce environment) are giving way to a more informed, data-driven approach that systematically classifies a wide range of operational conditions based on underlying causes (e.g., weather, incident, and demand patterns) as well as profiles of system performance (e.g., travel time, bottleneck throughput, and delay patterns).

Current ICM best practices use a data-driven method to identify multiple distinct operational conditions to better characterize transportation system dynamics. This set of operational conditions is a more effective and useful basis for the comparison of potential ICM response plans and is a foundational element of any
effort aimed at improving corridor performance. Figure 5 illustrates that to support the development and evaluation of complex, condition-dependent ICM response plans, a systematic analysis of data to identify a practical set of representative operational conditions is required.

Characterizing and Visualizing Operational Conditions

This is a review of different methods for visualizing and communicating the severity, extent (temporal or spatial), nature, and/or characteristics of congestion, such as through color-coded network diagrams, geographic information system (GIS) maps, speed contour plots, travel time reliability charts, vehicle trajectory plots (i.e., time-space vehicle plots), cumulative count curves, and other methods.

An operational conditions analysis ingests several months of contemporaneous, time-dynamic travel time, bottleneck throughput, weather, incident, and travel demand data to create mutually exclusive and exhaustive set of similar conditions – and their frequency of occurrence. For example, an analysis of a Seattle corridor identified 30 distinct operational conditions. As depicted in Figure 6 the 30 conditions are organized spatially based on increasing travel demand (along the x-axis) and disruptions to roadway supply (along the y-axis). Each condition is a collection of four or more actual days, and the total size of the box representing the condition reflects its frequency of occurrence.
In 2017, FHWA released a key document related to the systematic identification of operational conditions, *Scoping and Conducting Data-Driven 21st Century Transportation System Analyses*, a guide to the systematic integration of data and analytic resources into transportation systems management. This FHWA guidebook provides a wealth of material to reference and draw upon for the ICM community, and this section in the NCHRP 03-131 Guidebook draws heavily from the 21st Century Guide. The goal of the ICM-specific guidance is not to parrot these materials, but to put the statistical methods and data management processes detailed in the FHWA guidebook into context for the ICM stakeholder.

ICM focuses on various multimodal travel scenarios under varying operational conditions, both recurrent and nonrecurrent traffic congestion. A corridor’s nonrecurrent congestion scenarios entail combinations of demand increases and capacity decreases. The overall premise is that key ICM impacts may be lost if only “normal” travel conditions are considered. The ICM scenarios consider both average- and high-travel demand within the corridor, with and without incidents. The relative frequency of nonrecurrent operational conditions (i.e., incidents or other significant nonrecurrent operational conditions that affect corridor performance such as work zones, special events, weather, etc.) is also important to estimate (based on archived traffic conditions) in this process. While ICM is designed to address both recurrent and nonrecurrent events, the post-deployment evaluation of the two demonstration sites (Dallas and San Diego) focused solely on incident- or congestion-related events. The potential ICM deployment-related alternatives were identified using cluster analysis that grouped together incidents or congestion events that occurred under operational conditions (e.g., time of day, direction of traffic, length of time until the incident was cleared, etc.) which were more like each other, than to those in other groups (clusters). These clusters were then prioritized based on total delay impact.

Data and tools can be brought together to provide increasingly robust and quantitative measures of system performance. Some useful measures of system products over some period (e.g., a peak period, or a day, or a month) may include reliably completed trips and total value of goods delivered. These may be hard to measure directly. However, using time-variant travel time data and supporting estimates of ridership and volume data, travel reliability analysis can be conducted as a key first step in the measurement of system product. Reliability data is a key element in characterizing trip-making, since, if a trip takes much longer than expected, the disadvantages associated with disrupting travel plans outweigh the benefits. This is particularly true for goods movement within a supply chain, but the same basic principles hold for person-
trips. For example, if a trip home from work takes so much longer than expected that changes to child care agreements are required, this often has direct and measurable financial consequences.

Attributes of a Successful ICM Site

ICM requires consideration of more than congestion and incident information to be successful. FHWA compiled a list of the 10 attributes of a successful ICM site:

1. **Significant Congestion and Unreliable Travel Times** – The impact of ICM is more noticeable in areas with significant congestion and delay.
2. **Infrastructural Availabilities** – For ICM to work properly, there must be alternative means of travel (e.g., parallel arterials, additional transit options, etc.) to which people can shift based on the information and traffic data the system provides.
3. **Multimodal Capabilities** – Full implementation of ICM is nearly impossible without open communication – both technologically and organizationally – between the different modes of transportation.
4. **Centralized Data Hub** – A localized transportation management center is critical for housing all communication and traffic data in one centralized location.
5. **Successful Procurement Practices** – Efficient ICM sites are fully aware of the ITS expertise requirements and act accordingly during the procurement and integration processes.
6. **Readily Available Alternative Transit/Travel Options** – Alternate transit/travel options such as bus rapid transit, high-occupancy vehicle (HOV) lanes, light rail, micro-mobility options, etc., are a necessity for successful ICM sites.
7. **Optimization of Existing Transportation Systems** – Successful ICM sites can fully optimize existing transportation systems.
8. **Public Engagement** – Keeping stakeholders and the public engaged provides the public with better understanding of expected changes and better enables them to make more informed travel choices.
9. **Open-mindedness for Change** – Successful ICM sites can encourage ICM stakeholders to have an open mind and acceptance to changing solutions for congestion and traffic.
10. **Institutional Support** – Without the coordination of transportation agencies and organizations, multimodal communication and coordination is extremely difficult.

Prioritizing Candidate Corridors

The first step to prioritizing multiple candidate corridors is to define and apply a specific set of criteria to identify the individual corridor segments for further analysis, followed by a broad inventory assessment spanning a diverse set of data sources to characterize and evaluate each corridor with respect to ICM opportunities, constraints, potential benefits, limitations/challenges, and other operational considerations. The purpose of this is to establish the analytical foundation upon which the corridor screening and operational evaluation will be conducted.

**Corridor and Segment Identification**

Defining each ICM candidate corridor segment for further investigation includes identifying segment limits and associated key corridor components, such as:

- Freeways and/or arterials and their limits
- Transit lines and their limits
- Intermodal transfer facilities (e.g., transit stations, transit/transfer centers, park and ride lots)

---

• Relevant agencies and jurisdictions affiliated with the corridor (e.g., transit operators, local jurisdictions, emergency responder jurisdictions, maintenance divisions, parking facility operators)

Selection of appropriate corridor limits is crucial to obtaining analysis results that are accurate and suitable for corridor prioritization, evaluation, and ranking purposes. Poorly defined corridors may result in segments that are inherently challenging to accurately evaluate due to such issues as congestion spillover from downstream sections, a lack of alternate arterial routes, or segments with highly inhomogeneous roadway configurations and travel patterns. Table 8 provides an initial set of potential criteria for evaluating the most appropriate segment extents of a given ICM corridor.

Table 8. Sample Criteria and Considerations for Corridor Segmentation

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Rationale and Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic characteristics (e.g., truck volumes, average annual daily traffic [AADT], speeds, variability, congestion)</td>
<td>Locations with large shifts in volume are natural break points. Segments should avoid splitting queues for more equitable treatment of bottlenecks.</td>
</tr>
<tr>
<td>Incident concentrations and occurrence patterns</td>
<td>Many ICM strategies target nonrecurrent congestion, but such strategies are only effective if the incidents tend to occur mid-corridor, such that detour routes are available.</td>
</tr>
<tr>
<td>Locations of transit services and routes</td>
<td>Transit may more readily operate as a feasible alternative mode for drivers on longer corridor segments that have both intermodal stations and transit service connections to major destinations.</td>
</tr>
<tr>
<td>Location of major trip generators and attractors</td>
<td>As major destinations can be expected to capture many corridor trips, it will be crucial to define corridor segments to include arterial and multimodal connections to all major trip ends.</td>
</tr>
<tr>
<td>ITS and TSMO Capabilities</td>
<td>Existing and planned ITS infrastructure, and organizational, institutional and technical agreements. Availability of ICM champions(s).</td>
</tr>
<tr>
<td>Major decision points; locations with opportunities for route and mode shift</td>
<td>Major junctions and route decision points are natural break points for segments. They are also more recognizable to general audiences. Diversion potential.</td>
</tr>
<tr>
<td>Roadway and Network characteristics (segment lengths, shoulders available? HOV and Managed Lanes available? lane configuration, freeway and arterial network configuration)</td>
<td>ICM capability and feasibility are dependent upon roadway characteristics and configuration, so maintaining relatively homogeneous analysis segments with respect to these factors (e.g., arrangement of the adjacent arterial grid) will provide more accurate and reliable ICM assessment results.</td>
</tr>
</tbody>
</table>

Once the corridors have been identified and evaluated according to the criteria shown in Table 8, they can be summarized graphically. These corridor graphics should include maps that clearly establish the extents and contents of each segment, and will also provide contextual data to further justify the selected analysis segment extents, through such visuals as corridor-wide speed contours, incident heat maps, volume charts, and lane configuration data (see Figure 7 and Figure 8.)
Corridor and Segment Data Collection

With the corridors now properly defined, it is necessary to identify the necessary data sources for a detailed evaluation of each corridor segment with respect to its potential for operational strategies and ICM. It is recommended to consider various institutional, technical, logistical, and infrastructural factors that are associated or correlated with successful deployment of ICM strategies. For example, availability of compatible signal controllers and relatively clear, flat terrain (for line-of-sight purposes) are supportive of transit signal priority (TSP). Different weights will be assigned to each of these factors according to the categorical relevance of the corresponding ICM strategies. For example, a corridor with few or no arterial bus routes will have correspondingly low weights for the TSP-specific criteria (e.g., TSP-compatible signal controllers and relatively clear terrain) but may have higher weights for factors supportive of adaptive ramp metering (e.g., traffic control systems capable of providing volume information) if recurrent congestion is a frequent problem on the segment.

In addition to these ICM-specific technical considerations, it will be important to also consider the broader institutional, organizational, cultural, and political factors in the context of each corridor analysis segment to evaluate the extent to which ICM strategies would be logistically feasible, contextually appropriate, and practical to deploy. An understanding of both the challenges (e.g., current mobility...
deficiencies and gaps) and opportunities (e.g., availability of a supportive institutional, technical, logistical, and political context) of a given analysis segment are essential to a proper evaluation of that segment’s feasibility and suitability for ICM. Examples of such non-technical factors include:

- **Coordination considerations** – Number of agencies along the corridor (e.g., Highway Patrol districts, emergency responder districts, maintenance districts, transit agencies).
- **Cultural considerations** – Stakeholder and agency priorities (e.g., mobility, environmental responsibility, economic growth), awareness/stance regarding TSMO compared to traditional capital strategies (e.g., experience with TSP and signal synchronization projects).
- **Resource considerations** – Availability of operations staff to support ICM; availability of funding and training for staff support.

Weighting factors for these qualitative criteria can be defined in close consultation with the lead ICM agency, with additional input from ICM stakeholders in the region. Once the weighting factors have been established for all evaluation criteria and dimensions, each of the analysis segments will be ascribed an overall ICM suitability score, which will be used to generate a prioritized list for consideration.

**Corridor and Segment Evaluation**

The technical, institutional, cultural, and political criteria need to be carefully evaluated for each corridor segment as part of a balanced and context-sensitive assessment of the feasibility and viability of relevant ICM strategies. Using well-defined criteria and an easily understood weight-based system for combining ratings across the different feasibility categories, the overall product of this analysis will be a data-driven, transparent set of corridor rankings by segment that are responsive to the specific needs, capabilities, constraints, and context of each corridor.

To efficiently capture and communicate the findings by corridor and/or criterion, it is recommended to employ a range of relevant visualization strategies, such as the corridor diagrams shown in (Source: FHWA Scoping and Conducting Data-Driven 21st Century Transportation System Analyses)

Figure 9 and the comparative corridor summary table shown in Table 9. Maps can be used to summarize the characteristics and ICM readiness/capability scores of individual segments, to provide comparisons of different corridors on one or more dimensions, and/or present the gap analysis results in an intuitive and insightful format.
Figure 9. Partial Graphical Summary of One Segment from a Detailed, Data-Driven Prioritization Exercise Spanning 100 Corridors
Table 9. Summary of High-Level Active Traffic Management Screening Results for Eight Major Freeway Corridors in LA

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONDITIONS</strong></td>
<td></td>
</tr>
<tr>
<td>Extents</td>
<td>Freeway</td>
</tr>
<tr>
<td>Start</td>
<td>SR 134</td>
</tr>
<tr>
<td>End</td>
<td>I-605</td>
</tr>
<tr>
<td>Congestion level</td>
<td>High</td>
</tr>
<tr>
<td>Incident rate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Congestion variability</td>
<td>High</td>
</tr>
<tr>
<td><strong>CONFIGURATION</strong></td>
<td></td>
</tr>
<tr>
<td>Truck traffic</td>
<td>Moderate</td>
</tr>
<tr>
<td>Diversion potential</td>
<td>Very Good</td>
</tr>
<tr>
<td>Shoulder availability</td>
<td>Moderate</td>
</tr>
<tr>
<td>Managed lanes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ramp/arterial storage</td>
<td>Good</td>
</tr>
<tr>
<td>Freeway CCTV</td>
<td>Good</td>
</tr>
<tr>
<td>Arterial CCTV</td>
<td>None</td>
</tr>
<tr>
<td>Ramp metering</td>
<td>Good</td>
</tr>
<tr>
<td>Info. dissemination</td>
<td>Good</td>
</tr>
<tr>
<td><strong>COORDINATION</strong></td>
<td></td>
</tr>
<tr>
<td>Number of agencies</td>
<td>Moderate</td>
</tr>
<tr>
<td>Potential champions</td>
<td>None</td>
</tr>
<tr>
<td>Overall Potential Opportunity</td>
<td>High</td>
</tr>
</tbody>
</table>

Task 1 Checklist

- Qualitatively characterize the system dynamics of potential ICM corridors.
- Define logical boundaries for potential ICM corridors.
- Identify whether existing problems along each corridor can be addressed using ICM.
- Set priorities among candidate corridors.

Task 2 – Establish ICM Objectives and Scale

Once the ICM team has determined that the identified transportation problem is indeed one that is suitable for ICM, they need to set measurable ICM goals and objectives.
Major Issues and Challenges

One challenge is task timing. Depending on the agency pursuing ICM, some opt to set goals and objectives ahead of engaging ICM partners, so that they guarantee the project aligns with the high-priority goals and objectives of their department. Others prefer to first gather potential ICM partners and identify the needs of the collective group before settling on a common set of goals and objectives. Either method is perfectly acceptable and it is up to each agency to decide how best to move forward. Tasks 2, 3, 4, and 5 listed in this chapter can be done out of order, if they all are completed ahead of Task 6.

In addition, many agencies embark on ICM planning efforts before securing funds for the entire project. This can make it difficult for agencies to determine a realistic scale for the ICM project in the planning stages.

Potential Solutions

Identifying Goals

Goals reflect key priorities for desired outcomes for the transportation system and/or society. The vision of ICM is to achieve significant improvements in the efficient movement of people and goods on transportation networks through aggressive, proactive integration of existing infrastructure along major corridors. By applying an ICM approach, transportation professionals manage the corridor as a multimodal system and make operational decisions for the benefit of the corridor.4

The broadness, versatility, and complexity of ICM is what makes this approach an effective solution for a wide range of situations. At a basic level, the goals of ICM projects generally involve:

- Improving travel time
- Increasing corridor throughput
- Improving travel time reliability
- Improving incident management
- Enabling intermodal travel decisions
- Improving safety for all travelers

Goals to reduce negative impacts on transportation network performance can include decreasing delay (freeway mainline, ramps, arterials), vehicle hours traveled, peak period duration, emissions, fuel consumption, speed variability, and primary and secondary incidents. Goals to maximize benefits for the traveling public can include increasing capacity, speeds, transit ridership, and transit on-time performance.

Establishing Objectives

Objectives are specific, measurable statements that support the achievement of goals, and play a key role in shaping investment and policy priorities. Table 10 maps example objectives to each of the general ICM goal areas.

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<table>
<thead>
<tr>
<th>ICM Goal</th>
<th>ICM Objectives</th>
</tr>
</thead>
</table>
| Improving travel time | • Provide alternative route and mode options  
                      • Enhance ITS (e.g., dynamic lane management, adaptive traffic signal control)  
                      • Reduce impacts of roadway incidents |
| Increasing corridor throughput | • Add capacity during periods of severe congestion  
                                • Coordinate signal control systems |
| Improving travel time reliability | • Allow people and goods to move with minimal congestion and time delay, and greater predictability  
                                   • Promote ride sharing, such as carpool, vanpool, and park and ride  
                                   • Enhance ITS (e.g., dynamic signal phasing and vehicle detection systems) |
| Improving incident management | • Reduce incident response times  
                               • Reduce secondary crash rate  
                               • Improve decision support systems and response plan coordination |
| Enabling intermodal travel decisions | • Enhance transit services, amenities, and facilities  
                                   • Improve bicycle and pedestrian facilities  
                                   • Increase use of affordable non-auto travel modes  
                                   • Support the development of new transit options (e.g., passenger rail) |
| Improving safety for all travelers | • Reduce injuries and fatalities  
                                    • Inform travelers of stop-and-go traffic  
                                    • Increase detection systems for all travel modes (including bicyclists and pedestrians) |

Tiered ICM Implementation Options

Agencies that are smaller in size or lacking in budget may not have the resources or capability maturity to implement full-scale ICM projects. NCHRP’s *Advances in Strategies for Implementing Integrated Corridor Management* report introduces the following basic building blocks of ICM. If it is not feasible to achieve full automation right away, agencies can explore tiered ICM implementation options, which allows them to achieve incremental process improvements at a pace that works best for them.

**Available Capacity** – There must be available capacity within the transportation to manage a corridor through a multiagency or intermodal ICM approach. If a freeway is congested, there must be capacity on an alternate freeway, the adjacent arterial network, or transit servicing the corridor for ICM to be considered.

The ideal ICM corridor incorporates multimodal travel alternatives for corridor users. Agencies that don’t have the bandwidth to incorporate all mode options into the ICM system from the start may decide to focus first on identifying parallel arterials that can handle excess freeway traffic. As a second step, they may bring in a transit agency partner who can provide the location and vehicle occupancy information of their transit fleet, to encourage mode switch opportunities in times of incident or severe congestion. When another opportunity arises to expand upon the ICM system, the lead ICM agency may decide to work in multimodal connections, such as information regarding ride shares, bike shares, or other various emerging micro-mobility options.

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Exchange of Data – There must be an exchange of data between agencies responding to an event with the managed corridor. At a minimum, this could be as simple as telephone calls discussing and agreeing to a response. For data exchange to be effective, the scan team recommends an automated data sharing system. Since these systems may vary among agencies responding to events, a standards-based system (e.g., center-to-center [C2C], Traffic Management Data Dictionary, Message Sets for External Traffic Management Center to Traffic Management Center Communication, or transit communications interface profiles) should be used for easier integration.

The main purpose of ICM is to improve the communication and data sharing between corridor operations and travelers so that everyone has access to better real-time information about travel conditions. Manual phone calls in times of incidents and regular email updates between transportation agencies that previously had no communication protocols in place is still an improvement. When feasible, an incremental improvement would be to identify common operational scenarios (e.g., freeway incident, transit incident, etc.) that occur along the ICM corridor and set up automatic push notifications between the corridor operations with information regarding the incident and instructions for each transportation agency. In an automated data sharing system, incidents may be automatically detected using closed-circuit television (CCTV) cameras, which are connected to the ICM system that is accessible by all corridor operators.

Institutional Cooperation – There must be open communication and cooperation among agencies to operate the assets within the corridor. This can be done informally (i.e., operational personnel share information and coordinate responses among agencies) or more formally (i.e., through intergovernmental agreements or memorandums of understanding [MOUs] that define roles and responsibilities). Some areas have been successful using high-level ITS cooperative MOUs, while others have developed ICM-specific MOUs.

Informal agreements indicate that transportation agencies involved in the ICM corridor have at least come together and believe in the overall ICM cause. However, unlike with formal agreements, informal agreements lack the guarantee that operating agencies will prioritize their assigned ICM responsibilities when certain situations arise – for example, when their primary job responsibilities leave them with no time or resources to dedicate to the needs of the ICM system. When MPOs are involved in the programming and funding of ICM projects, this institutional support helps make resources available within each operating agency to make ICM a priority.
Coordinated Response – For ICM to work properly, all agencies involved with the corridor’s operations must coordinate their response to events. An agency that does not coordinate its response has the potential to negatively affect the corridor. Once the ICM program is in place and operational, it is time to test, update, and validate the response plans used by the corridor.

Collaboratively coming up with and documenting response plans for common operational scenarios in the ICM corridor is the first step. This ensures that each participating partner understands their roles and responsibilities for each scenario. As a second step, it is important to test out each response plan before implementation to validate that the assigned responsibilities yield the desired outcome in each scenario. This step requires more planning, time, and potentially manual manipulation of ITS equipment during off-peak hours (e.g., testing specific messages on changeable message signs (CMS) or traveler information systems). As described earlier, a transportation system is inherently a dynamic entity. As such, changes such as new developments impacting land use or growing populations in the region may impact travel patterns. Ideally, response plans would be tested, updated, and validated on a regular basis, otherwise they may be rendered ineffective when they are needed the most.

Traveler Information – Providing timely notifications to the public is beneficial. A system that supports automated notifications (e.g., congestion, incidents, strategies for minimizing delay) among operating agencies as well as roadway users allows for more proactive traffic management and emergency routing during recurrent and nonrecurrent congestion.

In addition to traveler information provided by the private sector (such as Google Maps and Waze), traveler information can be provided on CMSs or on platforms such as 511 systems. Providing notifications of planned events and closures would be the first step, as this type of information is not real-time. Notification of arterial and freeway incidents would require real-time data feeds, while notification of traffic impacts and alternate routes may require data analytics and a decision support system on top of real-time data feeds.
Task 2 Checklist

- Identify main goals for the potential ICM project.
- Establish objectives to meet each goal.
- Explore realistic tiered ICM implementation options.

Task 3 – Determine Potential Partners

The objectives and scale of the ICM project will help the ICM team determine who will be directly or indirectly affected and which stakeholder entities would make good potential partners.

Major Issues and Challenges

It is widely believed that collecting stakeholder input early on in a project results in a system that is better designed for its users. As a result, stakeholder engagement is often a top priority for transportation agencies embarking on an ICM project. The major challenges with stakeholder engagement are tied to the fact that ICM projects are usually multiagency, multi-jurisdictional, and multimodal. The combination of these factors can result in a never-ending stakeholder list. Lead agencies can find themselves in a difficult situation where they know who they want to invite to the table, but they have a hard time convincing them to dedicate the time and resources to support an ICM project. Other major challenges that agencies leading ICM efforts run into are that they want to follow best practices and collect stakeholder input from the planning and concept phase through the Operations and Maintenance Phase but know that they need to find ways to avoid stakeholder fatigue. Otherwise, stakeholders may lose interest part way through and stop providing input.

Potential Solutions

Types of Decision Makers to Involve

The three main types of decision makers to consider involving in an ICM project are shown in Table 11.

<table>
<thead>
<tr>
<th>Type of Decision Maker</th>
<th>Who Should Be Included</th>
<th>How to Involve Each Decision Maker</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-User</td>
<td>Entities whose decisions are intended to be influenced or supported by ICM.</td>
<td>Ensure that proposed ICM strategies are designed to address the needs and concerns of all identified end users.</td>
</tr>
</tbody>
</table>
Each type of decision maker plays a crucial role in the deployment, operation, and overall success of ICM, as discussed below.

**End-User Decision Makers**

Identification of the individuals on the corridor who make decisions regarding travel behavior are the easiest to identify, as they are the people that are affected by the ICM strategies and operations. Examples of these decision makers include freight vehicle operators, pedestrians, bicyclists, motorists (for mode switch opportunities), transit vehicle passengers, and highway patrol staff that respond to the scenes of incidents. These are the individuals whose decisions are intended to be influenced or supported by ICM and are generally the users of the facilities. In some cases, the decision makers may not be present on the corridor itself, as with fleet managers or supervisors that dictate what the freight and transit operators in the field must do. An initial set of end-user decision makers for each stakeholder group may be identified through a review of various ICM scenarios and consideration of which entities are the ones that would be directly affected by the ICM strategies. This may be further informed by a review of not only the candidate ICM scenarios, but also of the outcomes and results of those scenarios as implemented in real-world ICM sites (e.g., post-incident debriefing notes).

**Operations-Level Decision Makers**

Operations-level decision makers are responsible for designing the course of action to take in any ICM scenario. These decision makers generally must have a thorough understanding of what is feasible to do, and what is acceptable/suitable given the current conditions. Traditionally, departments of transportation (DOTs), MPOs, traffic management center (TMC) staff, and local agencies are at the center of operations decisions, as they are generally responsible for initiating route diversions, overriding traffic signal timings, and disseminating actionable traveler information. Dispatchers and fleet managers can provide the required input regarding whether a specific ICM strategy would be helpful or harmful from each stakeholder’s perspective, given the current state of the system, and can also indicate whether a strategy is feasible or not. An initial set of operations-level decision makers for each stakeholder group may be identified through a review of various ICM scenarios and consideration of which entities would be best suited to evaluate the feasibility and benefit/disadvantage associated with each choice. Identification of appropriate parties for each stakeholder group may be further informed by reviews of agency organization charts, operational decision-making processes, and/or information obtained from stakeholders themselves.

**Program-Level Decision Makers**

Finally, the most abstract level of decision makers involves those whose input influences the overall decision regarding whether to engage in ICM planning and operations at a program level. This can include upper management and executive-level staff at freight companies, departments of safety (for emergency responders), active transportation planners at MPOs or city agencies, or transit agencies. An initial set of program level decision makers for each stakeholder group may be identified through a review of agency organization charts, along with the presence of any policy-forming or policy-setting entities such as steering...
committees, advisory panels, or executive boards for each stakeholder group. They can also include higher-level policy setting or policy-influencing entities and organizations that may be identified through the tracing of funding sources for each stakeholder group.

**Stakeholders of Interest**

As a corridor is being considered for ICM, it is important that all agencies affecting the operations and maintenance of the network are invited to and participate in ICM planning. It is recommended to cast a wide net early in the process, so as not to exclude possible stakeholders early on. The roles and level of involvement may differ, but to be most effective, the ICM team should consider all transportation resources. Figure 10 can be used a starting point for identifying stakeholders to reach out to. Depending on the assets and characteristics (e.g., modal options, proximity to other countries, proximity to railroads, etc.) of the ICM corridor, some of the stakeholders listed in (Source: NCHRP report 899 - Broadening Integrated Corridor Management Stakeholders)

Figure 10 may not need to be directly involved, although keeping them informed is recommended.
Figure 10. Examples of Stakeholders at Each Decision Maker Level

Identifying Stakeholder Entities in Each Region

The following can be helpful starting points for identifying or building relationships with stakeholder entities in each region:

- State or regional transportation commissions.
- MPO, DOT, and local transportation agency divisions or departments related to traffic operations, TSMO, or traffic safety.
- TMC operators.
- Internal DOT committees and advisory groups related to freight and safety; freight associations; trade associations and user groups; major carriers; major freight rail operators; distribution centers; and port authorities.
- Establishing freight coalitions at the DOT, holding a regional operations forum, or leveraging existing relationships that other agencies already have (e.g., MPOs, chambers of commerce) are potential ways to identify major freight stakeholders and subsequently engage them.
- XM/Sirius Radio (currently used by some freight operators for route information), can be a potential method for targeted outreach to freight stakeholders.
- The Federal Transit Administration (FTA), internal DOT committees and advisory groups related to transit or safety, regional agencies (e.g., MPOs), and transit agencies can be a helpful starting point for identifying and engaging transit stakeholders in ICM.
Common participants to consider include state DOT transit groups, regional MPO transit planning groups, and transit agencies at the statewide, intercity, and regional levels. Transit stakeholders may span several modes, including rail, bus, ferry, private shuttle, and streetcar. Internal DOT committees and advisory groups (or similar) related to incident management or safety can be helpful starting points for outreach and engagement for these stakeholders. Common incident responders to consider include fire departments, local police, state police, border patrol, port authorities, medical facility staff, and the coroner’s office. MPOs or regional agencies may be useful for coordination with responders. Internal DOT committees and advisory groups related to bicyclists, pedestrians or safety; state and local bicycle coalitions; local and regional advocacy groups; bicycle and pedestrian planning groups at local and regional agencies; and bicycle and pedestrian advisory groups/committees. Local agencies and campuses (e.g., colleges) may already have bicycle and pedestrian distribution lists of social media groups. Consider including both agency planners and end users in ICM planning, to capture both the real-world challenges and issues that the users face, and the politics and procedures of transportation planning/operations.

When to Engage

Program-level decision makers are the most critical to engage at the ICM planning stage. By convincing executive-level management of the value that ICM can bring to the freight community, program-level decision makers can provide top-down support and champion an ICM initiative by setting aside funding and resources. Gaining buy-in from operations-level decision makers can be used as a second resort. ICM initiatives often yield tangible benefits for operations-level decision makers, and as a result, they may advocate for ICM support from management.

Operations-level and end-user decision makers need to be engaged when deliberating ICM strategy options. This may begin during the development of the Concept of Operations for the ICMS and needs to continue through the detailed design of the strategies and response plans. End-user decision makers can provide insight into the desired actions and outcomes of an operational scenario, while operations-level decision makers will understand if the infrastructure, assets, and data are available to support such ICM strategies.

Task 3 Checklist

- Compile a list of potential partners, agencies, and organizations by type of decision maker.
- Create a stakeholder engagement plan that details specific agencies and organizations to reach out to and when each type of decision maker should be engaged.

Task 4 – Engage Potential Partners

This section describes issues, challenges, and solutions in engaging ICM agency program-level decision makers and potential stakeholders to support stakeholder engagement efforts by articulating the benefits of participation and operational opportunities in the ICM approach.

Major Issues and Challenges

As congestion and the number of incidents steadily increase in urban areas nationwide, the occasional collaboration and interaction among transportation agencies within a corridor is no longer enough to address the transportation needs of the traveling public. While engaging additional groups of stakeholders is not an easy task, doing so ensures that ICM strategies are designed effectively with all roadway users in mind.
There are several major challenges to engaging potential partners. Sometimes stakeholders outside of organizations that are well versed in ITS/TSMO don’t understand the benefits that ICM can offer them. Additionally, each additional stakeholder group that is brought to the table requires not only time from the stakeholders themselves, but also a time commitment from the ICM agency to regularly meet with them, and more importantly, to make an honest effort to address their concerns. This is the key component to gaining stakeholders’ trust of your commitment to their needs. Keeping each stakeholder group engaged throughout the ICM project can be challenging. If they do not see progress being made, or don’t see benefits specific to their stakeholder group, they may lose interest part way through. Lastly, a two-way information flow between the ICM agency and stakeholders once the ICM system is operational may require changes to existing standard operating procedures.

Potential Solutions

Articulating the Value of ICM

Upon embarking on an ICM project, the lead ICM agency has the responsibility to involve stakeholders who may be directly or even indirectly affected by the project as early as possible. For example, in addition to corridor operators, convincing roadway users such as freight, transit, incident responders, and bicyclist/pedestrian stakeholders to engage in the ICM project may result in an expansion of corridor resources, available corridor data that can be used in the final ICM concept and help to ensure that the ICM concept is designed to address the needs of all corridor users.

For most people outside of the ITS/TSMO industry, ICM is a foreign concept. To gain their buy-in, in terms of time and resources, lead agencies will need to be able to clearly articulate the benefits of ICM. The value of ICM may be best illustrated through the following two versions of the same operational scenario: a major freeway incident occurs during the afternoon peak period, causing two lanes of traffic to be blocked for three hours. The first version describes traffic operations without ICM, while the second version demonstrates the added value that ICM can provide in these types of situations.

Major Freeway Incident: Response Plan without ICM

TMC staff receive a call reporting the incident and notify highway patrol and first responders to clear the incident. Highway patrol personnel closest to the incident head over and set up cones to close the two left lanes impacted by the incident, causing traffic to back up on the remaining lanes. Watching the action on their camera feed, TMC staff change the message on the CMSs in the impacted area, notifying travelers to slow down, merge into the right lanes and proceed with caution. Once the incident is cleared, highway patrol notifies TMC staff to clear the incident notification from the CMSs.

Major Freeway Incident: Response Plan with ICM

TMC staff receive a call indicating the incident’s location. TMC staff verify the incident on the video feed from their CCTV cameras and review the recommended ICM response plans specified for a major freeway incident at the affected location. The plans are generated in near-real-time by the decision support system based on the set of business rules and response postures designed for the corridor. At the same time, the incident responders use Emergency Vehicle Signal Preemption to get to the scene of the accident, shaving critical minutes off their response time. Once the incident responders close the left two lanes and assess the situation, they enter the estimated incident clearance time into the Regional Event Management System, which is automatically fed into the ICMS. This proactive approach to traffic management by both the operators and incident responders enhances response and control of unexpected incidents.
Once the TMC staff sign off on the recommended response plan, **existing infrastructure is optimized** to disseminate pertinent traveler information to the public. The CMSs in the affected region, as well as other traveler information sources (e.g., 511) are automatically updated to broadcast incident notification, providing **improved situational awareness** to corridor users and advising travelers to take specific alternate routes or shift to transit. If the alternate route does not support freight vehicles, the traveler information sources alert trucks to stay on the freeway. The **better-informed travelers** who detour off the freeway are further aided by a new signal timing plan on the alternate route (one component of the recommended response plan) that gives more green time to the flow of the detoured traffic, while transit operators prepare for increased volumes by adding more buses or light rail vehicles along the impacted route. This **dynamic management of supply relative to demand** reduces the negative impacts to corridor performance in the event of an incident.

Regional mobility and safety challenges will not be solved through the actions of a single agency; the proactive coordination between organizations is critical to solving these issues. The synergies and shared goals of the transportation agencies operating in a corridor are clear and mutually beneficial.

Additional benefits cited by agencies involved in implementing complex multi-year and multiagency ICM projects include the following:

- ICM provides the opportunity to proactively improve and maximize the performance of the transportation system by serving as an alternate to traditional major infrastructure investments that may be more expensive or constrained by environmental issues.\(^6\)
- Proactive management of incidents and congestion helps to minimize negative impacts to network performance when faced with unexpected or unusual events.
- ICM solutions provide corridor users with real-time situational awareness (travel times, incident information, and expected delays) via traveler information sources, enabling travelers to make smarter travel decisions.
- ICM produces benefits across different operational conditions (recurrent and nonrecurrent congestion).
- Developing relationships with other agencies that operate in the same corridor opens opportunities for tackling overlapping transportation issues using coordinated efforts, shared resources, and different perspectives.

**Benefits of Participation**

Communicating the benefits of ICM participation may be among the most effective approaches to encourage participation in ICM projects. ICM leaders must build a compelling case to incorporate stakeholder groups in ICM projects by understanding the benefits to corridor operators and to the stakeholder groups themselves. Refer to NCHRP’s *Broadening Integrated Corridor Management Stakeholders* report\(^7\) for additional benefits.

**Benefits for Corridor Operators**

When trying to convince the ICM manager to encourage participation from additional stakeholder groups, some key talking points to highlight the benefits to the ICM project may include:

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\(^6\) Feedback from Alex Estrella (San Diego Association of Governments), ICM Manager of the I-15 Demonstration Site.

• **Buy-in from influential stakeholder groups** – Gaining buy-in from stakeholders can help ICM project leaders make a case for ICM in a region. Several ICM projects have encountered roadblocks related to the proposed strategies that may pose additional risk to bicyclists and pedestrians. For example, in situations of major freeway congestion, ICM strategies may temporarily route traffic onto major arterial streets – the influx of vehicles who may be unfamiliar with the alternate route can cause additional safety concerns at conflict points with pedestrians and bicyclists, who may be uninformed of the sudden increase in vehicular traffic. All jurisdictions within an ICM corridor must be on board for an ICM project to be successful. Integrating the needs and concerns of bicyclists and pedestrians into ICM planning is one way to gain support from local agencies for ICM.

• **Users’ perspective of the corridor** – ICM provides a platform for various stakeholder groups to share the unique challenges that they face from a corridor and provide input into the design of a system that can better meet their needs.

• **More effective ICM strategies** – Many ICM strategies to date focus solely on improving mobility for motorists. Partnering with other stakeholder groups opens doors to explore ICM strategies with a wider range of benefits, such as transit signal priority, integrated fare payment, coordinated detour routing, pedestrian/bicyclist detection at signalized intersections, etc.

• **Additional sources of ICM funding** – Transit agencies that participate in a coordinated initiative like ICM may be able to make stronger arguments to secure funding for various improvements that provide direct travel time benefits for transit along an ICM corridor, such as an automatic vehicle location (AVL) system for buses that feeds data into an ICM system.

**Benefits for Stakeholder Groups**

By becoming involved in the ICM planning process, stakeholders may be able to request information that they would like to receive through the ICM platform to help improve decision-making, reduce delays, and increase travel alternatives. Some benefits that stakeholders themselves may experience with ICM include:

• **Improved situational awareness of corridor conditions** – On a typical corridor, work zones or congestion management strategies are not planned, executed, or communicated in an integrated fashion. The information that is available to the public often resides on disparate channels, making it difficult to see the complete picture. In an ICM corridor, stakeholders can receive regular, validated information updates (e.g., travel times, incidents, work zones, road closures, suggested alternate routes, etc.) from operating agencies along the corridor. With insight into accurate, up-to-date conditions along the corridor, stakeholders have the means to be more proactive, instead of reactive.

• **Enhanced customer service** – By disseminating comprehensive and validated data on current conditions (e.g., transit vehicle expected arrival times, travel times, delays, passenger occupancies, transfer options, etc.) in a coordinated manner, the end users of the transportation network can benefit from better service and make more informed decisions about when and how they travel. And by funding projects that improve transit travel time or accessibility, public transportation may become a more appealing travel option for roadway users, leading to increased ridership. Increased ridership leads to secondary benefits, such as increased transit service revenue, reduced vehicular demands, lower fuel consumption, and reduced emissions. In return, transit agencies may be able to increase the affordability of transit service due to increased revenue from additional riders.

• **Reduced incident response times** – Managing transportation infrastructure as an integrated system can benefit traffic incident management (TIM) programs in many ways. When incidents do occur, ICM strategies can be deployed to reroute and divert traffic away from the incident scene to clear the way for incident responder vehicles to approach the incident more quickly and safely, respond to those in need, and transport victims in need of service to care. Motorists can be encouraged to proceed more cautiously around incident responders on scene, therefore improving the safety of the responders.
By diverting roadway traffic to other facilities or modes, incident queues are reduced, which helps to minimize the potential for secondary incidents, allowing traffic flow to be restored more quickly.

- **Improve safety and equity in transportation operations** – Traffic management strategies typically prioritize motorists above all others. For example, arterial diversion routes are usually programmed to give major arterials more green time to maximize vehicle throughput. As a result, pedestrians and bicyclists at signalized crosswalks may experience increased levels of delay that can be exacerbated by exposure to the elements (e.g., rain, snow, vehicle exhaust). To improve equity in these situations, ICM strategies involving signal coordination may be redesigned to consider pedestrian and bicyclist progression.

- **Improved mode-specific diversion routes** – Awareness of heavily traveled pedestrian and bicyclist routes within an ICM corridor can help inform suitable diversion routes for vehicles or pedestrians/bicyclists. Non-motorized roadway users are limited in their ability to divert long distances – even half a mile may be considered a long distance to non-motorized roadway users. Also, pedestrians and bicyclists tend not to access traveler information sources pre-trip or en-route as motorists do, so it may be easier to divert motorists instead.

**Mutual Benefits**

The following are several examples of synergies and mutual benefits for both corridor operators and stakeholders when they participate in ICM:

- **Enhanced data and information sharing** – Untapped data that can be shared from stakeholders such as the freight community (e.g., truck origins and destinations, port turn times, etc.), transit agencies (e.g., transit vehicle expected arrival times, delays, etc.), incident responders (e.g., incident-related delays, expected roadway clearance times), bicyclists/pedestrians (e.g., high volume routes, preferred communication channels, etc.) would help to provide a more robust picture of traffic conditions within a corridor or region for corridor operators and the traveling public. This would help identify appropriate alternate route or modal choices, which can help improve corridor performance.

- **Forum for collaboration** – In areas where TIM programs may not be as well established or formalized, ICM provides a platform for collaboration among TIM partners and a proving ground for coordinated incident response. Resulting relationships among TIM stakeholders can eventually be capitalized on and used to expand and formalize the TIM program beyond the ICM corridor.

- **Increased monitoring capabilities and assets** – Stakeholders may also benefit from the inventory of available traffic management and transportation operations infrastructure, systems, and assets. For example, 511 systems, which are usually managed by state and regional transportation agencies, may be an effective platform for incident responders to disseminate incident alerts. Traffic management centers may also be ideal places to co-locate TIM personnel. This allows traffic operators and incident responders to share traffic monitoring video feeds and coordinate an immediate response when an incident is detected.

- **Eliminate redundancies in infrastructure investments** – On a planning level, coordinated planning between agencies can help identify opportunities where various improvements can be incorporated into the same design and construction, and where key infrastructure (e.g., a communication network), can be implemented to serve multiple purposes and agencies. This proactive coordination can help eliminate redundancies and minimize disruptions for construction, which leads to significant cost savings.

**Stakeholder Concerns**

Common concerns from stakeholder groups that make them hesitant to get involved in ICM projects have been summarized in Table 12. Some potential uses of this table include the following:
- Use this list to have more informed conversations with potential stakeholders.
- Work around the competing objectives or operational constraints that make it difficult to become more engaged in ICM.
- Design ICM strategies to either address the needs or mitigate the concerns of each stakeholder group.
- Potential stakeholders may be much more inclined to engage in ICM planning and design if they see potential for ICM strategies to improve their existing situation.

Table 12. Examples of Stakeholder Concerns

<table>
<thead>
<tr>
<th>Type of Concern</th>
<th>Concern</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>Funding Prioritization</td>
<td>Current cost-benefit project ranking methods are designed for capital improvement projects; the benefits and costs of TSMO projects and ICM are not always reliably captured by these processes, making it harder to secure funding and resources for ICM at various agencies.</td>
</tr>
<tr>
<td></td>
<td>Project Continuity</td>
<td>Delays related to ICM project approval and funding awards can create additional project-related problems later, as staffing turnover occurs in the interim and other demands for staff time arise.</td>
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<td></td>
<td>Access to ICM Experts</td>
<td>Contractor and consultant support for stakeholder engagement is limited.</td>
</tr>
<tr>
<td></td>
<td>Inflexible Response Plans</td>
<td>A predetermined set of formal response plans can limit the ability of the ICM system to respond effectively to all possible conditions and situations.</td>
</tr>
<tr>
<td>Freight-Specific Operational Constraints</td>
<td>Disparate Traveler Information Sources</td>
<td>Incident information and construction closure information is not readily available to freight users from a centralized on-demand information hub, which would be preferable. Instead, freight users must check multiple sources and then synthesize it themselves.</td>
</tr>
<tr>
<td></td>
<td>Inconsistent Traveler Information</td>
<td>Sometimes the information provided to freight is inconsistent across different sources (e.g., CMSs, 511 systems, highway advisory radio).</td>
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<td></td>
<td>Lack of Timely Traveler Information</td>
<td>Freight stakeholders are interested in detailed real-time information about incidents, including expected clearance times, nature of the closure, and extent of current (or predicted) delays. Such information, when available, is often outdated and inaccurate.</td>
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<td></td>
<td>Data Privacy Concerns</td>
<td>Freight companies are reluctant to share information and data, out of concern that their competitors will use it to their advantage.</td>
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<tr>
<td></td>
<td>Alternate Route Limitations</td>
<td>Rerouting trucks off freeways during congested periods or incident occurrences as an ICM strategy may not be worthwhile to implement, or may be opposed by local jurisdictions, due to inadequate shoulders and the roadway damage trucks can cause on arterials, in addition to the added safety risk trucks may pose to non-motorized roadway users. Unless a major incident creates a complete roadway closure, it may be logistically simpler to keep trucks (particularly oversize/overweight trucks) on the main route instead of attempting to reroute them.</td>
</tr>
<tr>
<td></td>
<td>Reluctance to Adopt New Technologies</td>
<td>Freight stakeholders are generally unwilling to install additional equipment for data collection.</td>
</tr>
<tr>
<td>Type of Concern</td>
<td>Concern</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------------</td>
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<td>----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Transit-Specific Operational Constraints</td>
<td>Making a Case for ICM</td>
<td>Detailed operational benefits of ICM and associated technologies (e.g., real-time vehicle occupancy counters) are not readily appreciated or well understood at transit agencies.</td>
</tr>
<tr>
<td>ITS Investment Coordination</td>
<td></td>
<td>Transit agencies may struggle to understand where they fit in the ITS architecture. Transit agencies may be unable to articulate when they need upgrades to their systems for continued ICM support and securing funds for such ongoing investment can be particularly challenging.</td>
</tr>
<tr>
<td>Potential Interoperability Issues</td>
<td></td>
<td>Because FTA guidelines do not require the systems engineering process, not all transit projects follow the process, which can potentially lead to design and interoperability issues.</td>
</tr>
<tr>
<td>One-directional Information Flow</td>
<td></td>
<td>During major events and incidents, the flow of information is often one-directional, from the DOT to the transit agencies. The DOT may alert transit agencies to expect more riders, which is then used for dynamic transit vehicle routing. Some DOTs have informal agreements to notify rail operators in such situations as well.</td>
</tr>
<tr>
<td>Lack of ITS Infrastructure</td>
<td></td>
<td>Better notification systems are needed to alert DOTs and local agencies when rail problems that will have impacts on the roadway network (e.g., blocked road crossings, gate malfunctions) occur.</td>
</tr>
<tr>
<td>Restricted Access to Roadway Assets</td>
<td></td>
<td>CMSs are owned and operated by other agencies (e.g., state and local DOTs), and they are often unavailable for displaying transit-related messages.</td>
</tr>
<tr>
<td>Right-of-way Constraints</td>
<td></td>
<td>It can be difficult for transit agencies to implement strategies given the number of jurisdictions and signal systems that must be coordinated with, since transit agencies generally do not own the roadway right-of-way.</td>
</tr>
<tr>
<td>Incident Responder-Specific Operational Constraints</td>
<td>Lack of Coordination</td>
<td>State police and DOT operations staff often do not coordinate with local police departments during incident situations, apart from alerting them of potential traffic diversion. Incident response teams are largely unaware of ICM strategies and activities.</td>
</tr>
<tr>
<td></td>
<td>Point of Contact Complexity</td>
<td>Jurisdiction over incidents may vary by facility, such as bridges, tunnels, or standard freeway segments. In areas near international borders and ports of entry, it may be necessary to coordinate with border patrol staff in addition to state patrol and other emergency responders.</td>
</tr>
<tr>
<td></td>
<td>Procedural Conditions</td>
<td>Incidents involving heavy vehicles can take longer to clear due to insurance issues. Insurance companies recommend leaving the vehicle exactly where it is after an incident (if the vehicle does not block traffic), so that evidence can be collected for the official accident report and insurance claims.</td>
</tr>
<tr>
<td>Bicyclist/Pedestrian-Specific Operational Constraints</td>
<td>Competing Agency Priorities</td>
<td>Smaller cities tend not to have dedicated bicycle and pedestrian staff (either planning or operations), and so these responsibilities become competing priorities for city traffic engineers.</td>
</tr>
<tr>
<td></td>
<td>Understanding of DOT Processes and Procedures</td>
<td>Coordinating with bicyclists and pedestrians is complicated by the levels of understanding of and familiarity with the politics and procedures of transportation planning/operations.</td>
</tr>
<tr>
<td>Type of Concern</td>
<td>Concern</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Competing Objectives</td>
<td>Bicyclists and pedestrians are often more concerned about safety than</td>
<td>about mobility, but ICM strategies often focus on mobility performance metrics first. Traffic diversion strategies to improve mobility for motorists can negatively impact the safety of local streets for bicyclists and pedestrians.</td>
</tr>
<tr>
<td>Funding Constraints</td>
<td>Cities often assign lower priority to investing in improvements on</td>
<td>corridor arterials for bicycle and pedestrian users.</td>
</tr>
<tr>
<td>Physical Limitations</td>
<td>Pedestrians and bicyclists, by the nature of these modes, cannot divert</td>
<td>nearly as far from their original routes as motorized modes can. In addition, for ICM strategies that encourage mode switches, bicycling and pedestrian modes are often poorly suited modes for most commuters for logistical/distance reasons.</td>
</tr>
<tr>
<td>Overlooked Needs</td>
<td>Bicycle and pedestrian groups may be overlooked in ICM planning</td>
<td>because they contribute relatively short-distance trips, even though they are also crucial components of transit trips as last-mile connections. Sometimes the most outspoken bicycle and pedestrian activists do not properly convey the opinion or desires of the majority of bicycle and pedestrian users. Many bicycle and pedestrian incidents may currently go unreported, and as such, the gravity of bicyclist and pedestrian needs may be inadequately represented.</td>
</tr>
<tr>
<td>Lack of Bicyclist/Pedestrian ITS Assets</td>
<td>Signal coordination can often be provided with respect to one mode</td>
<td>and travel speed, and the default is often to provide it to vehicles traveling at the speed limit, rather than to pedestrians at walking speed, or bicyclists at cruising speed. DOTs are unsure how to integrate historical data about bicycle and pedestrian volumes into ICM. One agency uses these data for post-incident evaluations only. Automated technologies for measuring pedestrian and bicycle volumes are not yet available. No known mobile apps are available that provide real-time bicycle-specific traffic alerts (such as to expect higher-than-normal arterial volumes due to a nearby freeway incident).</td>
</tr>
</tbody>
</table>

**Communication Strategies**

Once stakeholders are engaged in the ICM planning process, making sure there are dedicated two-way channels of communication between the ICM agency and the stakeholder group is critical. This serves to provide stakeholder groups with the information needed to make more informed travel decisions, as well as provide data feeds to the ICM system that were not previously available.

Table 13 is an example of potential communication strategies, organized by increasing capability maturity, for bicyclists and pedestrians collected through stakeholder interviews to help ensure their continued involvement in ICM. Potential communication strategies specific to freight, transit, and incident responder decision makers are available in NCHRP Report 899 on *Broadening Integrated Corridor Management Stakeholders*. The strategies are organized by the decision maker types (end-user, operations-
level, and program-level) outlined in Task 3: Determine Potential Partners, in a format that follows the five levels of maturity in the ICM Capability Maturity Model (CMM):8

- **Level 1, Silo** – Agencies do not coordinate their operations with other agencies. They manage their own network independent of neighbors.
- **Level 2, Centralized** – Some agencies share data but operate their networks independently. Traffic or operational data may be shared either through an automated process or manually.
- **Level 3, Partially Integrated** – Agencies share data, and some cooperative responses are done. Data is shared through an automated feed (e.g., C2C) or manually.
- **Level 4, Multimodal Integrated** – Agencies share data and implement multimodal incident response plans. Incident response uses a multimodal approach with defined detour routes.
- **Level 5, Multimodal Optimized** – Operations are centralized for the corridor, and personnel operate the corridor cooperatively. A central system is used to coordinate operations, and personnel may be co-located or work virtually with robust communication among agencies.

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Table 13. Communication Strategies for Bicyclists and Pedestrians

<table>
<thead>
<tr>
<th>Decision Maker Type</th>
<th>Level 1, Silo</th>
<th>Level 2, Centralized</th>
<th>Level 3, Partially Integrated</th>
<th>Level 4, Multimodal Integrated</th>
<th>Level 5, Multimodal Optimized</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-User</td>
<td>Arterial CMSs DOT websites (for planned closures) State Patrol websites (for incident information)</td>
<td>Social media (e.g., agency Twitter accounts) 511 systems Apps that warn non-motorized roadway users of locations with high crash risk</td>
<td>Audible countdown signals at intersections Apps that provide incident locations and appropriate pedestrian, bicyclist detour routes Apps that indicate real-time speed and congestion levels of vehicular traffic on arterials</td>
<td>Audible countdown signals at intersections that adjust for pedestrian detection Multimodal navigation apps that integrate crowdsourced non-motorized roadway user global positioning system (GPS) data and incident reporting</td>
<td>Navigation apps that offer mode-specific alternate routing</td>
</tr>
<tr>
<td>Operations-Level</td>
<td>Announcements/ press releases from public information officers for major events (e.g., full freeway closures, long-term closures) 511 systems State Patrol websites (for incident information) Phone calls, emails to DOT operations staff to discuss response plans, comments, concerns</td>
<td>Bicycle and pedestrian advocacy and advisory group representatives are involved with the regular updating of a static playbook of response plans State, local DOTs broadcast manually selected response plan on agencies’ social media channels</td>
<td>State, local DOTs receive data feeds from mobile apps that track real-time pedestrian and bicyclist movement (e.g., Live Trekker, Strava Metro) Limited real-time data is used to inform response plan selection State, local DOTs broadcast selected response plan on agencies’ social media channels</td>
<td>Model uses real-time non-motorized roadway user GPS data to inform response plan selection Non-motorized roadway user operations-level decision makers receive automatic alerts with response plan instructions</td>
<td>Connected non-motorized roadway users receive dynamic response plan information directly GPS tracking from connected non-motorized roadway users provides insight into real-time non-motorized roadway user volumes, delays Cloud-based performance measure dashboard accessible by non-motorized roadway user operations-level decision makers and DOTs</td>
</tr>
<tr>
<td>Decision Maker Type</td>
<td>Level 1, Silo</td>
<td>Level 2, Centralized</td>
<td>Level 3, Partially Integrated</td>
<td>Level 4, Multimodal Integrated</td>
<td>Level 5, Multimodal Optimized</td>
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</tr>
<tr>
<td>Program-Level</td>
<td>Attending existing freight, transit, incident responder, non-motorized roadway user association, coalition meetings Leveraging existing relationships that other agencies have built (e.g., MPOs, chambers of commerce)</td>
<td>Establishing internal DOT committees and advisory groups Developing freight, transit, incident responder, non-motorized roadway user plans to build relationships and trust with the stakeholders</td>
<td>Involving program-level decision makers in regional operations forums can help them understand the bigger ICM perspective, objectives, opportunities, and constraints</td>
<td>Establishing a corridor coalition and formalizing information dissemination strategies to member agencies, emergency services, and the public</td>
<td>Sharing operational responsibilities in a joint TMC (e.g., Niagara International Transportation Technology Coalition [NITTEC]) ICM corridor operations and maintenance costs are shared between corridor coalition member agencies</td>
</tr>
</tbody>
</table>
Task 4 Checklist

- Convince potential partners of the value of ICM.
- Detail the potential benefits of ICM participation in terms of your audience’s goals.
- Understand stated concerns from stakeholders and develop strategies to work around or mitigate operational constraints.
- Establish communication channels with participating stakeholder groups for information sharing.

Task 5 – Assess Potential Partners’ Needs

This task describes ways to understand stakeholders’ major objectives and needs and incorporate them into the ICM concept.

Major Issues and Challenges

Historically, ICM projects have been motivated by the need to reduce both recurrent and nonrecurrent forms of congestion, typically found on freeways. Now that agencies embarking on ICM are more aware of additional opportunities to optimize the transportation system through the incorporation of multimodal ICM strategies, it is critical for ICM agencies to understand the goals and objectives of various types of travelers operating along the potential ICM corridor.

While Task 3 helps to identify the appropriate stakeholders to involve and Task 4 provides tools for ICM agencies to start meaningful conversations with various stakeholder groups, ICM agencies may still face challenges getting them to dedicate their time to an ICM project, as several years may go by before an ICM project is deployed. It is the responsibility of the ICM agency to listen to the needs of each stakeholder group they engage and identify strategies that enable each group to receive significant benefits from the ICM system.

Potential Solutions

Understanding Stakeholder Objectives

In a world with limited time and resources, it is understandable that stakeholders may not feel compelled to partner in an ICM project unless they see potential benefits for their stakeholder group. Table 14 outlines the main goals and objectives of several common stakeholder groups, including freight, transit, incident responders, and bicyclists/pedestrians. This table can be used not only to frame the conversation with each group but ensure that the final ICM concept incorporates the highest priority objectives voiced by each group.

For most of these stakeholder groups, mobility or travel time is not their highest priority. Interestingly, based on our work conducted for NCHRP Report 899 on Broadening Integrated Corridor Management Stakeholders, we have heard that these stakeholder groups are driven by other factors, such as the following:

- **Freight** – The freight industry is much more conscientious of travel time reliability, which is critical for on-time deliveries and pick-ups, as truck operators ultimately answer to cargo owners and other clients. Cargo type, such as perishable items, is another critical factor that depends on travel time reliability.
- **Transit** – As with freight stakeholders, travel time reliability is of upmost importance. One of the easiest ways to lose ridership is through unpredictable schedule delays.
- **Incident Responders** – While safety is included on the list of goals and objectives for freight and transit stakeholders, operational processes are not as heavily dictated by this objective as they are for
incident responders. Incident responder stakeholders will sacrifice mobility goals to protect on-site responders from harm and provide the necessary aid to incident victims.

- **Bicyclists/Pedestrians** – As the most physically vulnerable stakeholder group, safety is the main concern. One of the core strategies employed in ICM involves diverting freeway traffic to parallel arterials or to other modes when accidents, construction, or other nonrecurrent obstacles degrade freeway performance. These diversions, no matter how well managed, have the potential to create high volumes of traffic at arterial intersections and/or transit stations and park and ride lots. Since there is a correlation between the volume of travel through an intersection and pedestrian and bicycle safety, these additional diversions may require improvements to better protect pedestrians and bicyclists. Furthermore, traffic planning for impacted intersections may need to mitigate the impacts on pedestrian and bicycle wait times crossing in the perpendicular direction of arterial flows. Involving bicyclists/pedestrians in ICM planning provides opportunities to balance the transportation needs of all roadway users.

### Table 14. Example Goals and Objectives of Different Stakeholder Groups

<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>Main Goals and Objectives</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight</td>
<td>Reliability</td>
<td>Freight partners are not as concerned about congestion levels as the rest of the public is. They care much more about reliability, which is needed for on-time deliveries and pick-ups, rather than speed.</td>
</tr>
<tr>
<td></td>
<td>Navigability</td>
<td>Height restrictions, inadequate shoulder widths, inadequate turning path templates, etc. create physical accessibility barriers for trucks on truck routes and alternate routes.</td>
</tr>
<tr>
<td>Economic Efficiency, Productivity, and Competitiveness</td>
<td>Reducing the cost to transport and warehouse materials increases the profit the company earns from every client. Reducing energy costs can be accomplished by consolidating shipments or maximizing transportation routes.</td>
<td></td>
</tr>
<tr>
<td>Quality Customer Service</td>
<td>The goal of providing customers with outstanding customer service involves the ability to handle a business’s transportation and logistics needs in an efficient manner that enhances the logistic firm’s reputation in the industry.</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>Reduced rates of crashes, fatalities, and injuries associated with freight movements on the designated freight network.</td>
<td></td>
</tr>
<tr>
<td>Transit</td>
<td>Reliability</td>
<td>To maintain a loyal customer base, transit providers need to ensure reliable service. Passengers need to trust that their trip will be predictable or on time.</td>
</tr>
<tr>
<td></td>
<td>System Efficiency</td>
<td>Transit agencies want to use their resources as efficiently as possible by minimizing non-revenue miles and evolving with user needs.</td>
</tr>
<tr>
<td></td>
<td>Safety</td>
<td>As with all other transportation agencies, safety and security of the system is a major priority for public transit providers.</td>
</tr>
<tr>
<td></td>
<td>Affordability</td>
<td>Transit providers need to ensure that their services are priced affordably for their customer base.</td>
</tr>
<tr>
<td></td>
<td>Accessibility</td>
<td>Which types of transit services are available and where stations are located have a major impact on how frequently transit is used. Services must also be accessible for travelers with disabilities.</td>
</tr>
<tr>
<td>Incident Responders</td>
<td>Responder Safety</td>
<td>Drivers are asked to move over and slow down when approaching traffic incident response vehicles and traffic incident responders on the roadway. When drivers learn the proper protocols when</td>
</tr>
</tbody>
</table>
Stakeholder Group | Main Goals and Objectives | Description
---|---|---
encountering emergencies on the roadway, it helps to prevent secondary incidents, including incident responder injuries and deaths. | Safe, Quick Incident Clearance | TIM partners at the state, regional, and local levels are committed to achieving goals for traffic incident response and clearance times.

Prompt, Reliable, Interoperable Communications | All traffic incident responders should receive prompt, reliable notification of incidents to which they are expected to respond. TIM partners actively partner with news media and information service providers to provide prompt, reliable incident information to the public. TIM partners encourage the development of more prompt and reliable traveler information systems that will enable drivers to make travel decisions to reduce the impacts of emergency incidents on traffic flow.

Bicyclists/ Pedestrians | Safety | Safety is the main concern of non-motorized roadway users who are especially vulnerable in traffic incidents. Increasing the visibility of facility intersections and road and rail crossings; providing a buffer between side paths and vehicular traffic; enforcing speed limits and pedestrian rights in crosswalks; and adding user- or motion-activated signalization can increase safety for non-motorized roadway users.

Accessibility | Non-motorized roadway users often walk or bike as part of a multimodal trip, so accessibility to bike racks and transit stations are major deciding factors in mode choice.

Connectivity | Non-motorized roadway users desire a network of convenient, safe, and well-designed bicycle and pedestrian facilities that link all local and regional systems and community destinations.

Equity | Transportation needs of all motorists and non-motorists need to be balanced, otherwise pedestrians and bicyclists may experience significant delays at crosswalks.

**Mitigating Stakeholder Concerns**

Task 4 listed several common concerns from stakeholder groups that make them hesitant to get involved in ICM projects. Table 15 presents potential approaches that lead ICM agencies can use to help mitigate stakeholder concerns and make sure they have a positive ICM experience.

**Table 15. Examples of Mitigating Stakeholder Concerns**

<table>
<thead>
<tr>
<th>Type of Strategy</th>
<th>Strategy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICM Support</td>
<td>Advocate for Top-Down or Bottom-Up Support</td>
<td>Political or executive-level support for ICM can encourage cooperation and participation across all stakeholder groups. Involvement and support by FHWA and FTA can help encourage participation by other stakeholders. However, one agency found that while goals set by upper management can provide direction, the success of ICM and coordination depends on whether the operational staff feel invested and recognize the importance of it.</td>
</tr>
<tr>
<td>Type of Strategy</td>
<td>Strategy</td>
<td>Description</td>
</tr>
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<td>-------------------</td>
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</tr>
<tr>
<td></td>
<td><strong>Leverage Goals of Existing Initiatives</strong></td>
<td>Internal agency initiatives associated with interagency collaboration and communication can be used as motivation and justification for involvement in ICM.</td>
</tr>
<tr>
<td></td>
<td><strong>Establish Ongoing ICM Funding</strong></td>
<td>Established sources of ongoing funds to support ICM can encourage stakeholders to commit resources and time of their own and can demonstrate that it is a long-term priority.</td>
</tr>
<tr>
<td></td>
<td><strong>Use a Tiered Deployment Approach</strong></td>
<td>Deploying ICM in phases can help show stakeholders the potential of ICM and motivate them to get involved in further planning in later phases, before the full deployment is complete.</td>
</tr>
<tr>
<td></td>
<td><strong>Grant ICM Budgetary Authority to DOTs</strong></td>
<td>Granting the DOT budgetary authority for ICM implementations can allow the DOT to provide financial support to the local cities for needed improvements for bicycle and pedestrian users, in a coordinated and consistent manner across the corridor.</td>
</tr>
<tr>
<td>Stakeholder</td>
<td><strong>Involve Stakeholders Early On</strong></td>
<td>Coordinating with all stakeholders while the ICM plan is being developed (e.g., for goals, objectives, and proposed strategies), rather than simply seeking input from them during a review period for a completed plan, can help them feel more engaged and invested in the product, and allow planners to more easily implement fundamental design changes necessary in response to comments from the stakeholder groups. The various stakeholder groups may also be able to provide support for grant applications.</td>
</tr>
<tr>
<td>Participation</td>
<td><strong>Share Decision-Making Responsibilities</strong></td>
<td>Engaging non-traditional stakeholders and getting them to feel involved and invested may require relinquishing some influence and decision-making power to them regarding ICM. However, this also may require additional investment of time and resources from these stakeholders, such as staffing and training.</td>
</tr>
<tr>
<td></td>
<td><strong>Conduct Incident Debriefs</strong></td>
<td>Debriefing meetings to discuss all factors related to an incident can be beneficial for improving efficiency of incident clearance and management.</td>
</tr>
<tr>
<td>Information</td>
<td><strong>Use Knowledge Base of Regional Agencies</strong></td>
<td>Having an MPO or countywide/regional agency in charge of information sharing and dissemination back-end systems may facilitate participation by all ICM parties, as other agencies (e.g., the DOTs, transit agencies) often focus on specific modes or aspects of corridor data only. Regional agencies are often more closely connected with local groups (e.g., bicycle, pedestrian, and freight groups) than the state DOT, and are more likely to have done coordinated projects with these agencies in the past (which also facilitates ICM agreements).</td>
</tr>
<tr>
<td>Sharing</td>
<td><strong>Design Comprehensive Information Sharing Platforms</strong></td>
<td>Information sharing portals that include planned event information (e.g., construction closures, major corridor events) can help all stakeholders proactively prepare and plan for the impacts and add value to the ICM system.</td>
</tr>
<tr>
<td>Type of Strategy</td>
<td>Strategy</td>
<td>Description</td>
</tr>
<tr>
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<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Trade Public Sector Data for Private Sector Data or Functionality</td>
<td>Mobile app developers may not be interested in considering truck route considerations when providing rerouting guidance. However, DOTs have information that these mobile app developers desire (e.g., planned lane closures), and that can be used for leverage.</td>
</tr>
<tr>
<td>Operational Efficiencies</td>
<td>Formalize Response Plan Responsibilities</td>
<td>Formal response plans can help all stakeholders know what to expect.</td>
</tr>
<tr>
<td></td>
<td>Share Right-of-way Access</td>
<td>Transit agencies seeking to implement bus rapid transit, bus-on-shoulder, or bus-only lanes may be incentivized to make ICM planning and coordination a higher priority because these types of strategies can be reliant on state DOTs to facilitate deployment and formalize operational details.</td>
</tr>
<tr>
<td></td>
<td>Share ITS Assets Across Agencies</td>
<td>Transit agencies and incident responders are easier to incorporate into ICM planning when they already have back-end coordination/data systems in place, and when the DOT has incident monitoring infrastructure deployed in the field that incident responders can benefit from. Transit agencies and incident responders could benefit from being allowed to control DOT cameras as needed for incident monitoring, but this can conflict with the DOT and its own needs for the CCTV systems; read-only access may be more suitable.</td>
</tr>
</tbody>
</table>

**Task 5 Checklist**
- Compile and understand the main objectives of each participating stakeholder group.
- Identify strategies to mitigate stated stakeholder concerns.
- Short-list high priority stakeholder needs for inclusion in the ICM concept.

**Task 6 – Develop ICM Concept of Operations**

Define an ICM system concept by designing ICM strategies and response plans that incorporate the needs of all stakeholder groups.

**Major Issues and Challenges**

Through the stakeholder engagement activities conducted in Tasks 3, 4, and 5, the ICM lead agency should have a comprehensive idea of stakeholder needs and pain points. The challenge with using the user need inputs to develop the ICM Concept of Operations is to develop a concept that is feasible, within budget, and addresses the most critical needs. Keep in mind that not all user needs identified can be addressed using ICM solutions. It is important to assign priorities to the user needs compiled and to mark any that are outside of the scope of the project.
Potential Solutions

ICM Strategies to Consider

The collection of strategies to address corridor needs is how the ICM concept begins to be developed. ICM teams can refer to example strategies listed in Table 16 for ideas of which strategies may help them achieve their ICM objectives. Each strategy selected should be traceable back to one or more of the user needs. Appropriate ICM strategies are not limited to building an ICM system as the only end goal. Appropriate strategies could, for example, include ramp metering, hard shoulder running, parking lot information management, Mobility-as-a-Service (MaaS), etc. Even when an ICM system or a decision support system (DSS) is part of the ICM concept to be developed, it may be conceived of as a separate, external system, or it could be integrated with the advanced traffic management system (ATMS) or other existing system.

Table 16. Potential ICM Strategies

<table>
<thead>
<tr>
<th>ICM Strategy</th>
<th>Description</th>
<th>Potential Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved Dynamic Corridor Ramp Metering</td>
<td>Dynamic adjustment (up or down) of metering rates based on current facility conditions and remaining available capacity of the facility/system.</td>
<td>• Increased throughput</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Decreased vehicle hours traveled</td>
</tr>
<tr>
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<td></td>
<td>• Decreased primary incidents</td>
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<tr>
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<td></td>
<td>• Increased speeds</td>
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<tr>
<td></td>
<td></td>
<td>• Decreased travel times</td>
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<td></td>
<td></td>
<td>• Decreased delay</td>
</tr>
<tr>
<td>Queue Warning</td>
<td>Inform travelers of the presence of downstream stop-and-go traffic based on real-time traffic detection using warning signs and flashing lights.</td>
<td>• Decreased primary and secondary incidents</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Decreased speed variability</td>
</tr>
<tr>
<td>Improved Decision Support Systems (DSS)/Incident Response Plans</td>
<td>DSSs use real-time data and knowledge of the current state/conditions of the network to provide appropriate alternate routes to TMC operators as they respond to incidents (e.g., traffic collisions, severe weather, evacuations).</td>
<td>• Reduced response time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduced negative impacts on network performance</td>
</tr>
<tr>
<td>Media and Social Media Alerts</td>
<td>Mobile alerts for real-time traveler information such as congestion hot spots and locations of incidents, lane closures, and construction events can provide roadway users with actionable information.</td>
<td>• Decreased primary and secondary incidents</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Decreased delay</td>
</tr>
<tr>
<td>Dynamic HOV Lane Conversion</td>
<td>When congestion is light, the HOV lane can be operated as a general-purpose lane, and when congestion is severe, access can be limited to transit vehicles only. For facilities that lack dedicated HOV lanes, hard shoulder running can be used to add a general-purpose lane to the freeway, while the median lane is simultaneously converted into an HOV lane.</td>
<td>• Increased transit ridership</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increased transit on-time performance</td>
</tr>
<tr>
<td>ICM Strategy</td>
<td>Description</td>
<td>Potential Benefits</td>
</tr>
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<td>--------------------------------------------------</td>
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</tr>
<tr>
<td><strong>Speed Harmonization/Variable Speed Limits (VSL)</strong></td>
<td>VSL is used to gradually slow traffic down ahead of a congested area to reduce the occurrence of traffic collisions, and attempts to set speed limits appropriately in the congested regions so that traffic continues to flow smoothly rather than deteriorating to less efficient stop-and-go conditions.</td>
<td>• Increased capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Decreased primary and secondary incidents</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increased average speed</td>
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<td></td>
<td></td>
<td>• Decreased peak period duration</td>
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<td></td>
<td></td>
<td>• Decreased emissions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Decreased fuel consumption</td>
</tr>
<tr>
<td><strong>Dynamic Rerouting</strong></td>
<td>Alternate route guidance is provided to drivers heading for designated destinations when conditions on the primary route have deteriorated below a prescribed threshold due to congestion, weather conditions, or other situations. This strategy is closely supported by effective DSSs.</td>
<td>• Decreased travel time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increased average speed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Decreased speed variability</td>
</tr>
<tr>
<td><strong>Lane Use Signals/Dynamic Lane Management</strong></td>
<td>Opening and closing of lanes on a facility in response to real-time conditions. Congested conditions may result in the opening of additional lanes (such as reversible or shoulder lanes) to traffic. When closures occur, lane use signals provide drivers warning ahead of the closure so that they may anticipate the merge ahead.</td>
<td>• Increased throughput</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increased capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Decreased primary and secondary incidents</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Decreased emissions</td>
</tr>
<tr>
<td><strong>Dynamic Pricing</strong></td>
<td>Uses tolls to manage supply during periods of high demand. Prices are set to maintain a prescribed level of performance on the facility, such as a minimum acceptable speed. Provisions are sometimes enacted that allow HOVs and transit vehicles to receive discounted toll rates.</td>
<td>• Increased transit ridership</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increased transit on-time performance</td>
</tr>
<tr>
<td><strong>Dynamic Junction Control</strong></td>
<td>Lane configurations at a ramp merge or diverge are updated throughout the day to best accommodate the current traffic demands (high entrance volumes and/or high exit volumes).</td>
<td>• Decreased ramp and mainline delays</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Decreased mainline and ramp travel times</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Decreased primary accidents</td>
</tr>
<tr>
<td><strong>Emergency Vehicle Signal Preemption System</strong></td>
<td>Emergency services vehicles (ambulances, fire trucks, police cars) equipped with sensors can trigger signalized intersections to synchronize traffic and crosswalk signals in the forward path, allowing them pass through a corridor to reach the incident.</td>
<td>• Decreased travel time for emergency service vehicles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduced response time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Decreased secondary incidents</td>
</tr>
<tr>
<td><strong>Automated Work Zone Information System (AWIS)</strong></td>
<td>The AWIS system uses a Central System Controller, highway advisory radios (HAR), traffic sensors, CMSs, and speed stations to calculate and report delay times to travelers via CMSs. The public is provided with general work zone and delay information via various traveler information sources (e.g., 511, HAR system).</td>
<td>• Decreased fatal crash rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Decreased rear-end crash rate</td>
</tr>
<tr>
<td>ICM Strategy</td>
<td>Description</td>
<td>Potential Benefits</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------</td>
</tr>
<tr>
<td>Predictive Traveler Information</td>
<td>Travel time estimates are generated based on predicted (as opposed to recently observed) performance of the system, using models, expected incident clearance times, schedules of regional special events, etc. and are expected to be more reliable and accurate than those based on past data.</td>
<td>• Increased on-time performance</td>
</tr>
</tbody>
</table>
| Increased Transit and Parking Capacity| New parking spots planned within the corridor can be used to attract single occupancy vehicle (SOV) trips to transit. Additional buses or light rail vehicles can be added as necessary to accommodate increases in demand. Financial incentives such as reduction in fees for transit and parking may be incorporated into this strategy. | • Increased transit ridership  
• Decreased freeway and arterial travel time  
• Increased capacity                                      |
| Dynamic Lane Reversal                | A specialized and common form of dynamic lane management, this strategy involves the designation of a specialized lane (or lanes) on a facility to the direction of travel that would most benefit from its capacity according to current conditions. Some reversible lane facilities follow preset time of day schedules. | • Decreased travel time  
• Increased capacity  
• Decreased delay                                      |
| Coordination of Freeway Ramp Metering and Arterial Signal Control | Ramp metering and arterial signal control systems that are operated in isolation can lead to excess congestion. In a coordinated system, ramp metering rates are generally used to inform signal operations on nearby arterials, so that their operations complement – rather than conflict with – each other. | • Decreased delays  
• Decreased travel time  
• Reduced emissions  
• Increased throughput                                      |
| Adaptive Traffic Signal Control      | Operating a signalized intersection, corridor, or network of arterials such that the timing parameters are set based on current traffic conditions. These systems can respond reactively to atypical traffic conditions (e.g., high demands caused by special events), or proactively to anticipated recurrent congestion based on historical data. | • Decreased travel time  
• Decreased delay  
• Decreased number of stops                                      |
| Traffic Information for Route Planning | Through close system integration with real-time traffic condition data sources, freight dispatchers and fleet managers can more effectively route their vehicles around anticipated congestion and modify driver departure times to minimize overall vehicle hours traveled and optimize delivery times. | • Travel time reliability  
• Economic efficiency                                      |
<table>
<thead>
<tr>
<th>ICM Strategy</th>
<th>Description</th>
<th>Potential Benefits</th>
</tr>
</thead>
</table>
| Maintenance and Construction Planning    | Planned events, such as anticipated lane and roadway closures for scheduled maintenance, can be considered by freight dispatchers and fleet managers when driver plans are developed each day, such that the trip performance and delivery impacts of those closures can be minimized. Long-term freight planning data can also be used as inputs for optimizing maintenance schedules, so that closures on peak freight routes and travel days can be minimized or anticipated and mitigated. | - Travel time reliability  
- Economic productivity  
- Quality customer service |
| Dynamic Routing around Active Incidents  | Truck alternative routes are limited and can be challenging to locate during incident situations. With ICM, integration between truck operators and traveler information systems becomes possible, allowing specific truck route detour guidance to be directed toward relevant freight vehicle operators only. Additionally, integration between DOTs and local agencies helps ensure that the active detour truck routes are prepared to handle the rerouted traffic (e.g., through signal retiming, local traffic control, activation of arterial CMSs for guidance). | - Navigability  
- Travel time reliability |
| Improved Performance through Advanced Signal Coordination | With advanced detection technologies deployed as part of an ICM program, arterial traffic signals have the capacity to anticipate approaching freight vehicles and respond accordingly for optimized performance. With freight Eco-Driving, an equipped signal communicates its upcoming phase changes to approaching drivers, who can then adjust their speeds to conserve momentum/fuel and minimize the number of stops that are performed. | - Economic efficiency  
- Economic competitiveness |
| Real-Time Predictions for Freight Deliveries/Arrivals | When freight vehicle location data are integrated with real-time predictive models of future performance implemented with ICM programs, more accurate estimates for vehicle delivery times are possible. These data can be used by logistics companies to properly anticipate vehicle arrivals at terminals or warehouses, or to provide customers with more precise information about the progress of their shipments. | - Quality customer service  
- Economic competitiveness |
<table>
<thead>
<tr>
<th>ICM Strategy</th>
<th>Description</th>
<th>Potential Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Trip Planning and</td>
<td>Tools and information displays can be used to inform travelers about travel choices, such as bus routes or rail stations in the corridor that can serve commuters. Trip planning tools, most notably Google Transit, are widely used by transit riders to better understand transit options and schedules. For example, the San Diego ICM demonstration is providing en-route and pre-trip traveler information and enhanced transit network information through a new 511 smartphone app for trip decision-making.</td>
<td>• Travel time reliability</td>
</tr>
<tr>
<td>Wayfinding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real-Time Arrival and Status Information</td>
<td>Many transit systems already provide real-time train and bus information giving customers expected arrival times that use GPS-based vehicle location systems. Integrating bus location information with real-time traffic conditions (such as speeds) can improve the estimates of bus arrival times.</td>
<td>• Travel time reliability</td>
</tr>
<tr>
<td>Transit Access and Intermodal</td>
<td>Information systems can improve the ability of riders to make intermodal transfers. For example, space availability at park and ride lots and transit stations can be broadcast along the corridor to assist travelers in selecting the best parking location.</td>
<td>• System efficiency</td>
</tr>
<tr>
<td>Transfers</td>
<td></td>
<td>• Accessibility</td>
</tr>
<tr>
<td>Incident/Operations Management</td>
<td>Many regions have deployed procedures and communication systems to enable transit operators to receive real-time information on traffic congestion or disruptions, enabling them to reroute buses around incidents.</td>
<td>• Travel time reliability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• System efficiency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Safety</td>
</tr>
<tr>
<td>Transit Signal Priority (TSP)</td>
<td>In many corridors, traffic signal systems are being used to grant buses priority at intersections, using red truncation or extended green phases to allow buses to reduce intersection delay. Priority can be granted unconditionally to buses or can be conditional so that buses receive more green time when they are running behind schedule. TSP can also be used along with other roadway priority such as queue jumps and bus lanes.</td>
<td>• Travel time reliability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• System efficiency</td>
</tr>
<tr>
<td>Integrated Fare Payment</td>
<td>Integrating payment media so that travelers can pay for parking and transit with the same contactless smart card can promote more seamless transfers.</td>
<td>• System efficiency</td>
</tr>
<tr>
<td>ICM Strategy</td>
<td>Description</td>
<td>Potential Benefits</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------</td>
</tr>
<tr>
<td>Local Agency Coordination</td>
<td>A common challenge associated with major incident response situations is quickly and effectively coordinating with local jurisdictions and agencies to address evolving conditions that require immediate attention (e.g., deactivating live electrical wires, alerting rail agencies of obstructions/conditions that could impact their operations, issuing evacuations). ICM can improve the process for identifying and communicating with the appropriate points of contact at each agency in a variety of situations, as well as developing a predetermined set of procedures to be followed by each agency in a given situation as agreed upon by all parties in advance.</td>
<td>• Prompt, reliable, interoperable communication</td>
</tr>
<tr>
<td>Coordinated Detour Routing</td>
<td>With an ICM program, a set of approved detour routes for general traffic and for restricted vehicles (e.g., freight) can be determined in advance, along with the criteria and procedures for activating those routes. Doing so allows incident responders to quickly evaluate whether a detour route is warranted, and to efficiently activate suitable detour routes as needed. With appropriate ICM detour route procedures, incident responders can be confident that detour routes will be capable of handling the diverted traffic.</td>
<td>• Responder safety • Safe, quick incident clearance • Prompt, reliable, interoperable communication</td>
</tr>
<tr>
<td>Incident Confirmation</td>
<td>A common challenge associated with incident response is confirming the location and details of an incident, so that suitable responders may be promptly dispatched to the proper location. Integration between CAD systems, state and local agency CCTV systems, real-time traffic performance monitoring systems, and available personnel in the field (e.g., transit operators, tow truck operators) provides emergency dispatchers with the resources to confirm the specifics of an incident efficiently, thereby reducing response time and contributing to faster clearance times, reduced traffic impacts, fewer secondary incidents, and other positive outcomes.</td>
<td>• Responder safety • Safe, quick incident clearance • Prompt, reliable, interoperable communication</td>
</tr>
<tr>
<td>Pedestrian and Bicyclist Detection at Signalized Intersections</td>
<td>Pedestrians are often instructed to wait even during green phases at signalized intersections. Wait times are costlier to pedestrians and bicyclists (relative to vehicle occupants) as they are exposed to the elements. Signal timing plans can be designed to grant pedestrian green time more frequently, or video detection of non-motorized roadway users waiting in the crosswalk area can be used to inform signal timing plans.</td>
<td>• Equity • Safety</td>
</tr>
</tbody>
</table>
**ICM Strategy** | **Description** | **Potential Benefits**
--- | --- | ---
Expansion of Park and Ride Lots | Expansion of park and ride lots within the corridor including adding capacity to existing lots, increasing the number of lots, and improving their ingress and egress to the freeways, adjacent transit stations, and local communities. These lots also have significant potential to attract pedestrian and bicycle users who will board transit or carpool. Planning for these users could include bicycle paths, pedestrian trails, bike lockers, and other amenities that ensure users make the most of these non-auto modes. | • Accessibility  • Connectivity

Pedestrian and Bicyclist Crowdsourced Data Apps | Limited by the technology to accurately detect and count bicyclists and pedestrians the way vehicle volumes are obtained, crowdsourced data may be another option for collecting this type of real-time and historical data. Most non-motorized roadway users are equipped with connected mobile devices. By designing a user-friendly app that collects their volumes, origins, and destinations, alternate routes for vehicles can be designed to include minimal conflict points with popular non-motorized roadway user routes. ICM teams may integrate bicyclist and pedestrian data in the same systems that are already being used to share and analyze vehicle data. | • Safety

Pedestrian and Bicyclist-Specific Traveler Information Dissemination | Currently, traveler information disseminated through 511 systems and CMSs is rarely relevant to non-motorized roadway users. Pedestrian and bicyclist-specific traveler information (e.g., impacts to non-motorized roadway users during incidents, vehicle volumes and speeds on arterials, intersection delays, high frequency crash locations, impacts of ICM trip diversion on crash risk levels, quality of street lighting and sidewalks, etc.) may be more effectively communicated via real-time mobile alerts or pedestrian and bicyclist-specific trip planners. | • Safety

**Identify Data and Information Sources**

As the list of strategies to include in the ICM concept is being brainstormed, it is necessary to determine whether the data/information needed for each strategy exists and is available for use. This is when the lead ICM agency will begin to inventory all the existing ITS infrastructure elements that may be useful to the ICM project (e.g., traffic management field and central elements, communications, software). This is also where stakeholders can offer a lot of value. By prioritizing strategies that provide them benefits, they may be more willing to provide data inputs to the ICM system that were not previously available to the lead ICM agency. To define the envisioned process and inter-relations the ICM team can develop a high-level architecture diagram such as the one in Figure 11 to show the key systems that play a part in the ICM system and the directional flow of data. This is also an easy way to identify any data gaps and devise a plan to fill.
them (e.g., negotiate with stakeholders who own the data needed, install equipment to capture the necessary data, or purchase data from third-party data vendors), or revise the ICM concept as needed.

Figure 11. San Diego I-15 ICM High-Level Architecture Diagram

**Define Operational Scenarios and Roles and Responsibilities**

Obtaining buy-in from participating stakeholders is important, but it is only the first step. It must be clear to each member of the ICM team what their roles and responsibilities are for each operational scenario that engages the ICM system. These roles and responsibilities need to be documented as operational scenarios (story-telling format describing the sequence of events in each scenario) and response plans (specific instructions assigned to specific roles).

The bulleted list below is a set of representative operational scenarios. The first scenario is useful for recurring congestion conditions, while the other scenarios focus on addressing different types of incidents and planned events that can lead to nonrecurring congestion. Table 17 provides an example that can be used by agencies as a starting point for developing more specific response plans (location, duration, time of day, severity level, area of impact, etc.).

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• **Daily operations** – The agencies with operational jurisdiction over the ICM corridor (e.g., State DOT, regional MPOs, and/or local DOTs) should take the lead in this scenario since they oversee monitoring freeway and arterial traffic flow, operating freeway and arterial field devices, and coordinating Freeway Service Patrol services.

• **Freeway incident** – The State DOT or regional MPO with jurisdiction over the freeway should take the lead in this scenario since they are likely to be the first to identify any unusual activity through their incident detection systems.

• **Arterial incident** – The local DOT with jurisdiction over the arterial should take the lead in this scenario since they are likely to be the first to identify any unusual activity through their incident detection systems.

• **Transit incident** – The transit agency should take the lead in this scenario since the on-board transit operator is likely to be impacted by the incident first hand and can report the incident immediately to transit dispatchers.

• **Special event** – The regional MPO or local DOT should take the lead in this scenario since planned short-term or long-term events generally require advance coordination with these agencies that will implement the appropriate measures to handle temporary increases in traffic.

• **Disaster response** – Incident responders should take the lead in this scenario since 911 will be the first point of contact.

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**Table 17. Transit incident response plan**

<table>
<thead>
<tr>
<th>General Description</th>
<th>Major or Minor Incident Affects Transit Vehicle. Incident Potentially Involves Vehicle Mechanical Failures, Passenger Medical Issues, Crash with a Motor Vehicle, etc.</th>
</tr>
</thead>
</table>
| Operational Objectives | • Establish passenger safety  
• Increase responder safety  
• Reduce secondary crashes  
• Decrease incident clearance time  
• Reduce delay  
• Maintain travel time reliability |
| ICM Strategies to Consider | • Common incident management system (combination of incident detection systems and incident response plans)  
• Emergency vehicle signal preemption  
• AVL  
• Computer aided dispatch (CAD)  
• Corridor signal coordination/Adaptive signal coordination  
• Freeway-arterial traffic coordination  
• Pedestrian countdown signals at intersections  
• Queue warning  
• Dynamic traveler information (CMSs, 511 systems, mobile app alerts)  
• Dynamic routing around active incidents via actionable traveler information (e.g., travel times on alternate routes or modes) |
<table>
<thead>
<tr>
<th>General Description</th>
<th>Major or Minor Incident Affects Transit Vehicle. Incident Potentially Involves Vehicle Mechanical Failures, Passenger Medical Issues, Crash with a Motor Vehicle, etc.</th>
</tr>
</thead>
</table>
| Regional MPOs and local DOTs | • Reported incident is automatically disseminated to ICM team  
• Trigger CMS and 511 system updates to alert the traveling public of incident details and estimated clearance time (local jurisdictions may need to update their own CMSs)  
• Monitor incident detection systems (e.g., CCTVs, ATMSs) for activity that may further impact the transit incident (e.g., nearby arterial incident)  
• Dispatch traffic management team to provide traffic control around the primary incident and reduce chance of secondary incidents  
• Monitor freeway and arterial congestion levels on shared ATMS  
• Initiate response plan actions (e.g., lane closures, ramp meter and/or signal timing plan changes, setting up portable CMSs for queue detection, etc.) |
| Freight | • Reroute trucks to other freight-permitted arterials if possible  
• Delay truck departure times until incident is cleared  
• Reschedule pick-ups or deliveries as needed, based on estimated delays |
| Transit (Lead operating agency) | • On-board transit operator reports incident or activates panic button  
• Identify on-board passengers in need of aid  
• Dispatch vehicle maintenance or additional transit vehicle to transport on-board passengers |
| Incident Responders | • Local police department is alerted to possible arterial incident via automated incident detection system, TMC CCTV feeds, transit operators, or 911 reports  
• Police department dispatcher uses dynamic traveler information to reach the scene of the incident quickly and safely  
• Police department confirms incident details once on scene, requests the necessary incident responders (e.g., towing company, fire department, coroner’s office, hazardous materials [HAZMAT] response team, etc.), and estimates clearance time  
• Coordinate with MPOs and local jurisdiction to close roads, freeway on-ramps, off-ramps if necessary |
| Non-motorized Roadway Users | • Use dynamic traveler information sources and set up alerts for high crash risk locations  
• Avoid travel on major arterials with high levels of vehicular traffic |

**Develop Concept of Operations**

When the various components of the ICM concept have been brainstormed and defined, the next step is to document the planning work done to date in a Concept of Operations document. A Concept of Operations document describes at a high level how the system will be used from the viewpoint of various stakeholders. It builds upon the user needs identified through all the stakeholder engagement activities conducted. The document provides the initial systems engineering blueprint for the development of the ICM system, including high-level concept, main functionality of the system, operational scenarios, and anticipated impacts. The standard outline according to Institute of Electrical and Electronics Engineers (IEEE) 1362 contains the following sections:

- **Section 1, Scope** provides a document overview and a brief overview of the system to be built.
- **Section 2, Referenced Documents** lists any supporting documentation used and other resources that are useful in understanding the operations of the system.
• **Section 3, The Current System or Situation** describes the current system or situation, how it is used currently, and its drawbacks and limitations.
• **Section 4, Justification for and Nature of Changes** leads into the reasons for the proposed development, a discussion of the nature of the planned changes, and a justification for them.
• **Section 5, Concepts for the Proposed System** describes the high-level, conceptual operational concept for the selected approach, indicating the operational features that are to be provided, without specifying design details. It includes diagrams, graphics, and a high-level information connectivity diagram that together present the overall system concept.
• **Section 6, Operational Scenarios** is the heart of the document. This section presents how the project is envisioned to operate from various perspectives. These are developed as “day-in-the-life” descriptions of how participants/stakeholders would interface, use, and benefit from the system.
• **Section 7, Summary of Impacts** describes impacts the system will have on stakeholders, users, and system owners/operators.
• **Section 8, Analysis of the Proposed System** dives into anticipated impacts during development on existing operations, disadvantages and advantages of the proposed system, as well as alternative solutions and tradeoffs considered.

**Task 6 Checklist**

- Develop a list of high-interest ICM strategies that address stated user needs.
- Identify incoming and outgoing data needs and sources for each data need.
- Identify and fill data gaps.
- Develop a high-level architecture diagram that shows the key systems of the ICM system.
- Develop operational scenarios that describe in detail how the ICM system is anticipated to operate in each scenario.
- Define roles and responsibilities for each participating ICM entity/stakeholder through response plans.
- Develop a Concept of Operations document.

**Task 7 – Designate Performance Metrics**

Identifying performance metrics of interest to corridor operators and stakeholder entities is key to initiating conversations for enhanced two-way data and information sharing.

**Major Issues and Challenges**

Evaluating the ICM project using performance measures is critical to determine the effectiveness of the ICM investment and selected ICM strategies. The major challenge with performance measure evaluation is the availability of high quality, continuous, accurate data. With the incorporation of multimodal ICM strategies, chances are that the ICM agency cannot rely solely on internal systems for the data needed. They need to be aware of highly sensitive data that certain entities won’t be open to sharing. ICM agencies may also need to find ways to obtain data that is not currently being captured automatically. Discussions with stakeholder groups need to cover potential data sources and willingness to share information to determine the feasibility of high-interest ICM strategies.
**Potential Solutions**

ICM Performance Measures

Performance measures are quantifiable metrics of how well the ICM system is progressing towards the adopted goals and objectives. As recommended in FHWA’s *Scoping and Conducting Data-Driven 21st Century Transportation System Analyses* report⁹, early in the project, the ICM team should define performance measures that are in line with the project objectives, mitigation strategies under consideration, analysis scenarios, and operational conditions (shaped by the understanding of available data) identified for the project.

Performance measures should be closely tied to the identified overall project goals and objectives and the expected traveler responses. For many improvement strategies, it is important to consider a set of performance measures that are sensitive to recurring and nonrecurring congestion. The ICM team should identify the selected performance measures and the approach for calculating the performance measures based on the capabilities and available data of the ICM system.

An effective way to identify appropriate performance measures is to test one or more specific hypotheses for each objective. These hypotheses can indicate a change in travel conditions (such as: *The ICM strategies will reduce travel times during an incident by 5 percent*) or can be neutral in the prediction of an impact (such as: *The strategies will not result in a change in emissions rates*). Performance measures that support the testing of the formulated hypothesis should be identified. Using this method ensures that the performance measures are appropriately mapped to the project goals and objectives.

The performance measures should:

- Provide an understanding of travel conditions in the study area, including localized and system-wide metrics representing impacts in the immediate vicinity of the proposed improvement and in the larger study area.
- Be consistent with lead agency overall performance measures used to evaluate all sorts of transportation improvements.
- Demonstrate the ability of improvement strategies to improve mobility, throughput, and travel reliability based on current and future conditions.
- Help prioritize individual investments or investment packages within the study area.

Transportation analysis performance measures typically focus on five key areas: mobility, reliability and variability of travel time, transportation safety, emissions and fuel consumption, and cost estimation. However, customized measures may be selected based on unique impacts of individual mitigation strategies.

In attempting to optimize a system’s performance across all these measures, the analyst may be faced with conflicting objectives and constraints as they relate to different performance measures. For example, minimizing travel time or maximizing travel speed are often in conflict with minimizing emissions of fuel consumption. To overcome this conflict, the stakeholders and analysts must make tradeoffs that typically result in less than optimal system elements for a specific measure but also result in a system that strikes a balance between multiple performance measures, hopefully optimized in different ways for different operational conditions.

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NCHRP Document 97: Guide to Effective Freeway Performance Measurement\textsuperscript{10} is a resource that provides transportation engineers and planners assistance in developing and maintaining a comprehensive freeway performance monitoring program. Multiple aspects of freeway performance were considered, including congestion, mobility, safety, operational efficiency, ride quality, environmental, and customer satisfaction. This report’s guidance can lend itself to ICM projects where freeway congestion is often the driver for these types of project implementations. Adapted from NCHRP Document 97, the performance measures presented in Table 18 provide a wide variety of potential performance measures that can be used to evaluate how well an ICM project meets its goals and objectives. In the table, “Quality of Service” denotes a more intuitive term for the outcome category of measures, while “Activity-Based” is more apt for the output category of measures.

Table 18. Freeway Performance Measure Examples

<table>
<thead>
<tr>
<th>Type of Performance Metric</th>
<th>Performance Metric Category</th>
<th>Example Performance Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of Service</td>
<td>Average Congestion Conditions</td>
<td>Travel time; travel time index; total delay (vehicles, persons); delay per vehicle; spatial extent of congestion; temporal extent of congestion; density</td>
</tr>
<tr>
<td></td>
<td>Reliability</td>
<td>Buffer index; planning time index</td>
</tr>
<tr>
<td></td>
<td>Throughput</td>
<td>Throughput (vehicle, persons); vehicle miles of travel; truck vehicle miles of travel; lost highway productivity</td>
</tr>
<tr>
<td></td>
<td>Customer Satisfaction</td>
<td>Travelers usually remember the worst aspect of freeway congestion; satisfaction with time to make long distance trips using freeways</td>
</tr>
<tr>
<td></td>
<td>Safety</td>
<td>Total crashes; fatal crashes; overall crash rate; fatality crash rate; secondary crashes</td>
</tr>
<tr>
<td></td>
<td>Ride Quality</td>
<td>Present Serviceability Rating (PSR); International Roughness Index (IRI)</td>
</tr>
<tr>
<td></td>
<td>Environment</td>
<td>Nitrous oxides (NOx) emissions rate; Volatile Organic Compound (VOC) emission rate; Carbon Monoxide (CO) emission rate; fuel consumption per vehicle miles traveled</td>
</tr>
<tr>
<td>Activity-Based</td>
<td>Capacity Bottleneck</td>
<td>Geometric deficiencies related to traffic flow; major traffic-influencing bottlenecks</td>
</tr>
<tr>
<td></td>
<td>Incident Characteristics</td>
<td>Number of incidents by type and extent of blockage; incident duration; blockage duration; lane-hours lost due to incidents</td>
</tr>
<tr>
<td></td>
<td>Work Zones</td>
<td>Number of work zones by type of activity; lane-hours lost due to work zones; average work zone duration by type of activity; lane-miles lost due to work zones</td>
</tr>
<tr>
<td></td>
<td>Weather</td>
<td>Extent of highways affected by snow, ice, rain, or fog</td>
</tr>
<tr>
<td></td>
<td>Operational Efficiency</td>
<td>Percent freeway directional miles with equipment coverage; percent of equipment in “Good” condition; percent of total device-days out-of-service by type of device; number of service patrol assists</td>
</tr>
</tbody>
</table>

Figure 12 reiterates the main objectives of several major stakeholder groups, as outlined in Task 2. For ICM projects that involve any of these stakeholder groups, it would be beneficial to include performance measures tied to these objectives, in addition to any selected from Figure 12.

(Source: NCHRP report 899 - Broadening Integrated Corridor Management Stakeholders)

**Figure 12. Main Objectives of Various Stakeholder Groups**

**Data for Performance Measure Evaluation**

To the extent possible, ICM performance measures selected should be reported for the overall system and by:

- **Mode**—SOVs, HOVs, transit, freight, etc.
- **Facility Type**—Freeways, expressways, arterials, local streets, etc.
- **Jurisdiction**—Region, county, city, neighborhood, and study area-wide.

Listed below are examples of data that can be collected to evaluate each performance measure area. Much of the work done in Task 6 to identify data and information sources for the ICM concept will lay the foundation for data needed to calculate performance metrics of interest.

- **Mobility** – Travel time (average travel time), delay (vehicle hours of delay, person hours of delay), throughput (vehicle miles traveled, person miles traveled, vehicle hours traveled, person hours traveled)
- **Reliability** – Buffer time, changes in the Planning Index, variability (changes in the standard deviation of travel time)
- **Safety** – Number of primary and secondary accidents/crashes in the study area, severity of accidents/crashes in the study area, locations of accidents/crashes in the study area
- **Emissions and Fuel Consumption** – Emissions (nitrogen oxides, particulate matter, hydrocarbons, volatile organic compounds, carbon monoxide, sulfur dioxide, hazardous air pollutants, greenhouse gases) rates, gallons consumed per fuel type
- **Cost Estimation** – Capital costs (infrastructure costs, incremental costs), operating costs, maintenance costs
- **Navigability** – Relevance of alternate routes proposed (e.g., freight vs. bicyclists/pedestrians)
- **Economic Competitiveness** – Delay, number of freight vehicle moves per day
- **Customer Service** – Timeliness of traveler information, accuracy of traveler information, incident response and clearance times
- **System Efficiency** – Delay, transit schedule adherence, transit ridership, transit vehicle occupancy levels
- **Affordability** – Cost to customers
- **Accessibility** – Variety of transit services available (e.g., ADA compliant), location of transit stations, proximity of transit stations to bike racks, bicycle/pedestrian paths, or park and ride lots
• **Communications** – Timeliness and reliability of incident information to incident responders, as well as the traveling public
• **Connectivity** – Number of continuous miles of bicycle and pedestrian facilities, parking availability at transit facilities, parking demand at transit facilities
• **Equity** – Travel times per mode, delays per mode, accidents/crashes per mode

**Task 7 Checklist**

- Identify performance metrics that are in line with the project objectives.
- Identify data elements needed to evaluate each performance metric.
- Identify potential data sources for selected performance metrics.

**Task 8 – Assess Benefits of the Planned ICM Deployment**

Assessing the expected benefits and impacts of ICM can provide valuable insight into the potential cost-benefits of ICM. This assists the ICM team and corridor stakeholders implementing ICM to:

- Gain institutional and financial support for an ICM project by assessing the benefits of the planned ICM deployment in a data-driven approach.
- Invest in the right strategies. ICM analysis offers corridor managers a predictive forecasting capability to help them determine which combinations of ICM strategies are likely to be most effective and under which conditions.
- Help decision makers identify technical and implementation gaps, evaluate ICM strategies, and invest in the combination of strategies that would most minimize congestion and produce the greatest benefits. Analysis increases the likelihood of ICM success and helps minimize the unintended consequences of applying ICM strategies to a corridor. It provides an enhanced understanding of existing corridor conditions and deficiencies, allowing for the improved ability to match and configure proposed ICM strategies to the situation at hand.
- Help managers estimate the benefits resulting from ICM across different transportation modes and traffic control systems. Importantly, it helps managers to align these estimates with specific assumptions about corridor conditions and ICM strategies. Without being able to predict the effects of ICM strategies corridor transportation agencies may not take the risk of making the institutional and operational changes needed to optimize corridor operations.
- Facilitate the detailed development of concepts of operations and requirements by stakeholders and help corridor managers define and communicate key analysis questions, project scope, partner roles, and partner responsibilities. ICM analysis facilitates the development of concepts of operations and requirements by stakeholders in more detail and helps corridor managers understand in advance what questions to ask about their system and potential combinations of strategies to make any implementation more successful. This can lower the risk associated with implementation.
- Help to communicate the scope of the project and appropriately set expectations among differing project stakeholders and provide a clearer definition of expected roles and responsibilities. ICM analysis also helps managers identify and prioritize resources to project objectives, allowing for the effective and efficient allocation of resources and sounder project management.

**Major Issues and Challenges**

One of the most effective ways to convince program-level decision makers to support an ICM effort and add the ICM project to the Statewide Transportation Improvement Program (STIP) and Transportation Improvement Program (TIP) is to show the quantitative benefits anticipated from the project. The value gained from ICM analysis usually outweighs the expense and pays dividends throughout an ICM project.
by reducing the chance of very expensive missteps in implementation, streamlining the implementation process. As the ICM analysis continues in parallel with the ICM system development and design process, it is likely that new strategies, alternatives, and scenarios will emerge that will need to be evaluated within the analysis process; therefore, the flexibility to foresee and account for several iterations of analysis is critical. The design process may reveal new strategies or alternatives that may need to be analyzed. Likewise, the analysis may reveal parts of the concept of operations that are unworkable or uncover opportunities that may be leveraged that result in changes to the ultimate ICM design. ICM analysis can be demanding in terms of data needs, staff skill levels, and the amount of time and resources that need to be devoted to implement and conduct the analysis successfully. Caveats to practitioners include the following:

- Significant data may be needed to conduct the analysis. These data may need to be high quality, reliable, and provide continuous coverage over long periods of time. If data fitting the requirements of the analysis are not readily available, the costs and resources necessary to conduct the analysis may need to be expanded to collect and analyze the necessary data. Using poor-quality or insufficient data will produce inaccurate results that may lead to poor investment decisions. These data requirements have become less of an issue with the advent of private sector data sources based on information provided by smart phones and in-vehicle GPS devices; travel times, travel speeds, and even origin-destination information can now be obtained inexpensively from private sector data sources. Traffic volumes, however, are still needed at many locations in the analysis network.
- Staff skill levels must be suitable to the analysis requirements. Agencies with only cursory or even intermediate analysis skills should plan either to add budget for staff training or to acquire consultant services to meet these needs.
- Even if data are available and staff skills are robust, the cost of compiling and analyzing the baseline data, developing the analysis framework, calibrating the tools, and completing the analysis is significant and should only be undertaken in situations where the risk of making a poor investment decision outweighs the costs.

Potential Solutions

Analysis, Modeling, and Simulation

There are different approaches to assessing ICM benefits and impacts – some more precise than others. Analysis, Modeling, and Simulation (AMS) (shown in Figure 13 was used to analyze the USDOT’s ICM demonstration deployments in San Diego and Dallas, and is being used to assess benefits and impacts at complex ICM deployments in Los Angeles, Buffalo, NY, and Orlando, FL. It is used to assist corridor operators in forecasting and assessing the potential benefits and implications of ICM in their corridors of interest by analyzing different operational conditions across time and modes and across a large enough geographic area to absorb all impacts. One major benefit of conducting AMS is that it helps to assess the feasibility of and refine the concept of ICM, work with stakeholders to address expected impacts, and iteratively enhance the Concept of Operations until a workable ICM plan is developed. It is recommended to conduct AMS iteratively to assess the feasibility of the proposed ICM strategies, identify the most promising strategies, and identify the operational conditions under which the ICMS would be most effective.
There are many variables that affect level of effort for any of these work steps, including the existence of, and level of precision in, available ICM Concept of Operations documentation; quantity, quality, and availability of needed data; cohesion in stakeholder vision for the AMS effort; and experience of the corridor staff with modeling tools in previous efforts, among others. Although each analysis will vary due to these factors, a rough order of magnitude estimates of the proportion of analysis resources that may be required of the different analysis steps includes:

- Develop Analysis Plan—15 percent
- Develop Data Collection Plan and Collect Data—15 percent
- Model Setup and Calibration—35 percent
- Alternatives Analysis and Documentation—30 percent
- Continuous Improvement—5 percent (in most cases this process is beyond the immediate project scope)

For the USDOT’s ICM Pioneer and Demonstration Sites, the costs of developing and conducting the AMS accounted for approximately five percent of the overall deployment budget. The AMS costs for the Pioneer and Demonstration Sites were likely proportionately higher than they would be in future analysis, due to the need to develop and refine new analysis methods and procedures. If the analysis was successful in better structuring the deployment to increase the efficiency of the ICM by a minimum of five percent or reduced the risk of a deployment cost overrun of five percent or more, the investment in AMS paid for itself. The partners at the Pioneer Sites felt there was significant value in AMS, which greatly outweighed the analysis costs.
Data Collection

Table 19 shows an example of an at-a-glance high-level summary of the preliminary types of data anticipated to be required for the AMS. The Analysis Plan should also identify those individuals/stakeholders responsible for compiling the data. The AMS managers should work closely with stakeholders in compiling the data. A significant challenge in collecting useful AMS data is that the data are often required to be concurrent (i.e., all collected for the same period, not assembled from data collected on various dates and times) across all facilities and modes to be useful. If possible, the AMS managers should obtain samples of the datasets prior to full collection to view the content and format of the data and adjust collection plans if necessary.

Table 19. Example Data Requirements for Analysis, Modeling, and Simulation

<table>
<thead>
<tr>
<th>Network</th>
<th>Travel Demand</th>
<th>Traffic Control</th>
<th>Transit</th>
<th>ITS Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Link Distances</td>
<td>Link Volumes</td>
<td>Freeways Ramp Metering</td>
<td>Transit Routes</td>
<td>Surveillance System</td>
</tr>
<tr>
<td>Geometrics—Freeways</td>
<td>Traffic Composition</td>
<td>Type (local, system-wide)</td>
<td>Transit Stops</td>
<td>Detector Type</td>
</tr>
<tr>
<td># Travel Lanes</td>
<td>On- and Off-Ramp Volumes</td>
<td>Detectors</td>
<td>Location</td>
<td>Detector Spacing</td>
</tr>
<tr>
<td>Presence of SHOULDERS</td>
<td>Turning Movement Counts</td>
<td>Metering Rates</td>
<td>Geometrics</td>
<td>CCTV</td>
</tr>
<tr>
<td>HOV Lanes (if any)</td>
<td>Vehicle Trip Tables</td>
<td>Algorithms (adaptive metering)</td>
<td>Dwelling Times</td>
<td>Information Dissemination</td>
</tr>
<tr>
<td>Operation of HOV Lanes</td>
<td>Person Trip Tables</td>
<td>Mainline Control</td>
<td>Transit Schedules</td>
<td>CMS</td>
</tr>
<tr>
<td>Accel/Dec Lanes</td>
<td>Transit Ridership</td>
<td>Lane Use Signals</td>
<td>Schedule Adherence Data</td>
<td>HAR</td>
</tr>
<tr>
<td>Grade</td>
<td>Grade</td>
<td>Variable Speed Limits</td>
<td>Transfer Locations</td>
<td>Other (e.g., 511)</td>
</tr>
<tr>
<td>CurveR</td>
<td>CurveR</td>
<td>Arterials</td>
<td>Transit Speeds</td>
<td>In-Vehicle Systems</td>
</tr>
<tr>
<td>Ramps</td>
<td>Ramps</td>
<td>Signal System Description</td>
<td>Transit Fares</td>
<td>Incident Management</td>
</tr>
<tr>
<td>Geometrics—Arterials</td>
<td>Controller Type</td>
<td>Controller Type</td>
<td>Payment Mechanisms</td>
<td>Incident Detection</td>
</tr>
<tr>
<td>Number of Lanes</td>
<td>Phasing</td>
<td>Detector Type and Placement</td>
<td>ParaTransit</td>
<td>CAD System</td>
</tr>
<tr>
<td>Lane Usage</td>
<td>Signal Settings</td>
<td>Signal Timing Plans</td>
<td>Demand-responsive</td>
<td>Response and Clearance</td>
</tr>
<tr>
<td>Length of Turn Pockets</td>
<td>Signing</td>
<td>Transit Signal Priority System</td>
<td>Rideshare programs</td>
<td>Incident Data Logs</td>
</tr>
<tr>
<td>Grade</td>
<td>Control Logic</td>
<td>Control Logic</td>
<td></td>
<td>Tolling System</td>
</tr>
<tr>
<td>Turning Restrictions</td>
<td>Detection</td>
<td>Detection</td>
<td></td>
<td>Type</td>
</tr>
<tr>
<td>Parking</td>
<td>Settings</td>
<td>Settings</td>
<td></td>
<td>Pricing Mechanisms</td>
</tr>
<tr>
<td>Parking Facilities</td>
<td>Emergency Preemption System</td>
<td>Emergency Preemption System</td>
<td></td>
<td>TMC</td>
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<tr>
<td>Location</td>
<td>Control Logic</td>
<td>Control Logic</td>
<td></td>
<td>Control Software/Functions</td>
</tr>
<tr>
<td>Capacity</td>
<td>Detection</td>
<td>Detection</td>
<td></td>
<td>Communications</td>
</tr>
<tr>
<td>Park-and-Ride Lots</td>
<td>Settings</td>
<td>Settings</td>
<td></td>
<td>Data Archival Dissemination</td>
</tr>
<tr>
<td>Location</td>
<td></td>
<td></td>
<td></td>
<td>Transit/Fleet Management System</td>
</tr>
<tr>
<td>Capacity</td>
<td></td>
<td></td>
<td></td>
<td>AVL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Communications</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Traveler Information Bus Stops</td>
</tr>
</tbody>
</table>

Notes:
- These data must be provided for all links in the corridor study area.
- These data must be provided for a consistent analysis time period, including the same date for data from all facilities in the corridor area.
- To facilitate the assessment of variability in traffic volumes and speeds, data must be provided for multiple days of the week and months of the year for all facilities in the study corridor.

Tools for ICM AMS

The development and refinement of the AMS process at the ICM site locations revealed limitations in using currently available models for conducting assessment of ICM. Different tool types have different advantages and limitations. Sites may find that no single model currently available provides all the needed visibility into the cascading impacts of various ICM strategies, much less combinations of strategies, across the entire network, transportation modes, and facility types. Therefore, an integrated approach is often necessary to support management of ICM planning, design, and operations by combining the capabilities of existing tools.

For many regions, the existing tool that is available will be the regional travel demand model. Subareas and networks will likely need to be developed from the larger macro scale models to focus on the more micro-level corridor. (Source: FHWA Traffic Analysis Tools Volume XIII: Integrated Corridor Management Analysis, Modeling, and Simulation Guide)
Figure 14 presents a sample view of the cascading effect of corridor concentration in the various types of models.

The ICM analysis effort helps illuminate which expectations are realistic, which may be unrealistic, and why. It identifies opportunities that optimize the study area’s transportation network by allowing analysts to experiment with adjusting mitigation strategies for the price of a model run rather than myopically making such adjustments to the actual deployed system, where the cascading second and third-order effects are more difficult to perceive in real-time.


**Figure 14. Network Detail Examples for Different Model Types**

For detailed guidance for each AMS work step, refer to FHWA’s *Traffic Analysis Toolbox Volume XIII: Integrated Corridor Management Analysis, Modeling, and Simulation Guide*\(^1\). The Guide is targeted at technical and/or program managers in transportation agencies at the State or local level who may oversee implementation of ICM and/or an ICM AMS initiative.

**Benefit/Cost Analysis**

A benefit/cost analysis is a rich analytic method, with its own supporting literature. A properly calculated benefit/cost analysis will monetize metrics that are comprehensive, mutually exclusive, and designed to render all effects to the appropriate side of the ledger as either a cost or a benefit.

To estimate the benefits in annual dollar values of the performance measures selected in Task 7, the annual incremental change in the various performance measures should be multiplied with an estimate of the monetary value of benefits (e.g., the value of an hour of travel time saved). Monetary values of benefits (e.g., value of time, value of accident reduction) should be consistent with those values typically applied in

the region. For those performance measures with no established local value, national benefit valuations may be applied. A potential source of benefit values is in FHWA guidance for conducting benefit/cost analysis for operations strategies compiled in the Operations Benefit/Cost Desk Reference. This documentation can be found at http://www.ops.fhwa.dot.gov/plan4ops/topsbctool/.

For the identified ICM strategies, planning level cost estimates will need to be prepared, including life cycle costs (capital, operating, and maintenance costs). Costs need to be expressed in terms of an annualized cost or the net present value of various components over a given time horizon (e.g., 20 years) and are defined as follows:

- **Capital Costs**—Include up-front costs necessary to procure and install ICM equipment. These costs will be shown as a total (one-time) expenditure and will include the capital equipment costs as well as the soft costs required for design and installation of the equipment.

- **Operations and Maintenance (O&M) Costs**—Include those continuing costs necessary to operate and maintain the deployed equipment, including labor costs. While these costs do contain provisions for upkeep and replacement of minor components of the system, they do not contain provisions for wholesale replacement of the equipment when it reaches the end of its useful life. These O&M costs will be presented as annual estimates.

- **Annualized Costs**—Represent the average annual expenditure that would be expected to deploy, operate, and maintain the ICM improvement; and replace (or redeploy) the equipment as they reach the end of their useful life. Within this cost figure, the capital cost of the equipment is amortized over the anticipated life of each individual piece of equipment. This annualized figure is added with the reoccurring annual O&M cost to produce the annualized cost figure. This figure is particularly useful in estimating the long-term budgetary impacts of ICM deployments.

The complexity of these deployments warrants that these cost figures be further segmented to ensure their usefulness. Within each of the capital, O&M, and annualized cost estimates, costs should be further disaggregated to show the infrastructure and incremental costs. These are defined as follows:

- **Infrastructure Costs**—Include the basic “backbone” infrastructure equipment necessary to enable the system. For example, to deploy a CCTV surveillance system, certain infrastructure equipment must first be deployed at the traffic management center to support the roadside ITS elements. This may include costs, such as computer hardware/software, video monitors, and the labor to operate the system. Once this equipment is in place, however, multiple roadside elements may be integrated and linked to this backbone infrastructure without experiencing significant incremental costs (i.e., the equipment does not need to be redeployed every time a new camera is added to the system). These infrastructure costs typically include equipment and resources installed at the traffic management center but may include some shared roadside elements as well.

- **Incremental Costs**—Include the costs necessary to add one additional roadside element to the deployment. For example, the incremental costs for the camera surveillance example include the costs of purchasing and installing one additional camera. Other deployments may include incremental costs for multiple units. For instance, an emergency vehicle signal priority system would include incremental unit costs for each additional intersection and for each additional emergency vehicle that would be equipped as part of the deployment. Analysts should be careful to include incremental costs of infrastructure created by issues of scale. For example, if the traffic management center CCTV infrastructure has the bandwidth to support 30 cameras but the deployment being analyzed would take the number from 25 to 35, then some incremental infrastructure cost would be incurred beyond the incremental camera costs themselves.

Structuring the cost data in this framework enables the user to readily scale the cost estimates to the size of potential deployments. Infrastructure costs would be incurred for any new technology deployment. Incremental costs would be multiplied with the appropriate unit (e.g., number of intersections equipped,
number of ramps equipped, number of variable message sign locations, etc.) and added to the infrastructure costs to determine the total estimated cost of the deployment. Presenting the costs in this scalable format provides the opportunity to easily estimate the costs of expanding or contracting the size of the deployment and allows the cost data to be reutilized for evaluating other corridors.

**Adherence to the Transportation Planning Process**

Per the USDOT, the transportation planning process is used to manage how limited funds available each year are distributed to projects. Transportation planning involves Federal and State government, MPOs, transit agencies, local public agencies, and the public. State DOTs are responsible for statewide planning, while MPOs are responsible for transportation planning in any urbanized area over 50,000 in population. Each State is required to develop a STIP — a staged, multi-year, statewide intermodal program of transportation projects — covering a period of at least four years. All projects that will use Federal-aid funds, including local public agency projects, must be listed in the STIP. Each MPO develops its own TIP that governs the project list for their area. TIPs are incorporated directly or by reference in each State’s approved STIP. The STIP needs to be consistent with the statewide transportation plan and planning processes as well as metropolitan plans, TIPs, and planning processes. The STIP must be developed in cooperation with the MPOs, public transit providers, and any Regional Transportation Planning Organizations (RTPO) in the state and must be compatible with the TIPs for the state’s metropolitan areas.12

When the STIP is modified by adding a new project or significantly increasing the cost of an existing project, other projects may need to be revised or removed from the STIP to make room for these changes so that the cost of the complete list of projects does not exceed the allotted amount. This means that anticipated costs for the proposed ICM project need to be estimated in advance of adding the project to the STIP. If the estimated project cost varies significantly from the approved STIP amount, a STIP amendment may be required to resolve the issue before the project can be authorized for construction. If the ICM project is in an MPO area, the TIP must be modified before modifying the STIP. Time needs to be allotted in the ICM planning process to ensure that the ICM project is properly added to the STIP and TIP to avoid unnecessary delays to the delivery of any Federal-aid project.13

**Task 8 Checklist**

- Determine ICM analysis methodology.
- Develop an analysis work plan.
- Identify data requirements for analysis.
- Estimate ICM benefits and costs.
- Begin the process of adding the ICM project to the STIP and TIP.

**Task 9 – Initiate Formal Agreements**

This task discusses formalizing institutional, organizational, and technical agreements with partners, stakeholders and the private sector to ensure the long-term success of the ICM project.

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Major Issues and Challenges

Up to this point, ICM stakeholder engagement efforts have consisted mainly of informal discussions regarding needs and ICM strategy feasibility. Participating entities may seem committed to the ICM project, but there are no guarantees that they will carry out their roles and responsibilities once the ICM system is deployed. In many cases, high staff turnover rate results in the loss of institutional knowledge and commitments. Initiating formal agreements is one way to help ensure these commitments, whether they are institutional, operational, or technical. For some stakeholder relationships, depending on their level of involvement with the project, an informal agreement may be enough. Another challenge to consider is how formal and informal agreements should be maintained and enhanced over time.

Potential Solutions

Understanding the Need for Formal Agreements

Managing a dynamic corridor effectively requires an equally dynamic management of agreements among ICM system stakeholders. ICM solutions are often deployed in highly complex and dynamic transportation corridors. These complex transportation corridors have an equally complex set of stakeholders. Successful ICM deployments over time must recognize that just as the tangible corridor assets made of concrete, asphalt, steel and silicon must be maintained and sometimes refreshed or replaced, the agreements binding stakeholders together must also be maintained and sometimes refreshed or replaced. As user needs and technologies change, how the ICM is conceptualized, defined, operated, and financed among stakeholders must change in response. The agreements enabling the ICM system to function must also include mechanisms so these agreements can be adapted over time. The documents describing the shared vision, roles, responsibilities, and tactical agreements made among the ICM system stakeholders – the institutional capital of the ICM system – are arguably the most critical ICM assets to ensure long-term cohesion among stakeholders and long-term viability of the ICM deployment.

If an ICM system is deployed as a static build-and-forget solution, it may soon become ineffective, irrelevant, and eventually abandoned in favor of other more relevant solutions aligned with current issues and concerns. Technical, organizational, and institutional agreements are bringing together ICM stakeholders to periodically reexamine corridor performance, emerging threats/issues, underlying changes in corridor traveler/user needs and demand patterns, ICM system capabilities, and the potential of emerging technologies. These periodic assessments should begin with challenging the previous purpose and nature of the ICM system, assess the capability of the ICM to meet performance goals, and to make plans to refine/replace unsatisfactory aspects of the ICM system.

Identifying Suitable Agreements for each ICM Deployment

There are three main types of agreements ICM teams should consider:

- Institutional Agreements – Govern how ICM stakeholders determine and guide the strategic direction of the ICM deployment over time – including geographic boundaries, scope of actions, financial plan, stakeholder engagement/retention, and institutional form.
- Operational Agreements – Govern the roles, responsibilities, limitations, and tactical interactions among ICM system operators engaged in real-time day-to-day decision-making within the corridor.
- Technical Agreements – Govern the ownership and responsibility among stakeholders for the security, monitoring, maintenance, and enhancements of ICM system assets (both tangible and intangible).
Institutional Agreements

Institutional agreements govern how ICM stakeholders guide the strategic direction of the ICM deployment over time – including geographic boundaries, scope of actions, financial plan, stakeholder roster, and institutional form.

These agreements focus on strategic ownership and delegation of responsibilities for the ICM system. They include a discussion of what kinds of access and control partners have, and broad decisions to integrate several separate systems in a decentralized manner, or to take a more centralized approach. Each approach has benefits and drawbacks, so agreements must be aligned with the technical and non-technical maturity of the current ICM system and its stakeholder partners.

It is important to define limits and boundaries for what an ICM system should cover (and not cover) and the nature of the actions it will take (and not take). For example, ICM is often deployed as a combination of applications and strategies specifically targeting nonrecurrent congestion conditions associated with major incidents, special events, and severe weather. In these cases, the ICM system may be tightly, loosely, or simply not connected with specific stakeholders, transportation modes, information channels, or facilities (e.g., signal systems at critical junctions with pedestrian/bike routes, parking or tolling policies, and dynamic transit dispatching). Every ICM system depends on the capabilities of the participating organizations – and an appropriate shared vision of these organizations to provide and maintain assets, share data, and take coordinated actions.

At the inception of the ICM effort, it may not be clear among stakeholders the nature and capabilities of each stakeholder organization – and some time may need to be set aside so that this shared level of understanding matures prior to making key decisions regarding scope, financial relationships, and organizational form. While more elaborate visions of an end-state ICM are useful to provide motivation for stakeholder engagement and a collective sense of ultimate destination, near-term institutional agreements are required dependent on a realistic assessment of what each ICM partner can provide in terms of people, assets, and capabilities. For example, intersection pedestrian detection systems may need upgrading to accommodate ICM strategies for special events, or additional transit staff may need to be trained to operate under special event policies tailored to absorb a predicted surge of pedestrian demand. New corridor-focused roles may need to be created outside of existing partner organizational structures and a process to identify and staff these positions may need to be put in place.

Institutional agreements include maintaining the ICM system scope, vision, and goals over time; agreements describing the scope, nature and duration of ICM system integration; financial and capital planning agreements; and agreements covering organizational forms and governance policy.

The type, number, and complexity of institutional agreements are highly dependent on the organizational form/framework used by the ICM stakeholders. These organizational forms range from more ad hoc informal agreements at one end of the spectrum, to more formal models where roles and responsibilities are clearly defined. In general, the type, number, and complexity of institutional agreements grow proportionally with the amount of formal structure inherent in the overarching organizational framework. A risk to any developing ICM concept is balancing documented agreements with the current and forecasted needs of the ICM stakeholders. Too few or vaguely documented agreements will deter the development of more robust, effective, integrated ICM solutions. Burdening an emerging ICM solution with too many or needlessly complex agreements may slow progress towards initial successes needed to create momentum.

14 Diagrams in this section are from Scoping and Conducting Data-Driven 21st Century Transportation System Analyses
In these cases, a lightweight approach to formal agreements may serve the ICM stakeholder community well for several years as the ICM solution develops from an early to a more advanced state.

**Operational Agreements**

Operational agreements govern the roles, responsibilities, limitations, and tactical interactions among ICM system operators engaged in real-time day-to-day decision-making within the corridor. Examples include common procedural agreements for ICM (e.g., whether a set of actions will be selected based on an automated system following an optimization algorithm, or according to a predetermined list of increasingly severe strategy responses, or some other method).

Note that ICM system development following a system engineering process will describe and develop detail associated with many of these procedures. In this case, the agreements can either directly reference the systems engineering documentation or alternatively, operational practices and processes can be extracted to create new organizational agreements. When the systems engineering documentation is comprehensive and maintained in an updated format, agreements that reference these documents have the advantage of not having to keep two parallel sets of documents consistently updated.

**Technical Agreements**

Technical agreements govern the ownership and responsibility among stakeholders for the security, monitoring, maintenance, and enhancements of ICM system assets (both tangible and intangible).

In addition to considering the nature of the agreements themselves, any other related agreements dealing with inputs/outputs of the system itself should also be considered. Every ICM system both ingests and produces data. In some cases, non-disclosure agreements may be required if the system ingests freight information. Similarly, specific elements of a stakeholder organization may need to be consulted to ensure that individuals on a transit agency network can introduce connections to external networks for data sharing with corridor users (outputs).

Refer to NCHRP Report 899 *Broadening Integrated Corridor Management Stakeholders* for detailed examples of each type of agreement.

**Potential ICM Governance Frameworks**

Searching for innovative, new ICM stakeholder engagement frameworks or strategies can benefit from evaluations of similar efforts that have been performed by other entities and organizations in analogous contexts in other industries. Potential sources of such frameworks may involve coordinating large projects among a diverse set of stakeholders with different interests.

Six example frameworks are presented here for the purposes of helping ICM stakeholders to assess potential initial ICM organizational forms – and as the ICM system matures and develops over time, alternative forms that may be better aligned with the needs of the ICM community. Frameworks are presented in the order of increasing ICM complexity and integration, starting with frameworks most often considered in the early stages of ICM deployment and concluding with potential advanced ICM frameworks where corridor management roles and practices are well defined and more formal corridor-specific organizational structures are required to improve efficiency and accountability. Many ICM systems will function best using early organizational forms – and may not need to move beyond less formal frameworks. However, under specific circumstances, more advanced and formal frameworks may be required to deliver...
on the strategic corridor vision – and the ability to react flexibly and efficiently to the challenge of corridor management.

**Ad Hoc Coordination (Early Model)**

In this early model, there is no formal charter or ICM concept. However, there is corridor-level coordination that occurs informally among stakeholders because of the natural intersection of corridor issues, events, conditions and aspects that may have brought stakeholders together in the past. In some cases, staff in one organization may have worked previously in another organization and there are personal relationships that act as natural bridges among corridor stakeholders. Often, the eventual success of developing an early ICM concept is dependent on these kinds of informal connections among individuals who have developed trust relationships that span multiple ICM stakeholder organizations. Among these individuals, there may be a documented corridor vision statement or short description that describes shared intent.

In the diagram shown above, the *Ad Hoc Coordination* model can be characterized as a collection of these trust relationships. The open circles represent individual staff, and the solid black lines between them reflect formal organizational chains of command in terms of supervisors, direct reports, and peers. Trust relationships among pairs of staff in different organizations relevant to ICM coordination are highlighted with orange dashed connections. Note that ICM stakeholder organizations may be relatively large (e.g., law enforcement or transit agencies) or as small as a single individual (e.g., a private citizen acting as an advocate for pedestrian safety, or an independent freight owner/operator). Note that the diagram shows that some organizations may have more of the ICM-relevant trust relationships, while others may have none. In this model there may be some coordinated action to develop new relationships or bring new stakeholders together to discuss shared problems and issues. However, there is no formal organizational structure beyond a registry of ICM stakeholders and the organizational capability to conduct periodic meetings of these stakeholders.

Strengths include the following:

- **Low cost.** This framework can be an effective and useful framework to create momentum for an early ICM concept.
- **Strong trust among participating stakeholders** since the individuals know each other and relationships are primarily personal.
- **Trust relationships can be maintained and strengthened** using relatively informal means – meet-ups, invitations to corridor stakeholder events, shared fantasy sports leagues. These events can also be used to network the trust relationships beyond single individual to single individual relationships.

Weaknesses include the following:

- **Lack of defined organization** may result in the ICM concept to be skewed towards the existing trust relationships and may leave out key stakeholders where relationships do not exist – or focus on sub-problems that do not address more fundamental underlying corridor-level issues.
- **Difficult to scale.** Trust relationships are individual-to-individual and not always transferable. Just because person A has a trust relationship with person B, and person B has a trust relationship with person C – it is not always a sure thing that persons A and C will also have (or easily develop) an equivalent trust relationship. Further, this framework is subject to replacement risk if key individuals take a new job, move to a new area, or retire.
• **Ad hoc impact.** The ad hoc nature of relationships implies that impact is similarly ad hoc – in some areas may be effective, but in other key areas may have no capability to address corridor issues because of a lack of existing trust relationships.
• **Risk of staff turnover.**

Best applied for the following:

• **Early ICM Deployments with Limited Institutional Momentum.** The Ad Hoc model can be an effective model to follow when the ICM concept is in an early state and institutional momentum needs to be generated to move towards a more comprehensive solution. The framework is not included here as an organizational counter-example – in some cases, the needs of a corridor can be fleshed out when a collection of existing trust relationships can be identified and cataloged. These existing trust relationships and the informal value of coordination among agencies can jump start an ICM concept-building activity because it shows that there is a real need and there are already individuals in place working to resolve corridor-level issues.

• **When a Representative ICM Victory Is Within Grasp.** In some cases, a specific corridor issue or situation can be addressed with limited coordination among a handful of individuals with strong trust relationships. In these cases, there is an opportunity for informal corridor-level coordination to create a success story that can motivate others to join in a broader ICM concept development and implementation effort. Metaphorically speaking, people are more likely to want to jump onto a moving bandwagon with demonstrated forward momentum rather than a motionless bandwagon with the potential to move forward.

### Roundtable of Champions (Early Model)

In this early model, senior leaders gather together to initiate or further develop an ICM concept. In this case, creating a charter for the corridor stakeholders and establishing goals may be an early agenda item.

As shown in the diagram, the *Roundtable of Champions* model can be characterized as relatively senior management in each organization creating a roundtable of similar individuals across the ICM stakeholder spectrum and inviting participation. Note that, as depicted, the roundtable is reserved only for senior managers, from the top of each of the subsidiary org charts. These senior managers take time away from their typical duties and participate in roundtable events to discuss corridor-level issues, performance, and potential forms of coordination. Note that these individuals do not leave their regular day jobs behind them, but add representing their organization at the roundtable to their roles and responsibilities list. For stakeholders with well-defined organizational charts, who serves in the Roundtable of Champions may be simple. For other key stakeholders, it may not be clear who can/should act as an advocate (e.g., pedestrian or bike stakeholders), or there may not be an obvious neutral third-party advocate to represent competing stakeholders (e.g., corridor freight carriers).

Strengths include the following:

• **High visibility.** When a senior leader shows an interest in corridor-level performance and issues, other parts of the organization and the public will also take notice. This, in turn, may encourage senior leadership from other stakeholder organizations to participate, even if they had not been engaged earlier.

• **Senior Leaders Can Set Vision/Direct Action.** Buy-in from the top is critical to consider implementation of many of the most effective ICM strategies.
• **Durable Organizational Relationships.** Roundtable participation/invitation is based on title, not the individual. If there is turnover within organizations, the successor to the senior management position inherits the roundtable seat for their organization.

**Weaknesses:**

• **Risk of “Shallow” Coordination.** In some cases, there may be interest in showing coordination, but the group may lack inherent momentum to tackle specific issues at a technical level. High-level descriptions of shared vision may lack a focus on specific actions or pilot projects to be conducted. Further, senior managers may have extremely limited time to dedicate to corridor issues when there may be many pressing organizational, financial, and technical issues within their own home organizations. This can lead to good intentions but a lack of focus at senior level outside of the roundtable events themselves.

• **Difficult to Manage Rapid Growth.** Some roundtables become large quickly – and in these cases it may be impractical to organize and schedule. Keeping the roundtable small to start and then incrementally expanding membership can be a smart counter to this threat, but the risk is in alienating other stakeholders who would like to join but are initially put off.

• **Stakeholders with No Clear Organizational Chart.** In many cases, it may be hard to find a single voice that can speak for a broader stakeholder community (see above regarding bike/pedestrian and freight stakeholders). The same issue arises among stakeholders who have distributed jurisdictional control within the corridor (e.g., multiple transit agencies). In other cases, it may not be clear who within an organization has the power to influence and direct even a highly-structured corridor-specific project. In other cases, the actual power to put ICM strategies in place may be confounded by fiefdoms within a large organization. Some individuals will likely see ICM as a threat to their subsystems, or subsystem performance and not be inclined to support ICM activity.

**Best applied for the following:**

• **Early ICM Deployments with Risk Averse Stakeholders.** Some organizations are highly risk averse. Organizational top cover may be needed to institute a change in long-standing processes and procedures, and get buy-in to create new ICM-focused measures and processes.

• **Responding to Grant/Funding Opportunities.** An important catalyst for ICM in gaining the attention of senior management is the urge to coordinate in the goal of winning a grant or other competitive funding source related to ICM implementation. Here the shared goal among the stakeholders is clear – to develop a compelling, comprehensive, and technically feasible ICM concept as a shared team.

• **Capitalize on Success.** Alternatively, a good success story like the one described in the *Ad Hoc Coordination* framework discussion, can lead to the creation of a viable and energized Roundtable of Champions as a next logical step.

**Peer-to-Peer Connection (Early Model)**

In this early model, technical and operations staff gather together to solve specific corridor issues. In this case, this is a natural extension of the *Ad Hoc Coordination* model but advanced to a more mature state where trust relationships among multiple individuals have evolved into trust relationships among sub-elements of individual stakeholder organizations. These connections are encouraged, and possibly authorized, by the chain of command within each participating organization. However, the nature of these engagements is limited by the specific problem they are solving at a tactical level, and not
endorsed or specifically chartered as a part of a more comprehensive ICM organizational form (e.g., as might be initiated in the Roundtable of Champions framework).

In the diagram shown above, the Peer-to-Peer model can be characterized as a collection of multiple, networked relationships among staff positions in multiple organizations. These trust relationships, indicated in broken orange lines, represent connections that may have originally been based on trust relationships among individuals but have matured over time to represent organizational connections. Existing communities of coordination around recurrent special events, e.g., annual state fair, major conventions, seasonal severe weather or emergency response can assist early corridor planning and coordination among corridor stakeholders. An example might be connections among transit, freight, and bike/pedestrian stakeholders around managing goods and people movement in and around a large fairground for a 10-day period every year. In this case, there may be useful policies regarding when large freight deliveries might take place, when specific roads may be closed to all but transit or non-motorized traffic, or specific plans drawn up to deal with incidents or other emergencies that might arise during the critical 10-day period. While focused on specific event planning rather than more comprehensive corridor management, these relationships, policies, and coordinated activities can be critical building blocks for ICM. Some key corridor stakeholders may not be initially engaged (as depicted in the diagram where one organization has no orange connection lines) as there may not have been a good match between special event stakeholders and corridor stakeholders in early rounds of trust-building and organization formation.

Strengths include the following:

- **Problem-focused.** Much like the scenario planning work suggested throughout this document as a good conversation starter for ICM solutions, the peer-to-peer network focused on recurrent event planning can be a useful springboard for a more comprehensive solution.
- **Practical.** These types of cases often have motivating examples of why coordination works and how everyone benefits.
- **Durable Organizational Relationships.** Trust relationships have matured into tactical forms of institutional trust among coordinating organizations – and less likely to be undone by staff moving on to new positions.

Weaknesses:

- **Low Visibility Until Something Goes Wrong.** Aside from high visibility events like a major sports championship, even snow events and annual state fair planning may not receive significant high-level organizational or public attention. Unless something goes wrong – and then there may be significant attention. If this is the case, then an organized recovery and lessons learned from such an outcome can also be the seed for a more comprehensive ICM solution.
- **May Not Be Well-Positioned to Seek External Corridor-Related Funding.** Such agreements are tactical in nature and tend not to be flexible or scoped widely enough to be able to seek external funding. Also, since these communities are developed around one or more events, rather than from the mental frame of a corridor, there may not be a good match to corridor-concept funding mechanisms.
- **Issue of Scalability.** There may be only a few days a year that warrant or have historically warranted tactical coordination of this nature. The individuals and organizations managing the state fair operations may have limited overlap with the set of stakeholders from those that manage snow removal. It may be difficult to collect up these groups, find common ground, and then scale up to a more comprehensive ICM solution without a more formal organizational form (e.g., at a minimum incorporating senior management buy-in in some form as in the Roundtable of Champions model).

Best applied for the following:

- **Busy Corridors with Recurrent Special Events.** Corridors that see little or no day-to-day congestion may have little need for a more comprehensive ICM solution – and instead the corridor
management effort can be organized around the special events that drive unusually heavy demand patterns. These types of events are likely to impact a wide range of stakeholders, including incident management, transit, pedestrian/bike, and freight stakeholders.

- **Need for Comprehensive Integration Is Low.** In these cases, the relatively infrequent nature of the events may not support the need for deep technical or organizational integration. Law enforcement may be engaged in managing critical intersections and protecting pedestrian movements during peak periods. The need for a more complex technological traffic control system may be low since the benefit of the system can only be recouped a few days in the year.

**Coordinated Operations (Intermediate Model)**

In this intermediate model, stakeholders have formalized an agreement to coordinate activity, either in a playbook or a set of flexible rules. This is the first intermediate model and represents a level of coordinated action and formalized organizational form at a tier above the three early deployment frameworks discussed so far. In many cases the key difference between the early models and this intermediate model is a more mature set of institutional capital. Specifically, advancing to the intermediate framework requires more detailed operational and technical agreements that spell out the specific roles, responsibilities, and sequence of actions taken in response to observed conditions in the corridor. Rather than working from a general set of principles driving coordination among stakeholders at a broad level, this intermediate model seeks a set of (more or less) comprehensive response plans that stakeholders formulate together.

In the diagram shown above, the **Coordinated Operations** model can be characterized as a collection of stakeholder organizations (shown at the exterior points of the diagram) working together to create a detailed playbook (represented as the element in the center of the diagram) that deepens the level of coordinated action and technical integration among ICM stakeholders. Note that the dotted lines of trust relationships that dominate the diagrams for the early models are no longer the focus. Trust relationships among individuals and organizations are a given in this intermediate framework – and the focus has turned to leverage this trust relationship into developing agreements describing in detail a set of more complex, coordinated actions.

Strengths include the following:

- **Supports More Complex (and Effective) Deployments.** Some ICM strategies require high levels of detailed coordinated action. For example, a corridor may include some sub-elements where freight signal priority is required to assist on-time delivery at key intermodal facilities. Access to these facilities may run counter to optimal transit signal priority timing, bike lane access, pedestrian movements, and other considerations. To implement coordination among these competing corridor demands; detailed intersection and facility plans may be needed – far beyond informal coordination among the jurisdictions controlling the signals and the collection of stakeholders.
- **Higher Level of Responsiveness.** The development of a corridor playbook allows actions to be taken more quickly in response to a wide range of operational conditions.
- **Durable Action Plans.** One weakness of the early models is the general lack of detailed operational and technical agreements, and a reliance on trust relationships to execute corridor actions. Such informal agreements may be consistent with complex actions. However, when individuals change positions or retire, these undocumented plans are lost. Documenting the agreed-to actions allows new staff to step into clear roles with clear responsibilities and associated actions in the playbook.
Weaknesses include the following:

- **Limits of the Playbook.** In complex corridors, the number of plays needed in a playbook may grow large quickly. Maintaining the playbook and updating it to changing conditions may be difficult and time consuming. A detailed plan may be created for a situation that occurs infrequently (or never again). At the same time, operational conditions that warrant coordinated action but are not in the playbook may be large. At some point, a detailed playbook may need to be replaced with a more flexible set of rules that describe general actions to be taken supported by a set of automated adaptations. Whether such a system is needed depends on the repeatability and classification of the operational conditions experienced in the corridor — and the nature of the corridor management response.

- **Often Requires Corridor-Specific (External?) Funding.** Making the leap from one of the early models to the intermediate model often requires corridor-specific funding to both create the playbook and the supporting technical capability to implement it. Further, this model is difficult to leap into as a first step for an ICM stakeholders, since it is dependent on existing trust relationships already being in place among stakeholders (individuals and organizations).

- **Requires Institutional Maintenance.** The ICM playbook should not be viewed as a “one-and-done” activity. The playbook will need significant maintenance and enhancement over time. There should be an institutional commitment to periodically examine corridor performance, develop new plays (including modeling studies), and then to update the playbook. These updates may also require new technical agreements and possibly new field capabilities.

Best Applied for the following:

- **Target Next Step of Early ICM Frameworks.** Early framework ICM solutions that have an external or corridor-specific funding source are often good candidates to shoot for this level of integration. That is, the result of the funding is to advance to and realize an ICM capability Coordinated Operations, with the appropriate level of institutional capital.

- **ICM Showcases.** These types of deployments using this organizational form can serve as motivating examples of what is possible for deeper levels of corridor coordination.

**Integrated Consortium (Advanced Model)**

This is the first advanced model and represents a level of coordinated action and formalized organizational form at a tier above both the three early deployment frameworks and the intermediate framework discussed so far. The key difference in this advanced model is a more mature set of institutional capital. Specifically, advancing to the advanced framework requires more detailed institutional agreements that create a new organizing entity, the ICM consortium. The consortium, in turn, is staffed and is operated by members of stakeholder organizations to carry out corridor-specific activity as a full-time or nearly full-time activity exclusive of positions in the individual “home” organization.

In this advanced model, corridor management roles and practices are well defined and more formal corridor-specific organizational structures are required to improve efficiency and accountability. A new corridor-level organization is formed to carry out these roles and practices, staffed by individuals drawn from stakeholder organizations.

In the diagram shown above, the Integrated Consortium model can be characterized as a collection of stakeholder organizations (shown at the exterior points of the diagram) sending individuals and staff from their organizations to take roles in the new corridor-specific roles created by the consortium (represented as the element in the center of the diagram). This action provides yet another opportunity to deepen the
level of coordinated action and technical integration among ICM stakeholders. Note that the focus of this
diagram is at the institutional level – the playbook is no longer the focus. A comprehensive playbook is a
given in this advanced framework – and the focus has turned to creating a new organizational model that
(in large part) reflects a desire to enhance and execute the playbook as its sole responsibility.

Note that there are no current examples of the Integrated Consortium framework currently deployed for
the purposes of ICM. The following analysis of strengths, weaknesses, and best applications are based on
the experiences outside of ICM. These advanced models may be of interest for consideration by ICM
stakeholders but cannot be described as proven ICM organizational models.

Strengths include the following:

- **Corridor-Focused Operational Roles.** Creates an operational organization with the specific goal
  of the managing the corridor. Rotation in/out of these positions deepens understanding among
  stakeholders and reinforces the corridor world-view rather than the “coordination of silos” seen in
  earlier forms.
- **Dedicated Financial Agreements.** When the new organizational form is created, it requires a
  supporting financial arrangement. The independent financial stream helps to stabilize and help to
  achieve longer-term corridor goals. Drawn from other non-ICM solutions, this means that the
  management entity is supported by user fees (e.g., aviation passenger taxes, or toll road revenues).
- **Deep Integration.** Playbook approaches have logical limits (described above). The consortium
  model allows managers to consider higher levels of operational control, including increased use of
  automation, to optimize corridor management actions.

Weaknesses include the following:

- **Temporary Positions May be Weak.** Individual agencies may not involve much real power, so
  the roles created may speed coordination but may not actually achieve deep integration. One
  observation is that a move to the Integrated Consortium model may be difficult without establishing
  earned trust in an intermediate organizational form.
- **New Organization to Maintain and Support.** The leap to the Integrated Consortium model will
  require financial and other forms of support from stakeholders. Some organizations may balk at
  providing staff, and others may be reluctant to provide other resources. The benefits of the consortium
  may be difficult to quantify.

Best applied for the following:

- **Intermediate Models Exit Strategy.** The intermediate model may not prove sustainable over the
  long-term, for institutional reasons. In these cases, a consortium model may be a useful migration path
  – rather than dissolution of the ICM deployment.
- **Corridor Financial Flows.** Consortium models have been most successful when independent
  financial flows can be identified. This may be a significant barrier in many ICM solutions.
Third-Party Operator (Advanced Model)

This is the most advanced model and represents a level of coordinated action and formalized organizational form at a tier above all other frameworks discussed so far. As in the Integrated Consortium model, the key difference in this advanced model is a more mature set of institutional capital. Specifically, advancing to the advanced framework requires more detailed institutional agreements that solicits a third-party corridor management entity to enhance and execute defined ICM responsibilities. The third-party entity is free-standing, that is, it is NOT staffed by members of stakeholder organizations. It has defined scope, actions, and methods of financial recovery to conduct corridor-specific activity.

In this advanced model, corridor management roles and practices are well defined and more formal corridor-specific organizational structures are so well defined that separate organization is hired or formed to carry out these roles and practices.

In the diagram shown above, the Third-Party Operator model can be characterized as a collection of stakeholder organizations (shown at the exterior points of the diagram) defining the role and responsibility of the third-party ICM operator (represented as the element in the center of the diagram). The third-party ICM operator is shaded green (rather than orange) to emphasize the relationship is focused on a financial relationship and not an institutional trust relationship. Note that the focus of this diagram is at the institutional level – the playbook is no longer the focus. A comprehensive playbook is a given in this advanced framework, and the focus has turned to turning over the playbook to a third-party who has financial motivation to enhance and execute the playbook.

Note that there are no current examples of the Third-Party Operator framework currently deployed for the purposes of ICM. The following analysis of strengths, weaknesses, and best applications are based on the experiences outside of ICM. These advanced models may be of interest for consideration by ICM stakeholders but cannot be described as proven ICM organizational models.

Strengths include the following:

- **Profit-Performance Relationships.** Agreements put in place are likely to make the third-party operator motivated to improve corridor performance. This may help better align investment and performance in ways not possible with other organizational models. Further, these agreements often include new capital expenditures from the third-party that can be recouped over time through improved corridor performance.

- **Third-Party Operator May Innovate.** The desire to increase profits may bring innovation and new strategies into the corridor that stakeholders had not considered previously – innovations that may be highly effective.

Weaknesses include the following:

- **Lack of Day-to-Day Stakeholder Control.** The playbook needs to be well trusted by the stakeholders as they are likely giving away some aspects of their ability to control their own systems.

- **Fundamentals May Change.** It may not be possible to significantly modify these agreements after they have been put in place. This can be problematic for financial reasons, and the third-party operator model may not be viable over time. For an example drawn from privatizing toll road operations, see:
Best applied for the following:

- **Stable Corridors and Short Windows.** In an advanced state where corridor conditions and performance are extremely well known, it may be cost-effective to consider a third-party operator. However, long operational periods (e.g., 75 years in the toll road example above) expose all parties to significant risk. Stable, well understood corridors and much shorter operational periods (e.g., 5 or 10 years) may be considered. The downside for the third-party operator for shorter periods is more limited ability to recoup start-up costs and capital investment.

Refer to NCHRP Report 899 *Broadening Integrated Corridor Management Stakeholders* for examples of each type of framework.

**Task 9 Checklist**

- Determine whether there is a need for formal or informal agreements for this ICM project.
- Identify what types of agreements (institutional, operational, or technical) are necessary.
- Discuss agreement terms with stakeholders (roles and responsibilities).
- Develop a plan for long-term agreement management.

**Summary and Conclusion**

**Lessons Learned and Best Practices**

Major lessons learned from the *Integrated Corridor Management: Implementation Guide and Lessons Learned* report and other guidance documents include the following:

- Foster champions and organize stakeholders when initiating ICM activities
- All stakeholders need to be identified early in the process – all modes, IT staff, etc.
- Multiple levels of stakeholders need to be engaged, such as end users, operations-level decision makers, and program-level/executive decision makers
- Plan for success of an ICM project by developing a knowledgeable and committed project team that can provide oversight, direction, and necessary reviews
- Developing operational scenarios should begin with scenarios everyone can agree on and use a phased approach to increase the maturity of ICM
- Research analysis needs of the ICM alternatives and develop a sound Analysis Plan approach based on the operational conditions and the planned objectives of the ICM strategies
- Conduct Analysis, Modeling, and Simulation iteratively to assess the feasibility of the proposed ICM strategies, identify the most promising strategies, and identify the operational conditions under which the ICMS would be most effective
- Depending on consensus from stakeholders, start small – agree to keep channels of communication open before agreeing to a full MOU
- Develop a SEMP to achieve quality in project development and ultimately produce a successful ICMS
- Develop a ConOps to define the system that will be built

ICM best practices recommend engaging stakeholders as early as possible. Stakeholder collaboration and engaging partner agencies is a highly effective and often a necessary approach to managing and operating the transportation network. By working together, agencies save money, use their resources more efficiently, gain valuable knowledge, and avoid duplicating efforts. This enables them to provide a coordinated,
seamless experience to the public through improved services such as traveler information, incident management, traffic signal operations, special event management, and transit management.

Three of the eight Pioneer Sites (Dallas, Minneapolis, and San Diego) were selected to model the potential impact of ICM on their corridors after developing their Concept of Operations and System Requirements Specifications. Conducting analysis, modeling, and simulation (AMS) of ICM strategies and scenarios of interest is best begun during the ICM planning stages. The use of AMS provides ICM adopters with the means to assess operational strategies before they are implemented and to continuously monitor changing conditions and operational effectiveness. AMS has been credited by ICM adopters with improving the accuracy of the analyses, providing a more robust knowledge base for evaluating future strategies and investments. AMS is intended to be an ongoing, continual improvement process designed to assist practitioners in envisioning, designing, and refining ICM strategies.

“Reality Check” – A Process for Confirming that all Intended Elements in the Phase Have Been Accomplished

A new process will be developed for confirming that all intended elements in the phase have been accomplished:

1. **Stakeholders** – Stakeholders have been engaged and roles and responsibilities have been identified.
2. **Analysis** – ICM strategies considered have been analyzed and simulated and eliminated based on lack of feasibility or lack of performance improvements.
3. **Funding** – Initial funding sources have been secured and additional funding sources have been identified.
4. **Products** – Major deliverables have been completed, adhere to Federal guidelines (if necessary), and were approved by major stakeholders.

To complete the “reality check” process, the Planning and Concept Phase Task Checklist presented at the beginning of this chapter is repeated here in Table 20 for the ICM team to confirm that all intended elements in this phase have been accomplished.

**Table 20. Planning and Concept Phase Task Checklist**

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<tr>
<th>Task</th>
<th>Checklist</th>
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<tr>
<td>1. Identify and Diagnose Problem</td>
<td>• Qualitatively characterize the system dynamics of potential ICM corridors.</td>
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<td>• Define logical boundaries for potential ICM corridors.</td>
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<td>• Identify whether existing problems along each corridor can be addressed using ICM.</td>
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<td>• Set priorities among candidate corridors.</td>
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<td>2. Establish ICM Objectives and Scale</td>
<td>• Identify main goals for the potential ICM project.</td>
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<td>• Establish objectives to meet each goal.</td>
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<td></td>
<td>• Explore realistic tiered ICM implementation options.</td>
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<td>3. Determine Potential Partners</td>
<td>• Compile a list of potential partners, agencies, and organizations by type of decision maker.</td>
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<tr>
<td></td>
<td>• Create a stakeholder engagement plan, which details specific agencies and organizations to reach out to and when each type of decision maker should be engaged.</td>
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<td>Task</td>
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| 4. Engage Potential Partners | • Convince potential partners of the value of ICM.  
• Detail the potential benefits of ICM participation in terms of your audience’s goals.  
• Understand stated concerns from stakeholders and develop strategies to work around or mitigate operational constraints.  
• Establish communication channels with participating stakeholder groups for information sharing. |
| 5. Assess Potential Partners’ Needs | • Compile and understand the main objectives of each participating stakeholder group.  
• Identify strategies to mitigate stated stakeholder concerns.  
• Short-list high priority stakeholder needs for inclusion in the ICM concept. |
| 6. Develop ICM Concept of Operations | • Develop a list of high-interest ICM strategies that address stated user needs.  
• Identify incoming and outgoing data needs and sources for each data need.  
• Identify and fill data gaps.  
• Develop a high-level architecture diagram that shows the key systems of the ICM system.  
• Develop operational scenarios that describe in detail how the ICM system is anticipated to operate in each scenario.  
• Define roles and responsibilities for each participating ICM entity/stakeholder through response plans.  
• Develop a Concept of Operations document. |
| 7. Designate Performance Metrics | • Identify performance metrics that are in line with the project objectives.  
• Identify data elements needed to evaluate each performance metric.  
• Identify potential data sources for selected performance metrics. |
| 8. Assess Benefits of the Planned ICM Deployment | • Determine ICM analysis methodology.  
• Develop an analysis work plan.  
• Identify data requirements for analysis.  
• Estimate ICM benefits and costs.  
• Begin the process of adding the ICM project to the STIP and TIP. |
| 9. Initiate Formal Agreements | • Determine whether there is a need for formal or informal agreements for this ICM project.  
• Identify what types of agreements (institutional, operational, or technical) are necessary.  
• Discuss agreement terms with stakeholders (roles and responsibilities).  
• Develop a plan for long-term agreement management. |
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<th>Task</th>
<th>Checklist</th>
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| 10. Develop Plan for Implementation | - Identify dependencies between ICMS projects to come up with an optimal project sequence.  
- Explore Federal-aid, State, and local agency funding opportunities.  
- Obtain funding commitments from as many sources as needed.  
- Determine which ICMS project(s) will require procurement.  
- Develop documentation needed to solicit development and deployment services needed.  
- Document an agreed upon systems engineering process in a SEMP.  
- Document remaining implementation strategies and plans into an implementation plan. |
Chapter 5 - Planning for the Technical Components of Integrated Corridor Management

Overview

The purpose of this chapter is to introduce the design and deployment process for an ICM system, and the processes and plans agencies should perform in preparing for design and deployment. This chapter will consider the processes to take requirements to design, the key questions agencies need to ask to decide how they want to implement ICM, and which components of an ICM system will best fit their needs and requirements. Additionally, since funding limitations are almost always a constraint, this chapter will also discuss how to develop an implementation plan and phase the design and development of an ICM system.

The architectural and design process should include a multi-step process which builds to a detailed design, which can be used by developers to develop and deploy the system. Depending on the development process used (waterfall, agile, iterative), this process should be tailored to the design and development process selected. The Dallas ICM program used a formal architecture and design process, which allowed them to consider many alternatives in how the system was built and eventually developed and deployed.

Technical Components and Architectures for ICM System

Most commonly, ICM is thought of as the technological solution that enables coordinated traffic management based on operational procedures mutually agreed to by the various agency system managers owners and operators. An ICM system integrates agency solutions to support data sharing, create common situational awareness, and foster collaborative and cooperative event and congestion management. There are four primary shared systems that shape the overall technical ICM solution, as shown in Figure 15 and described in the paragraphs following.

![Figure 15. ICM Technical Solution Components](image-url)

Figure 15. ICM Technical Solution Components
**User Interface**: Interface for system managers to interact with the ICM. This could be a stand-alone, separate interface or could be attained by customizing the interface of existing systems used by the agency (e.g., adding functionality to an existing Freeway ATMS or Traffic Signal System).

**Decision Support System (DSS)**: This is the business logic that will define the operational coordination between agencies for a given event. DSSs are sophisticated centralized applications that use business rules and/or artificial intelligence/machine learning techniques to predict and detect problems with network throughput and suggest cooperative response strategies to mitigate congestion impacts.

**Integrated Data Exchange (IDE)**: A centralized data warehouse that collects, fuses, aggregates, and stores data from member agency systems.

**Business Intelligence (BI)**: Visualization tools, including reports and dashboards, that capture performance measures to assess how well the ICM system is meeting agency needs and goals.

**Sample ICM Architectures**

There is no “standard” architecture for ICM systems. ICM can be built around different system architectures depending on corridor needs, agency capabilities, and available budgets. There are two primary approaches to ICM architectures: (1) Using an existing traffic management system as the primary system and (2) creating a stand-alone, separate system to integrate all the stakeholder systems. These are described briefly below.

**Using a Master Operational System for ICM**: In this architecture, an existing operational system serves as the “Master” system. The DSS, IDE, and BI that exist in this Master System are expanded to include the data and response components for other agency stakeholders. Each system manager uses the user interface of their own system to interact with the ICM.

An example is shown in Figure 16 ICM capabilities are added to an existing statewide Freeway ATMS. Data from arterial management and transit management systems are shared with the Freeway ATMS. Incident response plans in the Freeway ATMS are expanded to support recommended signal time changes. The Freeway ATMS also captures multimodal travel times to post travel time for transit and arterials on message signs in the corridor.

![Diagram of ICM Modal Traffic Management System of Systems](source)

*Figure 16. ICM Modal Traffic Management System of Systems*

Variations to this approach include deploying the DSS and BI as centralized systems, as shown in Figure 17.
ICM as an “Umbrella” System: This architecture specifies an ICM system that is separate and apart from each traffic management system. The ICM receives data from each system manager solution but all activity occurs through the shared operational GUI. The DSS, IDE, and BI are centralized, shared subsystems external to the traffic management systems, as shown in Figure 18.

(Source: FHWA Scoping and Conducting Data-Driven 21st Century Transportation System Analyses)

**Figure 17. ICM System Integration**

**Figure 18. Modal Integration for ICM**
User Interface

The user interface (UI) provides the software application for users to interact and view the systems and data for the ICM system. UI can be graphical, text-based, or audio-video based, depending upon the underlying hardware and software combination. A graphical user interface (GUI) is the most common UI in newer transportation management systems and provides the user with a graphical means to interact with the system.

Potential Solutions

Related documents on UI design are available at:

Human Factors Guidelines for Transportation Management Centers

Decision Support System (DSS)

The central integration element of the ICMS is the collaborative management of the disparate transportation network systems, which is accomplished by human interaction and automated and non-automated tools. The Decision Support System (DSS) is the central element of many ICMS, connecting the transit management, traveler information services, incident management, arterial management, freeway management, parking management, and other transportation management systems available on the corridor.

The DSS provides computer-based aid to agency operators to assist with the decision-making process during operations. It is a tool that is informed by predetermined business rules agreed to by ICM stakeholders. Implementing a DSS is not required as part of all ICM systems, however, it helps agencies access integrated information from a multitude of sources, parses the data with pre-defined business rules, and provides operators with a candidate response plan that was pre-agreed upon by all partner agencies.

The DSS does not suggest responses for normal, recurring congestion, but instead assists in responding to incidents and nonrecurring congestion. The DSS evaluates the incident against the pre-programmed rules, which were determined during the ICM planning phase and approved by stakeholder agencies. For example, the rules used for the US-75 DSS include parameters including location of incident, severity of incident, length of queue, direction of travel, available capacity on adjacent arterials, evaluation of network conditions based on system detectors, future forecast of network impacts, and transit readiness to accept additional passengers and parked vehicles at the station.

Ultimately, agency operators have the decision-making responsibility and ability to accept, reject, or modify actions suggested by the DSS during incidents. ICM operators in each agency should be aware of the readiness of their system to carry out the response plan and are responsible for communicating their actions to the other partner agencies, whether through the DSS or through other forms of communication. If the involved agencies agree to implement, the DSS can assist in disseminating information on roadway DMS, 511 systems, websites, private sector traveler information tools, various websites, and other integrated traveler information providers.

Decision support should begin with agencies cooperatively developing the business process flow for decision-making that they would like to follow. An example of a decision support process that was then converted to a software system is shown in Figure 19 for the US-75 ICM deployment in Dallas.
In the San Diego I-15 ICM, the regional transportation network is controlled by the DSS, which integrates and provides control abilities for area transportation coordinators. Along with the DSS, two additional systems were developed to support the DSS:

- **Network Prediction System** (NPS) – developed as part of the ICM demonstration to support DSS operations and used to predict origin-destination flows within the I-15 corridor.

- **Real-Time Simulation System** (RTSS) – developed as part of the ICM demonstration to support DSS operations and used to manage and execute corridor simulations.

To describe the ICM system with integrated DSS, Dion and Skabardonis (2015) developed the diagram in Figure 20 and note that the diagram:

“…provides an early conceptual view of the DSS. Core functions of the DSS are represented in the gray box shown in the upper right corner of the diagram. Based on information received from the various transportation systems via the IMTMS web services (shown in the blue boxes surrounding the IMTMS cloud), the DSS would use a rules engine to assess corridor operations and develop suitable response plans. These plans would then be converted into control actions that would be passed back to the relevant systems via the IMTMS web servers. Examples of control actions that may be received by each transportation system are shown in the gray boxes surrounding the IMTMS cloud.”
Figure 20 contains the following acronyms:

- ATIS (advanced traveler information system)
- CAD (computer aided dispatch)
- CMS (changeable message sign)
- EV (emergency vehicle)
- IMTMS (intermodal transportation management system)
- RMS (ramp meter stations)
- RTMS (regional transit management system)
- XML (extensible markup language).

Figure 20. I-15 ICM Concept

In general, the DSS deployed for the example ICM projects have reusable components. For example, the rules engine software was a commercial product that can be used for any decision support process automation. Advanced modeling is not necessarily required for a DSS; while it does provide benefit, it has a higher cost.

Deciding what components of a DSS are needed are dependent on the data availability of the corridor, the needs and goals of the ICM program, and the available funding. As the capability maturity model for ICM that was developed for NCHRP 12-02 shows, a DSS can be as simple as a set of pre-defined response plans to a very mature software platform that predicts and develops responses dynamically.
Potential Solutions

Related documents are available at:

Elements of Business Rules and Decision Support Systems within Integrated Corridor Management: Understanding the Intersection of These Three Components

https://ops.fhwa.dot.gov/publications/fhwahop17027/index.htm


Integrated Data Exchange

Many existing transportation management systems were conceived, developed, and implemented as stand-alone, or “stovepipe,” systems and do not always provide for integration of data between systems. Through the development of a single integrated data environment (IDE), all necessary data for ICM can be fused into a single database.

The advantages of the IDE approach include the following:

• Single view of all data
• Single physical database from which all applications can draw data
• Some standards exist to assist agencies with development of an IDE (i.e., Traffic Management Data Dictionary, Center-to-Center)

While the disadvantages of the IDE approach include the following:

• Agencies need to agree on the data model
• Impact on all legacy systems, which are required to conform to the new global data model
• Complexity increases dramatically with the number of systems and types of data (i.e., ATMS data, transit data)
• The process to maintain the IDE may become unmanageable with large numbers of systems

Potential Solutions

Related documents for data exchange are available at:

Integrating Emerging Data Sources into Operational Practice


From LOS to VMT, VHT and beyond through data fusion: application to integrated corridor management


Business Intelligence

Business intelligence (BI) provides agencies with the tools and technologies for the data analysis of transportation information. BI technologies in transportation provide historical, current, and predictive views of the data within the IDE. BI solutions include reporting, online analytical processing, analytics, data mining, business performance management, benchmarking, and predictive analytics.
Potential Solutions

Related documents on Business Intelligence are available at:
NCHRP 03-128 Business Intelligence Techniques for Transportation Agency Decision Making

Design Process for ICM

The design process for ICM should follow the process and procedures developed as part of the SEMP. For this discussion, it is assumed that a design team, consisting of agency stakeholders, consultants, and system implementors, exists, and performs the high-level activities in the following subsections.

Review System Architecture

The design team will begin by reviewing system architecture developed in the systems requirements document, ensure understanding, and provide any updates, if deemed necessary. This provides stakeholders with a logical view of the technical integration of the systems needed to cooperatively operate the corridor.

Develop and Analyze Design Alternatives

The design team will perform the design activity in two stages, high-level and detailed, and obtain feedback from stakeholders at the end of each stage. The design team will also analyze design alternatives for the products and identify some of the key product components and interfaces that trace to the essential system requirements.

If required, the design team will develop, build, and conduct some proofs of concept or experiments to design the details of the interface design. The design team will identify the preliminary sequence for integrating the various product components. Alternate product component integration sequences will be evaluated and documented as contingency plans.

Identify Product Interfaces

The design team will identify the interfaces while deriving the High-Level Design Document from the architecture diagrams, and conduct periodic design reviews and discussions with the appropriate stakeholders to identify all interfaces. The design team will identify the complexities, technical problems, and dependencies between the different product/system components that need to be integrated.

Develop Build/ Buy/Reuse Options

The design team will identify if there are multiple commercial off the shelf software (COTS), or customizable COTS products and components available to meet the requirements of some components of the system. As discussed in Section 0, an evaluation of which parts of the system can be re-used or modified should be done. The team should also identify which parts of the system will need new development to complete the architecture developed in section 0.
**Update Requirements Traceability Matrix (RTM) for System Requirements**

The High-Level Design Document and the System Requirements Specifications will be reviewed together with the design team and stakeholders to verify that the proposed system of system solution satisfies the system requirements.

**Preliminary Design Review (PDR)**

The Preliminary Design Review is a meeting with the stakeholders and the design team to review and approve the preliminary design. The goals of the PDR are:
- Verify the technical content of the design document and its interfaces are complete and traceable
- Ensure the selected design methodology has been followed in producing the architectural design
- Obtain approval from the stakeholders to proceed into detailed design

**Update Preliminary Design Document**

Based on the output of the PDR, the design team will update the design document based on the feedback received from stakeholders and will resolve the technical and design related issues that arise due to the feedback.

**Baseline Design and Bill of Materials**

The design team will verify the review feedback has been incorporated into the design document and then send the documents to stakeholders to obtain formal approval to baseline the Design Document and Bill of Materials (BoM) and communicate the availability of the Final Design Document to all stakeholders.

**System Gaps**

Identification and prioritization of system gaps found in the ConOps and design phases of the ICM development provide the first steps in ICM implementation planning. Gaps should include field infrastructure, data sources, and agreements necessary for the ICM program and systems to operate more effectively.

**Major Issues and Challenges**

Almost every location that has planned or implemented ICM has found gaps in their field infrastructure, in the data provided by stakeholder systems, and their operational policies. Both the Dallas and San Diego ICM deployments received additional funds to deploy vehicle occupancy detectors for transit vehicles, so that the real-time passenger counts were available when considering transit diversion as a potential strategy.

The Florida Department of Transportation (FDOT) District 5 ICM program is considering a policy change that will allow detour route recommendations to be provided on their DMS. The current policy is to provide general “Use Alternate Routes” guidance, rather than providing specific detour routing.

**System Gap Checklist**

- Document current and planned devices within corridor.
- Document remaining implementation strategies and plans into an implementation plan.
- Document areas that need additional infrastructure to provide effective responses.
Potential Solutions

Through the development of the concept of operations and implementation plan, stakeholders should develop a list of current systems, data, and policies that impact ICM operations. Based on the overall concepts and strategies, agencies need to identify the gaps within their systems and infrastructure that would prevent them from implementing the strategies associated with ICM. Many improvement projects have direct impacts on the operations of ICM programs, including projects in the following categories:

- Projects that fill in gaps within existing Intelligent Transportation System (ITS) deployments by completing critical systems
- Projects that enhance interagency cooperation
- Projects that increase the reliability of the existing transportation system
- Projects that promote multimodal usage

Infrastructure Gaps

As part of the strategies identified within the ConOps, identification of field infrastructure improvements may be necessary. These include communication to devices, additional or upgraded devices (i.e., Traffic Signal Controllers, DMS), and detectors.

Data Gaps

Data is the key element of most multimodal, multiagency ICM systems. During the planning and development of an ICM system, data will most likely be the most challenging and time consuming for the development team. A data dictionary should be developed early in the planning process to document all data types, elements, and formats so that the development team can use a common format for all data that will be used, and the interfaces between systems are developed.

Additionally, gaps in the data needed for ICM operations should be identified early in the planning process, and potential solutions explored. For instance, the US-75 ICM program initially planned to use the Texas Department of Transportation (TxDOT) Center-to-Center for all data. Once design and development began, the resolution and content of the data was found to be insufficient for some of the ICM operations. Within the C2C system, lane speeds and volumes were averaged across all lanes, while the ICM system needed each lane’s data separately for model calibration and validation.

“Real-time” transit vehicle location and occupancy information was not available, so the USDOT provided additional funding to install a cellular based Automated Vehicle Location (AVL) system on the DART light rail vehicles, and automated passenger counters to provide occupancy. The system provides updates to the ICM system every 60 seconds, which was found to be enough for the ICM operation.

Policy Gaps

The most common policy issue to occur in the locations that have planned and implemented ICM is providing specific alternative route recommendations to the public. Many areas have policies that prevent specifying detour routes due to liability. The San Diego ICM program deployed permanent trailblazer/wayfinding signs along detour routes, which provided turning and route guidance to travelers.

Additionally, all projects associated with ICM should be planned and programmed in the TIP of the local MPO or through the STIP.

Implementation Planning

This section discusses the development of an implementation plan that supports the ConOps and provides guidance on the immediate next steps required for agencies to successfully deploy the ICM system.
Major Issues and Challenges

Once stakeholders are supportive of the ICM project, the ICM concept has been developed, and expected benefits of the system have been assessed, one of the next major challenges is to determine which agencies will provide resources or initial funding for preliminary activities. Often, an ICM project will be funded incrementally, which can add complications and uncertainty to the project schedule. And many times, ongoing operations and maintenance costs for the ICM system are not factored into the overall project cost estimates. Ongoing operations require ongoing funding, so it is necessary for ongoing sponsors to pay to support the system.

Procurement is a state of the ICM planning process that is not explicitly shown in the systems engineering “V-Diagram,” it is something that the ICM team needs to think ahead for. According to the USDOT, historically, the procurement of goods and services to support ITS deployments represents a major obstacle for transportation agencies responsible for deploying complex information technology systems. NCHRP 03-77 Guide to Contracting ITS report\(^\text{15}\) states that the use of inappropriate procurement methods may result in project cost-overruns, final designs that do not satisfy functional requirements, and long-term maintenance failures. An appropriate method of procuring ITS (including ICMS) must be flexible enough to accommodate the uncertainties of complex system acquisitions, while at the same time rigid enough to ensure that the responsibilities of the participants are fully defined, and their interests protected. To overcome the challenge of procuring ITS, transportation agencies must institutionalize innovative procurement methods.

Implementation Plan

An implementation plan is not required by the “V-Diagram” but is critical for the successful implementation of an ICM project. The implementation plan supports the ConOps and builds on the High-Level Requirements document developed for the ICM system. The purpose of the plan is to foster improved interagency planning and operational coordination, ITS interoperability, and intermodal connectivity and management of the ICM assets.

While there is no standard outline for an implementation plan, subtasks in Task 10 such as project sequencing, funding strategies, and procurement mechanisms all belong in this document, if it was not already covered in the SEMP. Other sections relevant to an implementation plan include, but are not limited to:

- **Implementation Strategy** – FHWA’s Integrated Corridor Management: Implementation Guide and Lessons Learned report recommends a seven phase ICM Implementation Process, as reiterated in Figure 21.

- **Definitions for all Projects and Project Tasks** – All work tasks and activities needed to accomplish the ICMS goals need to be defined, including, but not limited to, overall project management, construction management, testing and acceptance, participation in training, and other administrative tasks such as financial and contract support.
- **Cost Estimates/Funding Sources** – The costs for each project and the associated tasks need to be estimated (including contingencies) and funding sources and responsibilities identified.
- **Needed Resources** – The resources for each task, including which agencies are responsible for providing these resources, must be identified and obtained. This may include personnel, equipment, test equipment, and other facilities. The time frame for when these resources are needed also is identified.
- **Project Sequencing and Schedule** – An understanding of the individual ICMS projects and their dependencies, the associated project tasks, and the needed resources and budgets are combined into an ICMS Program Schedule, showing key milestones and inter-dependencies between projects and tasks.
- **Procurement Strategy** – Decisions regarding which ICM system sub-components will be developed in-house vs. contracted out to another agency, consultant, or system integrator. Deciding which sub-components will be grouped into each contract is also necessary.
- **Performance Management** – The work done in Phase 7 to designate performance metrics and data sources can be formally documented here in the implementation plan.

Example ICM Implementation Plans include the following:

- Broward County Metropolitan Planning Organization and Florida Department of Transportation, Broward County Interstate 95 Integrated Corridor Management Plan, Implementation Plan, February 2018.
**Design and Development Planning Checklist**

- Identify dependencies between ICMS projects to come up with an optimal project sequence.
- Explore Federal-aid, state, and local agency funding opportunities.
- Obtain funding commitments from as many sources as needed.
- Determine which ICMS project(s) will require procurement.
- Develop documentation needed to solicit development and deployment services needed.
- Document an agreed upon systems engineering process in a SEMP.
- Document remaining implementation strategies and plans into an implementation plan.

**Potential Solutions**

**Project Sequencing**

The Regional ITS Architecture Guidance Document\textsuperscript{16} recommends the following activities for the ICM team to define project sequencing:

- Gather initial project sequence information from existing regional planning documents.
- Define the projects for the corridor in terms of the ICMS architecture prepared in previous steps.
- Evaluate each ICMS project, considering:
  - Costs and benefits
  - Technical feasibility
  - Institutional issues
  - Readiness (agreements in place, funding available, policy decisions, data requirements, etc.).
- Identify the dependencies between ICMS projects based on the inventory, functional requirements, and system interfaces. Identify projects that must be implemented before other projects can begin.
- Develop an efficient project sequence that takes the feasibility, benefits, and dependencies of each project into account.
- Like traditional planning, project sequencing is a consensus building process and should not be viewed as a ranking of projects. Stakeholders should begin with existing planning documents and focus on short-, medium- and long-term planning decisions.

**Funding Strategies**

Funding for ICM projects and the ongoing operations and maintenance of the system will likely come from a wide variety of sources, including Federal-aid, state, and individual agency budgets. Just as ICM projects are generally multiagency in nature, the funding for these types of projects tends to also come from multiple agencies.

Several available Federal grant options include Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) and Infrastructure for Rebuilding America (BUILD). However, the ATCMTD grant program is anticipated to end in 2020, after the fifth and last round of grants is issued, and only one project for ICM has been selected per year.

ICM projects can be funded as part of the traditional Federal-aid highway program. Some areas have begun to use the metropolitan planning organization (MPO) to consolidate funding for ICM programs. In San Diego, the MPO (SANDAG) was the lead agency and continues to fund the program. In Dallas, the ICM program has transitioned from the Dallas Area Rapid Transit (DART) to the North Central Texas

Council of Governments (NCTCOG) to manage and coordinate funding for the program. TxDOT has continued to provide funding for a large portion of the project and has provided NCTCOG funds for parts of the 511DFW systems.

**Procurement Mechanisms**

Typically, the initial development and deployment of an ICMS will entail multiple projects, with each project requiring a specific form of stand-alone procurement documents covering a subset of the complete system design. Potential ICM projects may span a wide range of technology procurements, including, but not limited to:

- Procurement and deployment of additional ITS field devices (such as CCTV, surveillance, and DMS) along the various networks and cross-network connections. It is also possible that this specific activity may involve multiple projects, with each agency having a project covering its specific network.
- Installation or expansion of a communications network connecting the various Transportation Management Centers serving the corridor.
- Infrastructure improvements such as minor roadway widenings, expansions of park and ride lots, etc.
- Central hardware procurement (several agencies often purchase servers, workstations, and related equipment off an agency or statewide contract).
- Software development, including new ICM software programs and enhancements to existing network-specific software and firmware.
- Systems integration.

The ICM team needs to decide which activities should be done in-house by the system’s owner’s organization and which activities should be done by another agency, consultant, or system integrator. The decision model to identify an appropriate procurement approach proposed by NCHRP 03-77: Guide to Contracting ITS report includes the following activities and considerations:

- Making fundamental decisions, such as the possibility of outsourcing and the procurement of consultant services.
- Determining whether the procurement should be performed as a single contract or multiple contracts.
- Categorizing the project with respect to complexity and risk.
- Assessing transportation agency resources and capabilities as well as the environment in which the project will be procured.
- Selecting the applicable systems engineering processes and candidate procurement packages, and then applying differentiators to the candidate procurement packages to reduce their number.
- Involving agency procurement personnel to assist in making the final selection of the most appropriate procurement package.
- Selecting the necessary terms and conditions to be included in the contract.
- Determining whether a system integrator is needed to deliver a fully functional ICMS.

ICMS procurement documents should include specifications and plans addressing critical elements of the ICMS implementation, including the following:

- The integration of all the hardware, software, and/or database components into a fully functional ICMS, including responsibilities for developing and inputting ICMS and individual network system database information (e.g., response plans, any graphic displays).
- The testing procedures, including criteria for acceptance of each component, subsystem, and system. These specifications should also address who is responsible for developing and approving the

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test procedures, who is responsible for conducting and monitoring the test, and procedures in the event a test is not completed successfully.

- The training and documentation that are to be provided by the hardware and software suppliers and the system integrator, and when they are to be delivered.
- Warranties and ongoing system support.
- Intellectual property.
- Licensing agreements for pre-existing technologies and privately funded developments brought to the ICMS project and hardware and software developed during and for the ICMS project using public funds.

Summary and Conclusion

For planning for the design and development of the ICM system, stakeholders need to consider the technical aspects of integration, the gaps in their systems that need to be corrected, and the system validation and verification processes that should be followed. This chapter has provided some of the key design and deployment processes for an ICM, and the processes and plans agencies should perform in preparing for design and deployment. This chapter has provided some of the lessons learned from other agencies who have implemented ICM, the key questions agencies need to ask to decide how they want to implement ICM, and which components of an ICM will best fit their needs and requirements.
Chapter 6 - Planning for Operations and Maintenance of an Integrated Corridor Management System

Overview

The purpose of this chapter is to introduce the operations and maintenance process for an ICM program, and the processes and plans agencies should perform in preparing for operations and maintenance of their ICM system. Planning is needed to transition from the design and deployment of an ICM to the Operations and ongoing maintenance of the ICM, especially as travel patterns, operational polices, and expertise of the operators change.

ICM Operations Start-up

Major Issues and Challenges

Beginning operation of an ICM requires planning, coordination, and assurances that the systems and processes are in place and agreed to by stakeholders. Many of the ICM systems deployed have begun operations with less than full capabilities. This requires agencies to understand the expectations of each phase of start-up, beginning with systems testing and acceptance.

Potential Solutions

Prior to beginning systems acceptance, all stakeholders should be provided training on the ICM system, the processes and procedures for operations, and their roles and responsibilities, so that they better understand what they are reviewing and how the system should work. All stakeholders should, at a minimum, view the ICM system acceptance testing.

A “soft launch” approach was used by both Dallas and San Diego to iteratively improve the ICM system and gain confidence among stakeholders that the ICM was providing expected results. Over a 6-month period the “soft launch” built to an official “go-live” for both sites. During the first phase of the soft launch, training was provided, and stakeholders received recommendations from the ICM, but did not act upon the recommendations. Stakeholders met monthly to review the recommendations to confirm or make small modifications to the response plans and rules of the decision support system.

Staffing

Major Issues and Challenges

ICM requires some specialized staffing or training of existing operations staff to operate and maintain the ICM corridor’s technical and operational components. Agencies responsible for these components face growing needs for a fully competent workforce to provide technical and managerial expertise as staff members and consultants. Recruiting and developing such expertise is complicated by generational shifts within the larger professional and technical workforce and the rapid pace of technological innovation as well as by the particular challenges government agencies face in a competitive labor market.

Potential Solutions

NCHRP 20-07 – Task 408, Transportation Systems Management and Operations (TSMO) Workforce Guidebook provides for development of TSMO (and ICM) capabilities in several specific areas: model position descriptions for describing DOT staff at entry-level and advanced levels of TSMO responsibilities,
supporting documentation for characterizing TSMO entry-level and advanced technical and management positions, and guidance on effective and exemplary practices for recruitment, professional development, and retention of TSMO staff.

There are multiple ICM organizational staffing models developed by USDOT for the ICM pioneer sites to consider, to include a consortium organization, virtual management organization, and a dedicated ICM manager within an agency to lead and coordinate a corridor’s ICM operations.

**Operations Plan**

**Major Issues and Challenges**

Stakeholders need to understand their ongoing roles and responsibilities, and a plan should be developed to document the activities needed to effectively operate the ICM program in a coordinated, multiagency, multimodal basis.

**Potential Solutions**

The Operations and Maintenance (O&M) Plan describes how the ICMS will be used in daily transportation operations and maintenance activities. The Plan addresses the activities needed to effectively operate the ICM system in a coordinated, multimodal basis including the following:

- System operational vision, goals, objectives, and strategies
- Agencies that will be responsible for operations and maintenance
- The capabilities of the operating agencies
- Systems and tools that will be involved in operations and maintenance
- Policies and procedures that are to be used in operations and maintenance
- Daily operational activities and procedures
- Operating and Maintenance Costs and Funding Sources
- How system performance will be measured
- An organizational framework for ongoing management and coordination
- Actions needed to transition to full operations, including training needs

The Operations and Maintenance Plan is separate from operating manuals and maintenance manuals used in daily operations by agencies or provided by system or component developers or suppliers. Those documents describe detailed procedures, whereas this Plan describes resources, organization, responsibilities, policies, and activities.

The Dallas ICM O&M Plan is available at:


**Media Communication**

Marketing for ITS project and programs is important for the public to understand the technology and the reason for these systems. Several ICM sites have employed marketing companies to assist them with public facing systems, marketing and communication to executives, and media communication. The Dallas ICM site used an advertising agency to design the 511DFW logo, and the “look and feel” of the website. As part of the ATCMTD grant FDOT was awarded for parts of the Orlando ICM program, a marketing and communication company is developing a branding strategy and media communication plan to explain the
various components and reasons for ICM. These companies are useful to assist technical groups in explaining ICM in a way that is relatable and understandable.

**Major Issues and Challenges**

Travelers in most regions do not care that multiple agencies are operating the transportation network for their daily trips. Many ITS systems are used by the media (especially CCTV) to communicate the current conditions of the roadway network.

ICM provides an expansion of the potential benefits to the travelers, that the media can assist with helping the public understand. The FDOT D5 ICM program is being assisted by an outreach and media consultant to assist in the branding of the ICM program, explaining how detour routes will be recommended, the benefit of using those routes, and why travelers should use the recommendations that the local agencies are providing.

**Potential Solutions**

**Marketing Plans**

One of the planning aspects that ICM sites should consider is the development of a marketing plan, which provides agencies with an approach for marketing their ICM program to the public. The Plan should include based on existing marketing plans that have been done for 511 systems, ICM projects, and other public facing services provided by transportation agencies, a marketing plan, at a minimum, should include the following information:

- **Analysis of the current situation** – Provide an overview of the transportation environment, its users, and current performance metrics.
- **Marketing Objectives** – What is the objective of marketing the ICM program. Are there specific metrics or performance measures that are being pursued?
- **Launch Strategy** – How and when will you begin marketing the ICM program, using which media, how often.
- **Media Plan** – How will you inform the media of your program? Which information, and how will it be provided? Using simplified, specific information has been found to be easier for the media to use.

Example plans and documents with marketing plan components are available at:

- Dallas ICM Marketing Plan:  
- Monterey Bay Area 511 Implementation Plan:  
- How to change travel behavior through individualized marketing:  
  [https://511.org/sites/default/files/pdfs/How_to_Change_Travel_Behavior_Through_Individualized_Marketing.pdf](https://511.org/sites/default/files/pdfs/How_to_Change_Travel_Behavior_Through_Individualized_Marketing.pdf)

**Post-Deployment Agreements**

Ensuring that the ICM program continues once the system is deployed and operations begin is important to the continued operation of the system. The Dallas ICM program is a good example of what can occur if the agreements are not in place. Each year after the Federal grant was complete, the stakeholder agencies
individually decided if they would continue to fund the program. Eventually, parts of the system were no longer funded, and only the traveler information system (511DFW) was continued. The DSS’ maintenance funding was cancelled and the simulation model became out of date, which caused the DSS to be taken offline.

**Major Issues and Challenges**

Participating entities may seem committed to the ICM project initially, but there are no guarantees that they will carry out their roles and responsibilities once the ICM system is deployed. Initiating formal agreements is one way to help ensure these commitments, whether they are institutional, operational, or technical. For some stakeholder relationships, depending on their level of involvement with the project, an informal agreement may be enough.

**Potential Solutions**

As discussed in Section 0, operational agreements govern the roles, responsibilities, limitations, and tactical interactions among ICM system operators engaged in real-time day-to-day decision-making within the corridor. Developing agreements to document the roles, responsibilities, and funding requirements of each agency who will be a part of the ICM operation is important.

**Monitoring**

Using the performance metrics of interest identified during the planning phase, as discussed in Section 0, is important to monitor the effectiveness of the ICM program. Real-time dashboards, weekly reports, and monthly review meetings have all been used by ICM system deployers to continuously monitor and improve their ICM.

As an example, the Dallas ICM developed monthly reports and the operations committee met monthly to review the status, performance, and issues from these reports. The map in Figure 22 displays the incidents that occurred in the corridor and triggered a response plan by the DSS by location. The map shows the cross-streets along the US-75 corridor, and the number of response plans implemented by direction and cross-street.
Figure 22. Response Plans Implemented during the Demonstration Phase by Direction and Location.

Figure 23 displays a chart of the number of incidents within the corridor by month and the number of response plans recommended by the system for implementation. These metrics provided the operational agencies with a way to measure the impact of cooperatively responding to incidents. This also shows that many of the incidents within a region do not require a full ICM response, because they are localized and may not impact the corridor enough that a multiagency response is needed.
Major Issues and Challenges

Measuring the impact and benefits of the ICM is important for continuous improvement of the ICM system, for communicating its benefits to policy makers, and to ensure the system is operating as expected.

Potential Solutions

Performance Measures obtained via analytics and dashboards can be used to provide important statistics that can help to detect and correct issues found within a transportation network and the ICM system. A performance measures system should provide analytics and graphical dashboards that will allow the regional stakeholders to view archived, statistical data related to the ICM.

The dashboards should support multiple profiles corresponding to the multiple views and roles in the system ranging from seeing high-level status, to corridor-level performance, to very detailed status of arterial, transit, and freeway data.

Summary and Conclusion

For system operations and maintenance, stakeholders should realize that the system is always evolving. Crash patterns and travel patterns are always changing due to construction, changes in the economy, and changes in your transportation network. Stakeholders need to be flexible and understand that ICM is a process, and that it takes time and rigor to ensure the ICM evolves as traveler needs within the region change.