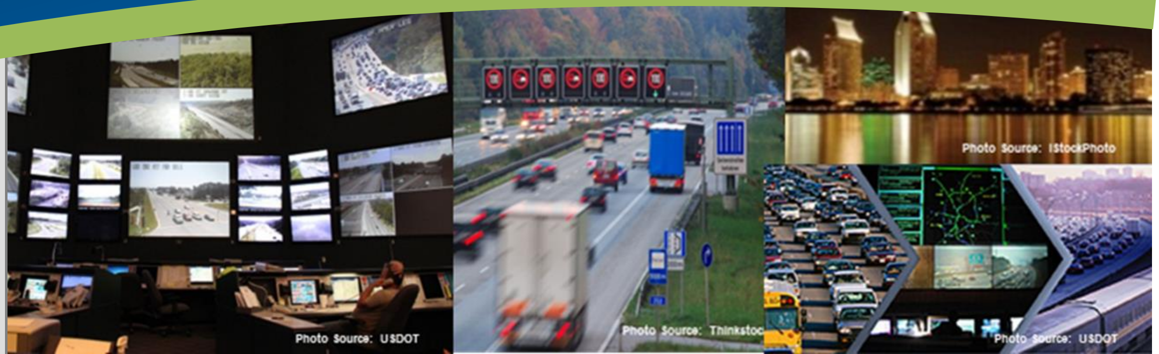
U.S. Department of Transportation

Integrated Corridor Management (ICM)

ITS Benefits, Costs, and Lessons Learned: 2017 Update Report



Integrated Corridor Management (ICM)

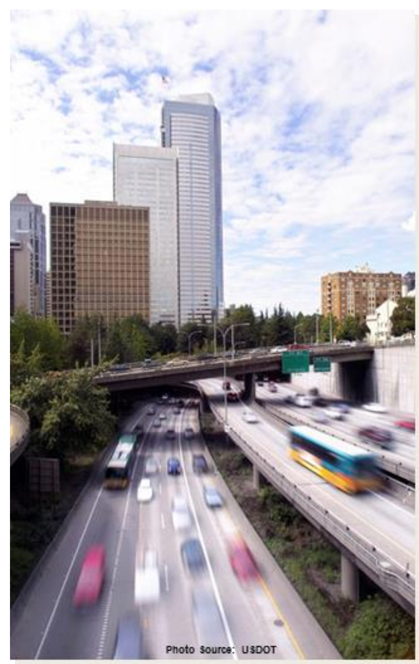
Highlights

- Decision Support System scenarios modeled on the ICM Corridor in Dallas Texas show travel time savings of nine percent on arterials when vehicles divert from the freeway.
- Planning-level studies indicate that an effective combination of ICM strategies can be implemented for $7.5 million per year (annualized capital and O&M).

Introduction

This factsheet is based on past evaluation data contained in the ITS Knowledge Resources database at: www.itskrs.its.dot.gov. The database is maintained by the U.S. DOT's ITS JPO Evaluation Program to support informed decision making regarding ITS investments by tracking the effectiveness of deployed ITS. The factsheet presents benefits, costs and lessons learned from past evaluations of ITS projects.

As ITS technologies continue to evolve, new strategies for operating our roadways continue to be researched and deployed. By focusing on ITS strategies that include freeways, arterials, transit, and transportation management centers, agencies can look beyond individual networks and explore regional corridors that may offer an opportunity to operate and optimize the entire system. The U.S. DOT has introduced the concept of Integrated Corridor Management (ICM), the purpose of which is to demonstrate that ITS technologies can be used to efficiently and proactively manage the movement of people and goods in major transportation corridors by facilitating integration of the management of all networks in a corridor. The results of the initiative will help to facilitate widespread use of ICM tools and strategies to improve mobility through integrated management of transportation assets. The ICM initiative will also demonstrate how proven and emerging ITS technologies can be used to coordinate the operations between separate corridor networks (including both transit and roadway facilities) to increase the effective use of the total transportation capacity of the corridor. Additional information on this initiative is available at the ITS JPO's Web site: www.its.dot.gov/icms.



ICM is defined as a collection of operational strategies and advanced technologies that allow transportation subsystems, managed by one or more transportation agencies, to operate in a coordinated and integrated manner [1]. With ICM, transportation professionals can manage the transportation corridor as a multimodal system rather than a fragmented network of individual assets. Using a wide variety of operating scenarios, operating agencies can manage demand and capacity across multiple travel modes in real-time to improve mobility, reduce fuel consumption and emissions, and increase travel time reliability and predictability. Initial guidance and lessons learned have been made available on the ICM Website.

As part of the USDOT ICM Initiative, large metropolitan areas across the country participated in research to assess the state of practice of corridor management and demonstrate the feasibility of ICM concepts. In 2015, ICM Deployment demonstrations in Dallas and San Diego were completed and lessons learned were documented as guidance materials for future ICM adopters.

ICM Implementation Guide and Lessons Learned
ICM Analysis, Modeling, and Simulation (AMS) Guide

Benefits

Transportation researchers have used Analysis, Modeling, and Simulation (AMS) methodologies to estimate the impacts of proposed ICM solutions. Projected benefit-cost ratios range from 10:1 to 25:1 over a 10 year period.

Table 1: Benefits of ICM.

Evaluation Measures	**San Diego** (2011-00736)	**Dallas** (2011-00757)	**Minneapolis** (2012-00804)	**San Francisco** (2009-00614)
Annual Travel Time Savings (Person-Hours)	246,000	740,000	132,000	1.2 million to 4.6 million
Improvement in Travel Time Reliability	10.6%	3%	4.4%	-
Gallons of Fuel Saved Annually	323,000	981,000	17,600	3.1 million to 4.6 million
Tons of Mobile Emissions Saved Annually	3,100	9,400	175	20,400 to 20,800
10-Year Net Benefit*	$104 million	$264 million	$82 million	$570 million
10-Year Cost	$12 million	$14 million	$4 million	$75 million
Benefit-Cost Ratio	10:1	20:1	22:1	7:1 to 25:1

*The values of safety benefits were not included in the San Diego, Dallas, and Minneapolis estimates.

Costs

While the 10 year project cost estimate for a corridor-wide ICM solution can range from $4 million to $75 million, the cost of a traditional improvement such as lengthening commuter trains, expanding bus rapid transit (BRT), or building a new highway lane can be much higher ranging from $400 million to $1 billion over the same period [2]. ICM solutions are a better value over time compared to traditional improvements [3]. Cost estimates for ICM implementation are represented in Table 2.

Table 2: Cost Estimates for ICM Implementations.

Planned ICM Deployments	**Estimated Costs**
ICM Strategies deployed on U.S. 75 in Dallas, Texas (2011-00236)	$13.6 million with annualized costs of $1.62 million per year for 10 years.
ICM strategies implemented on the I-15 Corridor in San Diego, California (2011-00219)	$12 million with annualized costs of $1.42 million per year for 10 years.
ICM Strategies deployed in Minneapolis, Minnesota (2012-00270)	$3.96 million
ICM Strategies deployed on the I-880 Corridor in San Francisco, California (2009-00194)	$7.5 Million Average Annual Capital and O&M Costs

Consistent with the ITS National Architecture cost estimates can be derived from ITS costs data housed in the U.S. DOT ITS Knowledge Resources. Table 3 provides an example of a planning-level cost estimate developed for the I-880 corridor. Additional data sets are available in the ITS Costs Database.

Table 3: Combined ICM Strategies, I-880 Corridor Estimate (2009-00194).

ICM System Components (2008)	Life (Years)	Capital Cost	Annual O&M Cost	Annualized Lifecycle Costs	Amount	Total Annual Cost
Common Infrastructure						
Basic TMC and Facilities				$633,333		$633,333
TMC Hardware and Software for Surveillance	20	$150,000	$7,500	$15,000		$15,000
Loop Detectors Double Set (each 0.5 mile)				$3,350	120	$402,000
Systems Integration	5-20	$1,435,000	$14,000	$155,750		$155,750
Communications						
DS3 Communications (Surveillance)	20			$2,700	120	$324,000
DS3 Communications (Transit and Traveler Info)	20	$8,000	$96,000	$96,400		$96,400
DS1 Communications (ETC and Signals)	20	$750	$6,000	$6,638	280	$1,858,500
Arterial Signal Control						
TMC Hardware for Signal Control	5	$22,500	$2,000	$6,500		$6,500
Linked Signal System LAN	20	$55,000	$1,100	$3,850		$3,850
Signal Controller Upgrade (per intersection)		$6,250	$350	$663	160	$106,000
Labor for Arterial Management			$540,000	$540,000		$540,000
Ramp Metering						
Ramp Meter (Signal, Controller)	5	$40,000	$2,000	$10,000	90	$900,000
Loop Detectors (2)	5	$11,000	$4,500	$6,700	90	$603,000
Transit and Traveler Information						
TMC Hardware and Software for Info Dissemination	5	$27,500	$1,375	$6,875		$6,875
Labor for Traffic Information Dissemination			$100,000	$100,000		$100,000
Info Service Center Hardware and Software	20	$457,000	$21,525	$44,375		$44,375
Map Database Software	2	$22,500		$11,250		$11,250
Labor for Information Service Center			$225,000	$225,000		$225,000
Transit Center Hardware	10	$22,500		$2,250		$2,250
Labor for Transit Center			$150,000	$150,000		$150,000
Electronic Toll Collection (ETC)						
Electronic Toll Collection Structure	20	$30,000		$1,500		$1,500
Electronic Toll Collection Software	10	$20,000		$2,000		$2,000
Software for Dynamic Electronic Tolls	5	$55,000	$2,700	$13,700		$13,700
Electronic Toll Reader (each 0.5 mile)	10	$10,000	$1,000	$2,000	120	$240,000
High-Speed Camera (each 0.5 mile)	10			$4,000	120	$480,000
Labor for HOT Lanes Management			$540,000	$540,000		$540,000
					TOTAL	**$7,461,283**

Lessons Learned

The U.S. DOT continues to encourage regions to become early adopters of Integrated Corridor Management Systems (ICMS). To assist local agencies with initial planning and implementation of ICM, and support the expanded operations and management of more mature systems, lessons learned have been collected from ICM Pioneer Sites across the country. The following lessons were derived from agency experience with implementing complex multi-year and multi-agency projects.

Stakeholder engagement

As a corridor is being considered for ICM, it is important that all agencies affecting the operation and maintenance of all networks be invited to participate in the planning process. Involve management across multiple levels including institutional, operational, and technical, and use transportation planners, modelers, and facilitators to help agencies understand each other's needs, capabilities, and priorities. Establish memorandums of understanding (MOUs), conduct interagency training and exercises such as incident reporting and dispatch drills, and hold meetings at the offices of other stakeholders to foster collaboration and commitment. The value of ICM is not readily visible on the surface and it can be challenging for smaller local agencies to buy into the overall vision of an ICMS, especially when under pressure to maintain tight budgets. With persistent marketing, however, stakeholders such as city officials, council members, and their constituents are more likely to support long term funding as needed to fully integrate regional ICM operations. When developing an ICMS business case, think about the ICMS from both the users' perspective and the ICM partners' perspective. Present the system as a complete solution that makes it easier to commute and get around. Do not underestimate the benefits of marketing that targets the traveler. Highlight outcomes that people can relate to.

Project management

Developing and deploying an ICMS is not a trivial exercise. Before proceeding with the development of an ICMS, it is essential that the stakeholders be able to describe why the proposed system is needed and what the goals of the ICMS are. During the planning process, examine the pros and cons of alternative systems engineering approaches. It is a good idea to consider a larger area of influence than expected around an ICM corridor. As attitudes change with respect to developing shared systems, agencies will need to keep up with technology advances in the private sector and respond more readily to increasing demand on larger networks. Focus on what is needed rather than the time that it will take to do it. Spend time figuring this out at management and operations levels. Put significant thought into what is wanted up front, but not so much that the project loses flexibility and is pigeon holed into a specific solution or tool. Decisions made early can have a vast impact on later activities for projects that have multiple procurements from multiple agencies. Needs and requirements will need to be screened and aligned. Partner with multiple modes to analyze dependencies so it is clearly understood which deliverables and activities are on the critical path. Change orders are common, but the impact of ripple effects on a multi-agency system should be mitigated using a common configuration management process and risk management plan. Have routine stakeholder team meetings to bring together lead members of each organization/committee, settle on common project terminology, and discuss progress with the project champion. This is a great way to help team members take ownership of their work and assess project resources. It is difficult to estimate resource needs for an ICMS well into the future, but this can be a key component of success. Future ICMS projects will require new technical skill sets in the areas of communications, fiber optics, traffic signals, and operations. Project managers will need to understand transportation policy, planning, local context, information technology, systems engineering, telecommunications, people, and meeting dynamics.

Project processes

As part of a Federal initiative to advance the state of practice of ICM, systems engineering was used to facilitate deployment at ICM demonstration projects in Dallas and San Diego. Example project documentation developed at each site included a concept of operations (Conops), project management plan (PMP), systems engineering management plan (SEMP), system requirements specifications (SRS), design documents (SDD), and the testing documentation used to verify and validate the system. At the conclusion of each project, researchers highlighted the following lessons learned to assist other cities considering similar projects.

- **Concept of operations** – Develop a Conops early in the project life cycle to allow stakeholders to clearly understand why the ICMS is needed, what the proposed system intends to do, and how they may be involved in the system's operations. (2016-00728)
- **Project planning** – Examine the pros and cons of alternative systems engineering approaches and understand the level of effort required to develop and maintain documentation for each alternative. Balance system engineering rigor with risk tolerance. Develop a SEMP to achieve quality in project development and ultimately produce a

successful ICMS. (2014-00668) The SEMP details the requirements documentation and management methodology that will be used, the traceability mechanisms that will be used, how needs elicitation will be conducted, how walkthroughs will be conducted, and how testing will be conducted. (2016-00728)

- **Requirements definition and analysis** – Develop a logical architecture as one key resource for describing what the ICMS will do. (2014-00670) The logical architecture and requirements should be developed iteratively. Write well-formed requirements from the perspective of the system and not the system user. They should be concise and include data elements that are uniquely identifiable. (2014-00671)
- **System design** – Develop initial ICMS designs that are robust enough to accept additional strategies. Enable each individual element to improve on its own without being constrained by the overall umbrella system. Early testing with a prototype may be useful when building a user interface. This could be done earlier at stakeholder meetings to help facilitate collection of stakeholder feedback and buy-in on the design.
- **Analysis, modeling, and simulation** – AMS tools can be used to assess operational strategies before they are implemented and to continuously monitor changing conditions and operational effectiveness. Analyze individual design possibilities to determine which are feasible, which provide the best performance, and which would be the most cost effective methods of system implementation. (2014-00672)
- **Build and test** – Consider using an iterative build process for new components of a system. For example, a decision support system can be developed in multiple ways using multiple strategies. It may be that several options need to be explored to fulfill stakeholder expectations. Iteration can help to take development in a piece by piece process when there is uncertainty in using new tools. When using a systems engineering approach such as Agile it is especially important to review increments of progress to keep velocity high even though the cost of maintaining documentation may be high. Conduct verification and validation activities at every stage of system implementation. Conduct multiple dry runs prior to acceptance testing. This will help personnel that need to participate remotely to confirm use of command and control functions at their regular workstations. If live testing is conducted, it is good to have a dead-man switch to end live testing quickly.
- **Operate and maintain** – A carefully planned, methodical transition plan can add to the efficiency of changing-over from old to new equipment. It is important to have good communications between stakeholders and maintenance staff during the transition processes. Bring this to the attention of stakeholders. A decision database should be maintained to inform new staff of decisions made early in the project. Identify system dependencies since the source of lost performance is not always immediately apparent. For example, a problem may present itself as a delay in a response plan; however, finding the problem would be very difficult without knowing all the system dependencies. It is a good idea to have a software support agreement. This makes it easier to identify what needs to be updated, replaced, and repaired, and the specific elements of system enhancements. When planning an ICMS estimate that maintenance costs will be about 10 percent of the design-build costs for the first year, and then about five percent per year thereafter
- **Training** – Adequately train all operations and maintenance (O&M) personnel and conduct regularly scheduled team meetings to continually improve processes and procedures as ICMS operations mature. (2014-00674) Provide a few weeks of classroom training as well as hands-on and practical training. Three months of practical training may be appropriate for a regional ICMS. Develop cliff-notes for O&M documentation and conduct refresher training every 8 to 12 months.
- **Retirement/Replacement** – Develop a list of factors and metrics to analyze system performance to determine when system replacement or retirement may become necessary. (2014-00675)

Case Study – ICM control of the I-394 and TH 55 corridor in Minneapolis, Minnesota (2014-00915)

A model used to simulate ICM control on a 3.5 mile section of I-394 and TH 55 corridor in Minneapolis, Minnesota indicated that diversion control used to fully utilize available capacity along parallel routes can significantly reduce network congestion. The diversion control system design included 10 intersections equipped with SMART-Signal systems and decision support logic that used 30-second traffic data sets from freeway surveillance systems and traffic demand profiles recorded at equipped intersections.

To simulate traffic conditions with and without ICM, a microscopic traffic simulation model (VISSIM) was built and calibrated using field data collected during morning peak hours (7:00-9:00 AM) from June 6-9, 2009. The model compared the results of two scenarios: a base scenario (independent control strategy) and an ICM control scenario (integrated control strategy).

To compare performance during an incident, a freeway car crash was introduced to each scenario decreasing freeway travel speeds to 10 mi/h along an 800 ft section of eastbound I-394 from 7:30-8:00 AM. Metrics included: average delay per vehicle, average number of stops per vehicle, and average vehicle speeds on the freeway and diversion route. The diversion control logic for the ICMS was set up to remain active until the diversion route travel time became longer than the freeway route travel time.

FINDINGS

ICM control strategies were found to smooth traffic flow and reduce congestion at varied levels of demand.

Table 4: Simulation with a 5 percent increase in freeway demand

Performance Measure	Base Scenario	With Diversion	Percentage Change
Average Delay (sec/vehicle)	76.79	64.27	-16.31%
Average Number of Stops (per vehicle)	3.45	2.13	-38.20%
Average Speed (mi/h)	37.63	40.26	7.00%

Table 5: Simulation with a 5 percent decrease in freeway demand

Performance Measure	Base Scenario	With Diversion	Percentage Change
Average Delay (sec/vehicle)	40.27	28.32	-29.67%
Average number of Stops (per vehicle)	1.41	0.73	-47.97%
Average Speed (mi/h)	45.98	49.58	7.82%

Table 6: Summary of network performance over the entire simulation period (7:00-9:00 AM)

Performance Measure	Base Scenario	With Diversion	Percentage Change
Average Delay (sec/vehicle)	55.69	41.14	-26.13%
Average Number of Stops (per vehicle)	2.21	1.28	-42.13%
Average Speed (mi/h)	42.12	45.86	8.89%

References

[1] "ITS ePrimer: Module 3 (Presentation)," Professional Capacity Building (PCB) Program, U.S. DOT RITA. September 2013. URL: http://www.pcb.its.dot.gov/eprimer/documents/module3p.pdf. Last accessed 22 April 2014.

[2] Anton, Lubov, and Associates. "Economic Analysis," Presentation, Minneapolis, MN. 2003. URL: http://nexus.umn.edu/Presentations/Northstar_economics.pdf. Last accessed 30 January 2014.

[3] Integrated Corridor Management Newsletter – 2012. U.S. DOT RITA webpage. URL: http://www.its.dot.gov/icms/docs/knowledgebase/html/news_fall12.htm. Last accessed 22 April 2014.

[4] *Integrated Corridor Management: Implementation Guide and Lessons Learned – Version 2.0*, U.S. DOT Federal Highway Administration website. URL: http://ntl.bts.gov/lib/59000/59600/59604/FHWA-JPO-16-280.pdf. Last accessed 6 September 2016.

All data referenced is available through the ITS Knowledge Resources Database, which can be found at http://www.itsknowledgeresources.its.dot.gov/.