Coordinated Freeway and Arterial Operations Handbook

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FOREWORD

Transportation agencies are realizing the importance of managing and operating transportation facilities to make the most of their existing capacity. Many agencies are successfully using traffic management strategies to operate freeways and arterials more efficiently. However, not many agencies are operating freeways and adjacent arterials together in a coordinated manner that treats these roadways as an interconnected traffic operations corridor rather than separate entities.

The purpose of the *Coordinated Freeway and Arterial Operations Handbook* is to provide direction, guidance, and recommendations on how to proactively and comprehensively coordinate freeway and adjacent arterial street operations together as a single, interconnected corridor. Agencies that make this shift from an agency perspective to systemwide perspective not only optimize traffic conditions on the overall corridor but on their own facilities as well.

The intended target audiences for this report are transportation professionals involved in the management, planning, engineering, design, and operations of traffic on freeway and arterial facilities. This includes managers, supervisors, planners, engineers, designers, and traffic operations staff.

Toni Wilbur
Director, Office of Operations Research
and Development

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16. Abstract Managing and operating freeways and adjacent arterials in a proactive and comprehensive manner, from a system user's perspective, is a major step toward operating all modes of the transportation system at maximum efficiency. The focus of this guide is on operating freeways and adjacent arterials together in a coordinated manner that treats these roadways not as separate entities, but as an interconnected traffic operations corridor. The purpose of this document is to provide direction, guidance, and recommendations for transportation managers, engineers, and planners on how to proactively and comprehensively coordinate freeway and arterial street operations.			
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SI* (MODERN METRIC) CONVERSION				
FACTORS APPROXIMATE CONVERSIONS TO SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
		APPROXIMATE CONVERSIONS FROM SI UNITS		
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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1 INTRODUCTION

1.1 Purpose

Traffic congestion is increasing significantly throughout the United States. Congestion is increasing in rural areas and urban areas, in small cities, and large cities. Further, the transportation community realizes there is no one proven way to fix the congestion problem and that a comprehensive approach of multiple congestion-reducing strategies is needed. One of these strategies is to operate the existing roadway system more efficiently or, in other words, to get more out of what already exists.

> The purpose of this document is to provide direction, guidance, and recommendations on how to proactively and comprehensively coordinate freeway and arterial street operations.

Proactively managing and operating existing freeways and adjacent arterials in a comprehensive manner, from a transportation system user's perspective, are major steps toward operating all modes of the transportation system at maximum efficiency. However, this handbook is not just about using system management strategies to operate freeways *and* arterials more efficiently; rather, the focus of this guide is on operating freeways and adjacent arterials *together* in a *coordinated manner* that treats these roadways not as separate entities, but as an interconnected traffic operations corridor. This is how transportation users view and use these roadways. Users will often, for example, divert from a freeway to an adjacent arterial during a freeway incident because they realize the adjacent arterial will get them to their destination more efficiently in this scenario.

The purpose of this handbook is to provide direction, guidance, and recommendations for transportation managers, engineers, technicians, and planners on how to proactively and comprehensively coordinate freeway and arterial street operations. There are many guidance documents on how to manage and operate transportation facilities individually, but this document is a first-of-a-kind because it focuses on how to *coordinate* the operations of different facility types that are typically operated by separate organizational entities with separate missions. To support the goal and purpose of this document, specific objectives include:

- Discuss the benefits of coordinated freeways and arterials (CFA) operations and why taking a coordinated approach benefits both users and managers of the transportation system.
- Explain how to take a broad, regional view of coordinating freeway and arterial streets before making plans and procedures for specific corridors.
- Describe how to develop a regional corridor management plan to support a broad, regional view of coordinated corridor operations.
- Describe a framework for planning and implementing coordinated plans and procedures for a single freeway and arterial corridor.
- Address the institutional challenges inherent in coordination and suggest ways to overcome these barriers.
- Define the range of possible operations strategies that can be used to address CFA operations, such as traveler information, traffic management and control, and information and resource sharing.

- Discuss how to package the operations strategies into operations plans and procedures for different response scenarios.
- Illustrate how coordinated plans and procedures can be developed for specific opportunities for coordination, including traffic incident management, work zone management, planned special events management, and day-to-day operations.
- Discuss the intelligent transportation system (ITS) technologies and components used to support coordinated operations and how to perform an ITS needs assessment to support the development of specific coordinated plans and procedures.
- Present a hypothetical application of state-of-the-art ITS in a regional area with multiple corridors to demonstrate real-time dynamic CFA operations.

1.2 The Underlying Problem

Demand for highway travel by Americans continues to grow as the population increases, particularly in metropolitan areas. The effects of congestion are captured in a number of measures and perceptions, including visible and consistent roadway congestion, the loss of personal and professional time, environmental degradation, and general traveler frustration—in essence, a reduction in overall mobility and accessibility. Figure 1 illustrates how congestion has grown in numerous ways to affect more people at a greater rate for longer periods of time.

While traffic congestion can be easily seen and measured, the underlying causes of traffic congestion are more difficult to discern. Recent research has determined these “root” causes on a national scale, as shown in figure 2. These percentages shown are national averages, so the percentages for an individual metropolitan area may vary depending on the local conditions.

Delays (resulting from congestion) at particular locations in a transportation network are certainly aggravating to those using the system; but these delays are part of a much larger picture of how a transportation system allows people and goods to move around a metropolitan area. The consequences of congestion are much more serious to a community. For example:(1)

- *Local Traffic Impacts*—Traffic bypassing congested conditions on a freeway can have large and unwanted impacts on local businesses and residential neighborhoods.
- *Economic Growth*—Efficient transportation access to employment and shopping sites is an important consideration to business and developers when considering expansion opportunities.
- *Quality-of-Life*—Long, frustrating commutes are contributors to human stress. In addition, this stress can be heightened when dealing with traffic jams and delays within neighborhoods after a long commute home from work. Traffic problems and congestion are an important characteristic of quality of life to many people.
- *Environmental Quality*—Congested road conditions can have a detrimental effect on the environment, in particular air quality. Making improvements to the transportation system or trying to change travel behavior has been an important objective of those wanting to improve environmental quality.

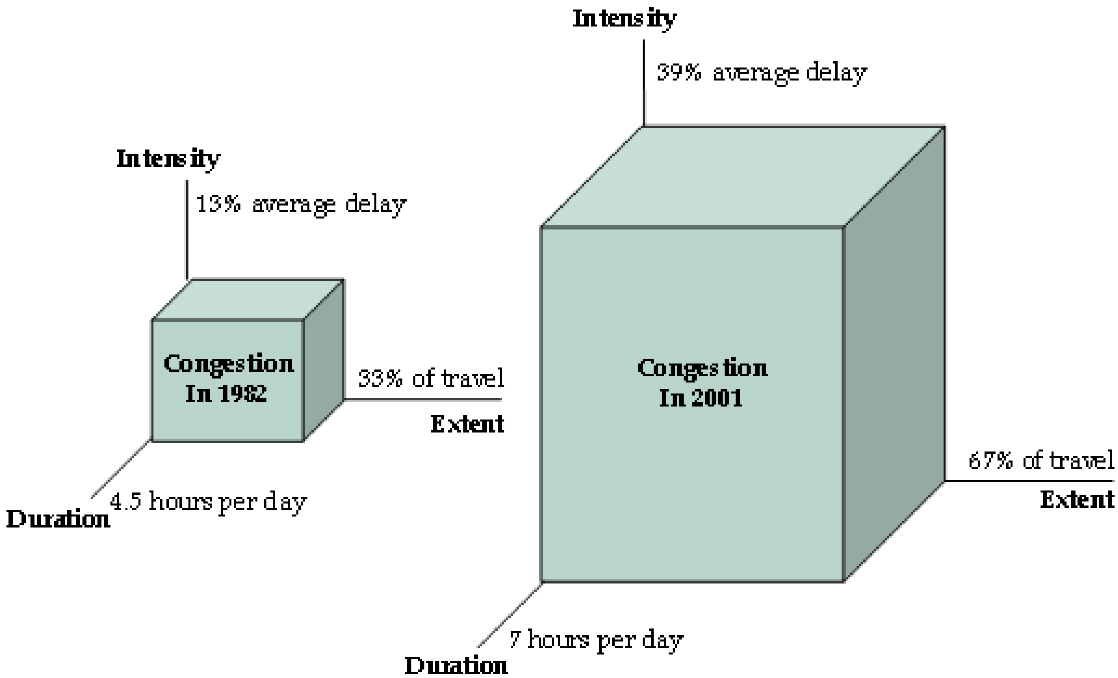


Figure 1. Chart. Increase in congestion in the past 20 years in the largest U.S. cities.[(2)]

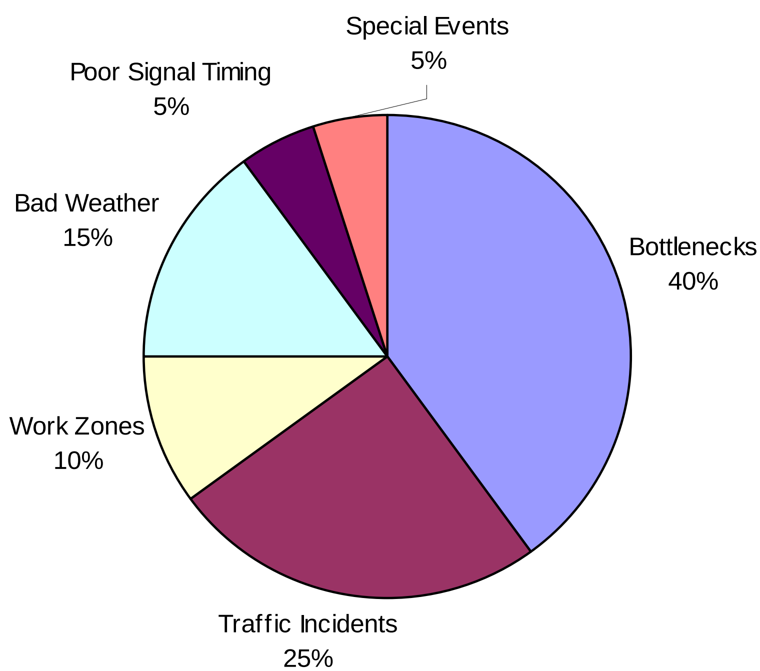


Figure 2. Chart. Sources of traffic congestion.[(3)]

1.3 The Challenge of Coordinated Operations

The surface transportation system has been operated historically by separate entities with specific missions, goals, and objectives. These entities may have varying authority that may be either very limited or rather broad. In addition, responsibilities may overlap. Typically, the State government manages and operates freeway facilities and most major arterials and city or county governments manage and operate secondary arterials, collectors, and local streets. Furthermore, some functions, such as policing or emergency services, typically do not correspond with the agency that operates the roadway facilities. The result of this complex institutional arrangement is that the transportation system is operated from a single agency or facility-specific perspective, resulting in less than optimal operations when viewed from a systemwide perspective. It is this suboptimal systemwide perspective that motorists experience.

This challenge of operating freeways and adjacent arterial streets from a coordinated, system perspective was identified long ago. Many agencies have discussed ways to better coordinate their freeways and arterials, but few have actually implemented a comprehensive method for doing so. The reasons for this lack of communication and interoperability range from institutional barriers to technical challenges. Recent advancements in technology (i.e., centralized software systems, high-speed telecommunications, and interoperable ITS devices through common standards), coupled with improvements in institutional coordination (i.e., many regions now have multi-agency, regional-level ITS and traffic operations working groups), are now providing regions with the tools and abilities to create proactive plans and procedures for operating freeways and arterial streets in a coordinated manner. While it is a challenge, regions may significantly benefit by taking advantage of these advancements in technology and institutional collaborations by operating their freeways and arterial streets in a coordinated manner.

1.4 What is Coordinated Freeways and Arterials Operations?

Coordinated freeways and arterials (CFA) operations is the implementation of policies, strategies, plans, procedures, and technologies that enable traffic on freeway and adjacent arterials to be managed jointly as a single corridor and not as individual, separate facilities. These policies, strategies, etc. should have an end goal of improving the mobility, safety, and environment of the overall corridor and not just individual facilities. For the purposes of this handbook, a corridor is defined as a freeway facility together with adjacent and connecting arterial streets that collectively function to move vehicles through a geographic area. While the term "corridor" could be applied to other facilities and modes of transportation, this handbook is designed to focus specifically on freeways and arterial streets. The concepts presented in this handbook could apply to corridors in urban, suburban, or rural areas.

> CFA operations are the implementation of policies, strategies, and so forth that manages traffic on freeways and adjacent arterials jointly as a single corridor and not as individual facilities.

1.4.1 The Need for CFA Operations

The operation of freeways and adjacent arterial streets is often closely linked and at visible example of how taking a single agency perspective can result in suboptimal, system-level performance. While agencies may not manage them as such, motorists view freeways and adjacent arterials as an interconnected corridor with multiple routes to travel from their origin to destination.

This point can perhaps be best illustrated with an example of a major incident occurring on a State freeway traversing a city. During a major incident, motorists will often attempt to divert around the incident via the adjacent city street system. Often, the routes chosen by motorists are not the quickest, most efficient alternatives. This "relief valve" effect can easily overwhelm the capacity of the local arterials, especially if the city traffic engineer has no advance warning of the impending wave of motorists on the local streets. If the city traffic engineer had known about the incident when it occurred and had pre-arranged signal timing plans to respond to the incident, the impact of the diversion could have been mitigated to some degree. In another freeway incident scenario, motorists may not respond to suggestions to divert off of the freeway if they do not know the local street system and are unaware of good alternate routes. In this case, the freeway is entirely overwhelmed while the adjacent arterial streets operate at normal conditions, which could be under capacity. As a result, this untapped arterial reserve capacity remains unknown to frustrated motorists stuck on the freeway.

> Agencies that shift from an agency perspective to a system perspective optimize not only the overall system but likely their own roadways as well.

These are classic scenarios that occur every day across the nation and highlight the need for CFA operations. It is clear these situations represent major delays and inefficiencies to motorists, who only look at a system perspective. Agencies that shift from an agency perspective to a system perspective not only optimize the entire system, but, in the process, optimize their own roadways as well.

1.4.2 Creating a Coordinated Operations Mindset

The previous sections documented the need and challenges of coordinating freeway and arterial operations; however, "coordinated operations" is easier said than done, and it involves thinking differently than the past. Many regions, particularly larger regions, have developed a mature system of ITS devices and technologies. Ramp metering systems, incident management systems, Transportation Management Centers (TMC), road weather information systems (RWIS), dynamic message signs (DMS), detector and video surveillance systems, and traveler information systems all represent excellent technologies that help agencies operate their systems more efficiently. However, all too often these systems, while operated more efficiently than in the past, are still operated separately. They are not coordinated across jurisdictional boundaries.

Having a coordinated operations mindset involves utilizing operations-enabling technologies and procedures in a seamless, comprehensive manner from a user's standpoint. Table 1 illustrates the thinking associated with a coordinated operations mindset, as opposed to the traditional mindset.

Table 1. Characteristics of a coordinated operations mindset.

Thinking…	Instead of…
Coordinated	Isolated
System	Jurisdiction
Customer focus	Project focus
Regional	Local
Proactive	Reactive
Comprehensive	Piecemeal
Real-time information	Historical information
24/7 operations	8/5 operations
Performance-based	Output-oriented

Source: Adapted from http://www.ops.fhwa.dot.gov/aboutus/opstory.htm.[3]

Institutional issues are at the core of having a coordinated operations mindset. All of the attributes of a coordinated operations program—policies, plans, procedures, agreements, funding mechanisms, strategies, systems and technologies, operational activities, and so on—take place within the institutional framework. This institutional foundation for transportation systems is multi-agency, multifunctional, and multimodal. Moreover, the authority for transportation decisionmaking is dispersed among several levels, or "tiers," of government (e.g., national, statewide, regional, agency, and individual systems), and often among several agencies or departments within each governmental level. This institutional disconnect can lead to a fragmented delivery system for transportation services, resulting in an agency-specific and/or a mode-specific focus rather than an areawide focus that considers the interaction and operation of the entire corridor. Gaining consensus across a region on having a coordinated operations mindset will help overcome these institutional challenges.

1.4.3 When To Implement CFA Operations

In the broadest sense, coordinated operations would be beneficial on any corridor that experiences congestion, either recurring or nonrecurring. More specifically, there are a number of opportunities for coordination of specific corridors. The opportunities relate back to the sources of congestion shown in figure 2. The sources of congestion lend themselves to four categories of potential CFA congestion mitigation:

- Traffic incident management.
- Work zone management.
- Planned special event management.
- Day-to-day or recurring operations.

Each of these categories presents congestion-causing challenges that would benefit by coordinating operations on a corridor. Combining corridor management strategies with traditional traffic engineering and management approaches will optimize the corridor safety and throughput.

A corridor may have a work zone only once every 10 years, but the impact of closing multiple lanes or entire roadways with major detours for days at a time can have a large impact on the corridor. On the other hand, recurrent congestion occurs very frequently (i.e., every weekday peak period), but the impact is typically less than that of a work zone because most motorists are aware of the bottlenecks and can make a plan to account for this congestion (i.e., leave work earlier or take an alternate route).

Ideally, determining which corridors are candidates for these opportunities for coordination should be made by a consensus of all stakeholders in the region. In the case of work zones and special events, these events are known in advance and should be identified early enough to adequately plan and implement plans and procedures to support corridor operations. Specific guidance on how to develop corridor implementation plans and procedures to mitigate these sources of congestion are provided in chapter 4.

1.5 Benefits of CFA Operations

Many studies have documented the benefits of transportation systems operations. For example, freeway management systems, such as ramp metering and incident management, have been shown to reduce traveltimes 20 to 48 percent, increase travel speeds 16 to 62 percent, and decrease accident rates 15 to 50 percent. Meanwhile, arterial management systems, such as advanced traffic signal systems, have been shown to reduce traveltimes 8 to 15 percent, increase travel speeds 14 to 22 percent, and decrease emissions 4 to 13 percent.[4]

However, these benefits are typically for operating freeway and arterial systems independently and not in a coordinated manner. Unfortunately, there have been few empirical studies to show the benefits of coordinated operations above and beyond isolated operations. Table 2 shows the results of a few selected studies that have documented the benefits of coordinating freeway and arterial operations.

As shown in table 2, an empirical study in Scotland showed that coordinating arterial signal timing plans, ramp metering plans, and DMS messages during heavy congestion reduced corridor traveltime by 13 percent. Three simulation-based studies demonstrated similar results.

Table 2. Benefits of CFA operations.

Location (Date)	Background	Impacts
M-8 Corridor, Glasgow, Scotland (1997–1998)[5]	Field deployment of adaptive signal control, ramp metering, and DMS messages to balance traffic loads through corridor.	Traffic volume: no change. Traveltime: 13% decrease.
Anaheim, CA (2000)[6]	Simulated deployment of alternative corridor operations plans (signal timing plans, ramp metering plans, DMS messages, route diversion plans) during nonrecurring congestion.	Traveltime: 2–30% decrease. Stop time: 15–56% decrease.
San Antonio, TX (2000)[7]	Simulated deployment of corridor operations plans for integrating incident management, DMS messages, and signal timing plans.	Freeway management only: 16.2% delay reduction. Integrated freeway and arterial management: 19.9% delay reduction.
Seattle, WA (2000)[8]	Simulated deployment of integrating arterial and freeway advanced traveler information systems (ATIS) in north I–5 corridor.	Freeway only ATIS: 1.5% delay reduction. Freeway plus arterial ATIS: 3.4% delay reduction.

The Anaheim study tested a comprehensive, coordinated set of corridor operations plans and found significant traveltime savings up to 30 percent. The San Antonio study found a more modest impact of coordinating freeway and arterial operations: a 16.2 percent delay reduction with just freeway incident management was increased to 19.9 percent when incorporating arterial management and incident management plans.

The benefits of coordinated operations may sometimes be difficult to assess quantitatively, yet in a corridor where tens of thousands of people commute, a modest decrease in traveltime may translate into many quantitative benefits in such areas as:

- Safety.
- Mobility and reliability.
- Quality of life.
- Environmental effects.
- Motorist perceptions.

To a large extent, collisions that occur as a result of stop-and-go-traffic can be reduced if congestion within a transportation corridor is effectively mitigated or the efficiency of corridor management is improved. On a corridorwide basis, these systemic improvements translate into increased safety for drivers.

Although less obvious, there is a known, direct correlation between improved traffic operations and environmental improvements. First, and perhaps most importantly, is the reduction in the amount of emissions released into the atmosphere. As average vehicle speeds increase towards the posted speed limit, the amount of vehicle pollutants released into the atmosphere generally decreases and vehicles operate at a more fuel-efficient mode due to a reduction in the stop-and-go behavior associated with congestion.

> Perhaps the biggest benefit of coordinated operations is the improved communication and coordination between agencies, from which the benefits of working together can far exceed those of just corridor operations.

Coordinated operations of freeway and arterial traffic can result in less easily defined qualitative benefits as well. Improved traffic flow, decreased traveltimes, and improved safety all work together to ease motorists' frustration and concerns, casting users' perception of regional transportation officials and agencies in a more positive light. This in turn makes it easier to acquire the needed funding to develop, implement, operate, and maintain transportation systems within the corridor.

Perhaps one of the most valuable benefits, however, is that by developing or improving lines of communication and coordination between agencies, organizations, and the public, the foundation is laid for improved overall understanding of the goals and objectives of each participant in a regional coordination effort. This improved understanding is, potentially, the basis for reaching long-term, corridorwide or regional transportation goals.

1.6 Document Organization

This document consists of 6 chapters. Table 3 gives a short description of each chapter in the document.

Table 3. Overview of document chapters.

Chapter	Title	Description
1	Introduction	This chapter describes the purpose and objectives of the document and subject area, the definition and need for coordinated operations, and how to use this document.
2	Planning for Coordinated Traffic Operations on Freeways and Arterials	This chapter provides a broad view of the planning-level activities recommended for the successful development of CFA operations examined at a regional level and a corridor-specific level.
3	A Framework for Coordinated Operations on a Corridor	This chapter details the recommended 11-step framework for the entire life cycle of coordinated operations for a specific corridor.
4	Applying CFA Operations to Four Opportunity Areas	This chapter demonstrates how the corridor-level framework can be applied to incident management, work zones, special events, and daily recurring operations.
5	Supporting Technologies and ITS Elements	This chapter presents concepts and technologies that will enhance the efficiency of coordinated freeway and arterial operations.
6	Examples of CFA Operations	This chapter presents practical applications of the CFA process and demonstrates the potential of ITS technology to enhance corridor operations.

The intended audience of this document is the team of individuals that is involved in or responsible for the planning, coordination, management, or operation of traffic on freeway and arterial facilities (e.g., managers, supervisors, engineers, planners, or technicians that are involved with legislation, policy, program funding, planning, design, project implementation, operations, or maintenance).

This handbook is intended to be an introductory manual to assist practitioners that may be involved in or responsible for the advanced planning and management of travel on freeway and arterial roadways for different congestion-causing scenarios. It is not intended to serve as a detailed technical reference or design guide that addresses all of the details or tasks to be performed that are associated with developing specific traffic control plans, designing interfaces to exchange information between systems, developing control algorithms, or implementing plans to coordinate traffic on and between freeways and surface street roadways.

2 PLANNING FOR COORDINATED OPERATION OF TRAFFIC ON FREEWAYS AND ARTERIALS

2.1 Purpose

The purpose of this chapter is to provide a broad view of the planning-level activities recommended for the successful development of CFA plans and procedures. Many of these planning-level activities should take place at a regional level before developing plans and procedures for a specific corridor. Collaboration and coordination among regional stakeholders on regional-level policies, agreements, operational strategies, and funding priorities will set the stage for successful corridor level plans and procedures. In addition, this chapter provides a corridor-level framework for the entire life cycle of planning, deploying, and operating plans and procedures for coordinated operations on a single corridor. Upon reading this chapter, the reader should have a good understanding of the importance and benefits of planning for CFA operations.

This chapter provides a top-down approach to the subject by first focusing on the regional-level planning and coordination activities recommended for corridor management and then introducing the corridor-level framework for corridor management. This corridor-level framework will be explained in more detail in the next chapter, chapter 3.

2.2 Introduction

While an agency could make the case for delving right into the development of corridor management plans and procedures, this chapter suggests that the chances for success will be much higher if some initial planning and coordination is done upfront. Further, the chances for success are even higher if this coordination and collaboration is first initiated at a regional level before filtering down to planning for a specific corridor. In terms of corridor management, taking a regional perspective means developing consensus among regional stakeholders through policies, procedures, agreements, strategies, and priorities for the entire region that will expedite the development of plans and procedures for individual corridors.

"Regional operations" means putting the available operations elements together into an integrated package that focuses on maximum system performance from the users' perspective. The critical integration elements among the regional stakeholders are:[9]

- Resource integration.
- Information exchange.
- Equipment sharing.
- Pooled funding.
- Personnel integration.
- Systems integration.
- Institutional integration.

The next section discusses the planning and coordination activities related to corridor management that should be done on a regional level. Section 2.4 introduces a system engineering framework for systematically developing and operating CFA plans and procedures for an individual corridor. The framework will be presented in more detail in the description of the corridor level framework in chapter 3.

2.3 Regional-Level Planning and Coordination

Today's realities require recognition of the constraints imposed upon further expansion of the highway network, particularly in metropolitan areas, and that maximization of system efficiency and system preservation need to become higher priorities. Regional planning for operations is a part of this new reality, and it must be assimilated into the broader metropolitan planning process undertaken by metropolitan planning organizations.

This process provides a systematic approach to improving regional traffic management, a portion of which is corridor traffic management.

While local metropolitan policymaking organizations currently exist with their own local agency interactions and relationships, to achieve a broader vision of the transportation system requires building new processes and procedures with a regional focus. It is the regional transportation planning process that brings regional collaboration and coordination to bear on operational issues. This process provides a systematic approach to improving regional traffic management, a portion of which is corridor traffic management.

The first step in developing CFA operations is understanding that a corridor mindset requires a regional perspective and function. Figure 3 illustrates how certain functions can only be executed with cooperation and collaboration at the regional level, not at the local or individual agency level. Local agencies cannot achieve coordinated operations based on their individual actions.

Examples of regional functions include:

- Coordination between freeways and arterials operations.
- Coordination of traffic signals across jurisdictional boundaries.
- Sharing resources such as DMSs across jurisdictions.
- Joining traveler information systems among multiple agencies.

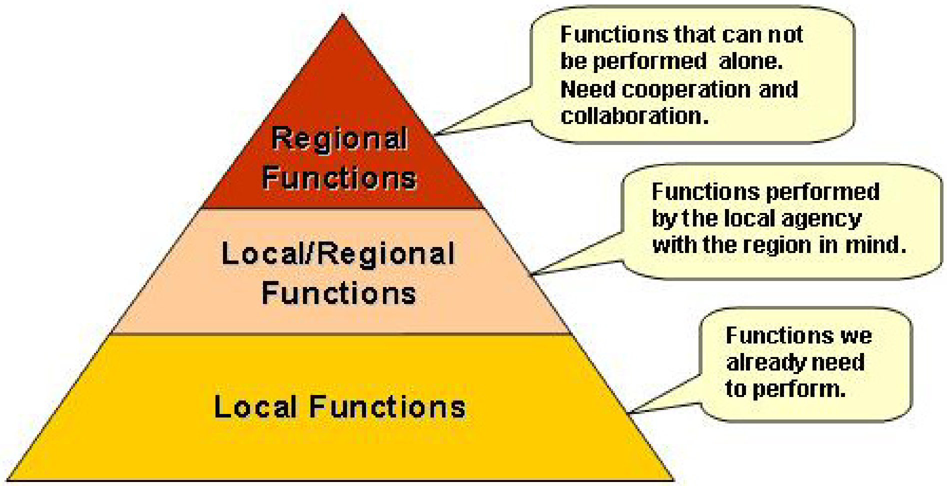


Figure 3. Chart. Relationship between regional and local functions.[(10)]

Regional-level focus provides multi-agency coordination for many aspects of the surface transportation system, fostering freeway mobility, arterial mobility, and traveler information. Regional coordination is also a primary factor in encouraging multi-agency sharing of data and resources.

Five major elements, shown in figure 4, form a collaboration and coordination framework on which to build sustained relationships between all affected agencies and stakeholders and create strategies to improve transportation system performance. The framework creates structures through which processes occur that result in products (e.g., a regional corridor traffic management plan as discussed in the next section). A commitment of resources is implied to support initiation and sustaining of regional collaboration and coordination and for implementing agreed upon solutions and procedures. The entire effort is motivated by a desire for measurable improvement in regional transportation system performance.[(11)]

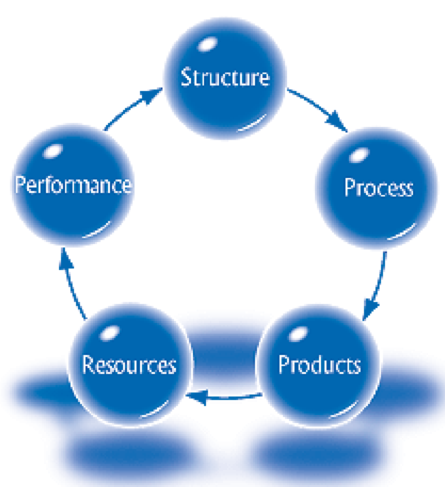


Figure 4. Chart. Elements of regional collaboration and coordination.[(11)]

The objective of the collaboration and coordination framework is to help institutionalize working together as a way of doing business among transportation agencies, public safety officials, and other public and private sector interests within a region. The framework is therefore appropriate for developing a CFA operations program. Depending on the state of operations in the region, corridor operations can either build upon an established collaboration and coordination framework or the collaboration and coordination framework can be used as an aid to develop the interagency partnership necessary for a successful corridor operations program.

A collaboration and coordination framework is important because existing institutional structures create barriers that make collaboration and coordination difficult. These barriers include resource constraints, internal stovepipes in large agencies, and the often narrow jurisdictional perspective of governing boards. The framework is intended to guide operators and service providers in overcoming these institutional barriers by establishing a process that has been shown to be successful in facilitating cooperative relationships.

An example of developing a regional-level structure to overcome these traditional institutional limitations is shown in figure 5. This figure is from the Maricopa Association of Governments (MAG) Regional Concept of Transportation Operations, which provides the vision and goals for regional operations around Phoenix, AZ as well as a high-level view of the initiatives and performance improvements that collaboration and coordination may achieve. This figure shows the relationship between local and regional functions developed by the MAG for its region and is illustrative of how a regional focus was established using existing agencies. Note that a Freeway-Arterial Operations subcommittee has been established within this structure. This subcommittee organizes and coordinates the regional efforts for corridor management with the local agencies.

Another example of a regional-level structure is a regional operating organization (ROO), which consists of traffic operations agencies, transit agencies, law enforcement, elected officials, and other operations agencies focused on the operation and performance of a regional transportation system. A ROO works to ensure interagency coordination of resources and information across jurisdictional boundaries. It builds partnerships and trust among agencies to improve their productivity and performance, creating a more responsive system to temporary capacity deficiencies. ROO member agencies may, for example, share traffic signal timing plans, coordinate planned strategies and resources for managing travel, conduct public outreach, and participate in interagency training.

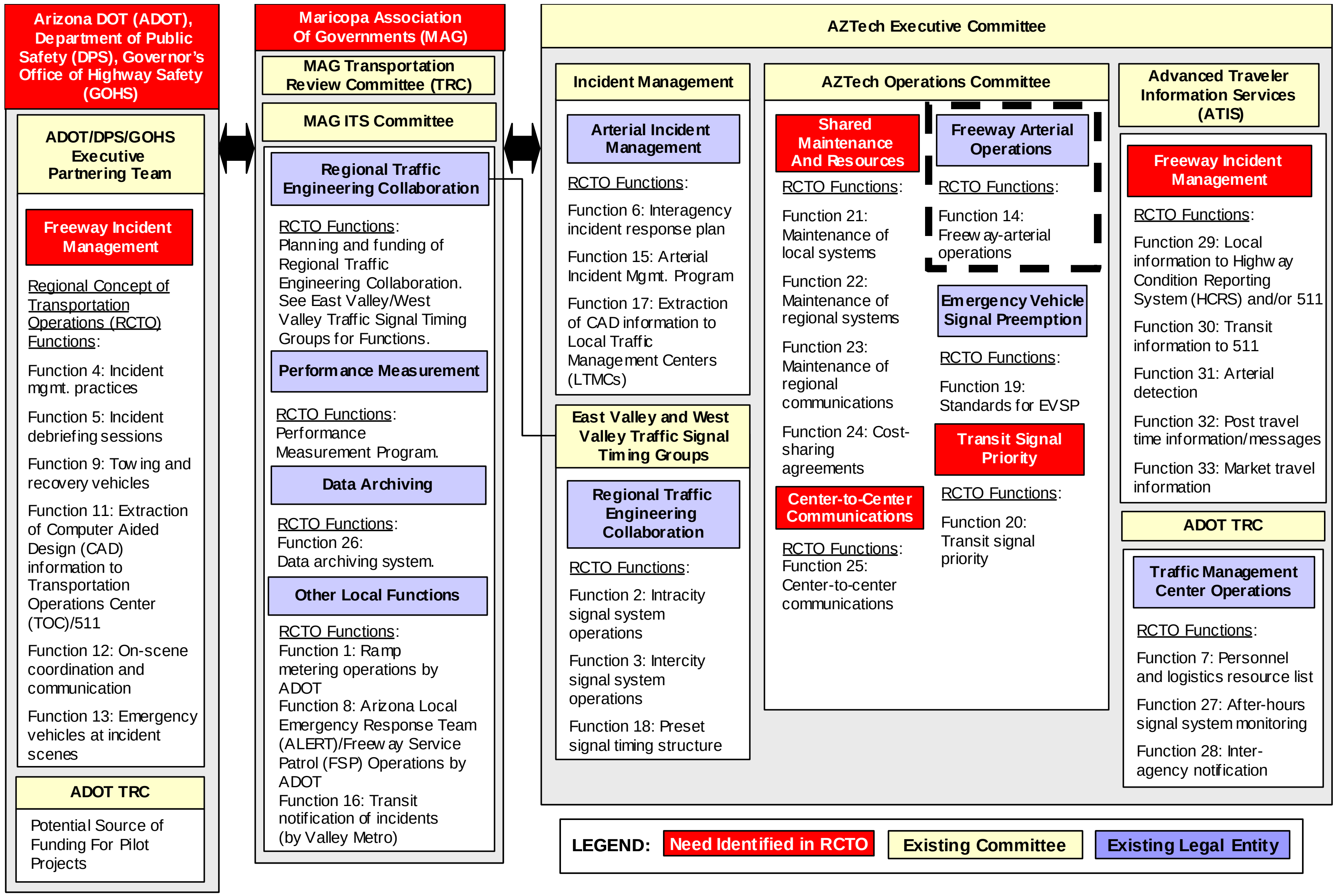


Figure 5. Chart. Example of integrating regional and local processes.[10]

2.3.1 Developing a Regional Corridor Traffic Management Plan

The first step in developing a corridor management plan is to leverage or build on the regional planning process. The goal of planning at the regional level is the development of a comprehensive plan for coordinating freeway and arterial operations throughout the region. Such a plan, developed or supported by key stakeholders in all affected agencies, would be more likely to gain the approval of key decisionmakers responsible for funding decisions in the region. Once funding and resources have been harnessed, plans and procedures for specific corridors can be developed.

> The first step in developing a corridor management plan is to leverage or build on the regional planning process.

The objective of a regional corridor traffic management plan would be to address issues and barriers related to coordinating freeway and arterial operations that are best dealt with at a regional level before developing and implementing specific plans, strategies, and procedures within specific corridors. In other words, it may be possible to solve a host of issues globally for an entire region rather than cause unnecessary repetition by addressing the issues individually for each specific corridor.

Operations issues that can be addressed and resolved at a regional level through policies, agreements, and plans include:

- Optimization and coordination of signals between agencies.
- Optimization and coordination of traffic signals and adjacent ramp meters.
- Altering freeway ramp meters during freeway and arterial incidents.
- Altering arterial signal timing during freeway and arterial incidents.
- Sharing data on incidents and traveler advisories.
- Sharing DMSs during various events.
- Developing regional route diversion plans during freeway and arterial incidents.

In addition to developing common regional-level operations policies, agreements, and plans, a regional corridor management plan could identify and address a number of other issues:

- Establish a regional working group comprised of key stakeholders and a champion to lead the group in being responsible for corridor management within the region.
- Develop the vision, goals, objectives, and performance measures for corridor traffic management in the region.
- Develop a regional corridor management concept of operations to identify high-level policies and plans needed to support plans and procedures for individual corridors (see the above bullet list for examples).
- Identify information and resource sharing needs on a regional level (e.g., identifying whether local agencies need to access and view freeway detector and closed circuit television (CCTV) cameras) for the purpose of corridor traffic management.
- Propose technology and ITS needs to support corridor traffic management at a regional level (e.g., identifying the need for an updated freeway transportation management center (TMC) software system that better allows for regional information and resource sharing).

- Identify and prioritize specific corridors that need corridor-level plans and procedures for CFA operations.
- Develop a plan for budgeting and phasing corridor-level studies and the subsequent design, implementation, operation, and maintenance of the individual corridor management plans.

The process of putting together a regional corridor management plan will be highly dependent upon existing programs and relationships among local agencies. Figure 5 in the previous section illustrates how one region created a region-based institutional structure that could be readily harnessed to develop such a regional corridor management plan. Each region will have to tailor their approach to the local institutional relationships and structures.

While a formal regional-level plan as suggested in this section is not a requirement before developing plans and procedures for individual corridors, there are benefits to developing a regional plan, such as:

- Resolving many of the institutional barriers on a regional level before proceeding to developing plans for individual corridors.
- Gaining region-wide consensus on the general approach and planning for corridor management in the region.
- Gaining the support of key decisionmakers responsible for funding decisions in the region.
- Cost savings through addressing regional operations issues just once rather than multiple times when developing plans and procedures for individual corridors.
- Cost and timesavings by early identification on what policies and agreements will be needed before proceeding to develop plans for individual corridors.

Some smaller regions may determine that the upfront cost of preparing a formal regional corridor management plan may outweigh the benefits listed above. For example, a region with one corridor that, both in the near- and long-term, would justify CFA plans, may not need a formal regional corridor management plan and could proceed directly to developing plans and procedures for that individual corridor.

After developing a regional corridor management plan, the region would have institutional structures in place, consensus by regional stakeholders, policies and plans to support corridor management, a prioritized list of corridors warranting individual plans, and the resources identified to develop and operate individual corridor implementation plans. The next section discusses a recommended framework for development and operation of individual corridor implementation plans and procedures.

2.4 Corridor-Level Planning and Coordination

A process roadmap, or framework, was developed to facilitate the life cycle (planning, design, operations, and maintenance) of CFA operations for an individual corridor. This framework is recommended for individual corridors after addressing regional-level issues identified in section 2.3. Because corridor traffic management is typically fragmented due to the institutional make up of the agencies involved in

> The framework provides a process to overcome the institutional seams that inhibit coordination and collaboration.

corridor traffic operations, the framework provides a process to overcome the institutional seams that inhibit coordination and collaboration.

The framework is scalable based on the complexity of the corridor and required operations strategies. For smaller corridors, some steps may not need to be formally addressed (e.g., a formal evaluation of operations strategies may not be necessary when there is only one feasible strategy). For larger, more complex corridors, formally going through each step in the framework may be necessary to ensure consensus is achieved by stakeholders, to provide a roadmap through the entire life cycle of the project, and to help to identify and address major problems before it is too late (i.e., already in the implementation phase).

The coordinated freeways and arterials framework is composed of the following elements (a graphical version of the framework is presented in chapter 3):

- Getting Started:
  - Step 1: Problem identification.
  - Step 2: Institutional considerations.
  - Step 3: Goals, objectives, and performance measures.
  - Step 4: Corridor concept of operations

- Decisionmaking:
  - Step 5: Corridor scenarios and operations strategies.
  - Step 6: Evaluation and selection of strategies.
  - Step 7: Corridor implementation plan.

- Implementation:
  - Step 8: Design and development.
  - Step 9: Deployment.
  - Step 10: Operations and maintenance.

- Continuous improvement:
  - Step 11: Continuous improvement.

It should be noted that the framework is cyclic, because the process often requires iteration between steps to resolve competing issues. For example, an operations strategy may be chosen for evaluation. Upon close consideration, the strategy may require more resources than are available, resulting in the reconsideration of alternative strategies more consistent with the available resources.

The steps in the framework are grouped into four categories: getting started, decisionmaking, implementation, and continuous improvement. The remainder of this section presents a high-level discussion of each of these four categories. The next chapter, chapter 3, discusses each of these steps in more detail.

2.4.1 Getting Started

Step 1 is to define the problem. This may occur either through a formal performance monitoring process that is part of a regional planning process or as the result of an obvious operational problem such as traffic backing up onto a freeway due to an arterial traffic signal. The definition of the problem in the broadest sense should actually begin at the regional planning and coordination stage discussed in the previous section. At the regional level, problems are identified at a minimal level of detail as part of a planning and programming function. What may be a problem to one agency may not be a problem to another; therefore, it is important to discuss and gain consensus on the extent and severity of the problem to be addressed.

> The success of the project is a direct result of the ability of a variety of institutions, agencies, and affected parties to gain consensus, have regular contact through meetings or other communication, and work within the context of other regional entities.

This is where Step 2 comes in, which is to assess institutional considerations. A CFA framework can create a bridge for agency structures to address an identified problem in a manner that all affected stakeholders can support. Part of overcoming institutional isolation is establishing a structure, such as a working group composed of various representatives from the affected agencies, early on to guide the entire process. The structure, whether an ad hoc group or formal committee, should consist of the broadest constituency of stakeholders possible. Participants should be representative of all agencies and parties involved in the planning, design, operation, or maintenance of the plans and procedures (e.g., planners, engineers, traffic managers and supervisors, TMC operators, and maintenance personnel), as well as those directly impacted by the plans and procedures (e.g., law enforcement, emergency services, transit operators, special event centers, and major employers). The size of the group should be commensurate with the size and complexity of the project. Overall, the success of the project is a direct result of the ability of a variety of institutions, agencies, and affected parties to gain consensus, have regular contact through meetings or other communication, and work within the context of other regional entities.

Once the structure for the stakeholders has been agreed upon and developed, it will be their responsibility to identify the goals, objectives and performance criteria for the corridor, step 3 in the process. Ideally, the goals and objectives established will be directly related to the problems identified in the first step. If the problem was identified broadly, it will be the responsibility of the stakeholder group to examine the problem and develop a more detailed assessment of its nature. The goals will be broad statements of the desired outcome once the problem is resolved. The objectives will be specific statements of what will be achieved in support of the goals (e.g., to reduce incident-related delays by 10 percent), and the performance measures identified will represent specific measurements that will be used to assess the goals and objectives (e.g., vehicle-hours of delay during the a.m. peak travel period). Performance measures should include metrics that users of the transportation system experience directly, such as traveltime between points.

Step 4 in getting started is to develop a corridor concept of operations. The corridor concept of operations is a document, either formal or informal, that provides a high-level, user-oriented view of operations in a specific corridor. It is developed to help communicate this view to other stakeholders in this process, such as the interested public, and to solicit their feedback. The final document should describe the goals, objectives, and performance measures of the corridor agreed upon by the stakeholder group. It should also provide a description of the existing corridor conditions, geometrics and traffic control devices, operating practices and policies, and ITS technologies and capabilities. It should also describe at a high level the operational scenarios (the traffic conditions during a given operational deficiency) when strategies, plans, and procedures are needed and the high-level strategies that can address the problems during these scenarios.

> The corridor concept of operations is a document, either formal or informal, that provides a high-level, user-oriented view of operations in a specific corridor.

2.4.2 Decisionmaking

Decisionmaking starts with step 5 and requires identification of detailed operations scenarios for the corridor, which allows the process to move toward the selection strategies. While an example of a high-level scenario may be a full closure of the freeway during an incident, a more detailed scenario would be a full closure of the northbound direction of the freeway from Mileposts 15 through 20 for more than 2 hours. Based on this scenario, a number of operations strategies should be identified that may mitigate this potential cause of congestion. The types of strategies that are appropriate within a corridor management context include:

- **Traveler information**—providing information to travelers through a variety of media, such as radio, television, Web sites, kiosks, telephone (511), highway advisory radio (HAR), and both fixed and portable DMSs. Most regions use at least one or more of these media, but often the information is not coordinated in a corridor- or systemwide perspective. An example of providing traveler information from a corridorwide perspective might be setting a DMS on a freeway that provides incident information on nearby arterial streets, or an arterial DMS that provides freeway congestion information. A proactive approach might include directions for alternate routes via DMS or trailblazer signs to guide motorists around an incident or bottleneck.
- **Traffic management and control**—coordinating traffic management and control devices, plans, and procedures is another effective way to optimize travel through a corridor. A primary example is coordinating traffic signals and/or ramp meter signals for movement throughout the corridor. Local agencies could develop pre-arranged signal timing plans that could be implemented quickly in response to freeway incidents. Adjustment plans for adjacent ramp meters could also be incorporated into operations plans. Reversible lanes offer capacity enhancement if directional movements allow. Vehicle type restrictions during peak periods may ease congestion. Suspending toll collection has proven effective on several major facilities when inordinate queues have formed. Access control within a corridor is another means of traffic management; activating turning restrictions along an arterial during an incident and changing ramp meter timing to restrict access, or even temporarily closing a ramp, are all examples of operations strategies to control and manage traffic.
- **Shared information and resources**—strategies to share information and resources across and within agencies can be very simple and effective, yet are often overlooked. Information sharing can be as simple as a telephone call, page, or an e-mail from a freeway TMC operator to a city engineer to provide incident notification. This notification enables the engineer to quickly activate a pre-arranged signal timing operations plan designed to alleviate congestion due to an incident. Another efficient strategy that would allow agencies to easily monitor

conditions along adjacent roadways is sharing CCTV cameras among agencies. Other resources that could be shared include incident response equipment such as service patrols, wreckers, or portable DMSs.

While many strategies may be easily identified, Step 6 is to evaluate and select the most appropriate strategies for each scenario. The assessment of strategies can vary from simple, pragmatic assessments to detailed traffic microsimulation studies. The method used should be appropriate to the complexity of the alternatives and the cost of implementation. The evaluation criteria should also be representative of the goals and objectives of the local area.

The final step in the decisionmaking phase of the CFA operations framework, step 7, is to develop a corridor implementation plan, which provides all the information necessary to proceed with the implementation phase. The corridor implementation plan may be a formal document that represents the sum total of all the work that has been undertaken up to this point, summarizing the identified problems; the goals, objectives, and performance measures; the corridor concept of operations; and the selected operations strategies for various corridor scenarios. When describing operations strategies, details such as capital and operating costs, potential programming priorities and scheduling, infrastructure needs in support of the strategies, and descriptions of maintenance procedures and costs can help create a valuable blueprint for the remainder of the project.

2.4.3 Implementation

The implementation phase consists of design and development, deployment, and operations and maintenance. Step 8, design and development, translates each of the various projects included in the corridor implementation plan into executable project operations plans. Operations plans would be developed only at a high level in the corridor implementation plan, while in this step the individual operations plans would be fully developed. For example, the corridor implementation plan may identify a light diversion signal timing plan as an operations strategy. In the design and development stage, the exact signal settings in the timing plan would be determined, the specific individual(s) authorized to implement the plan would be identified, and details of how the plans would be implemented would be agreed upon. The design of needed infrastructure to support the operations strategies, such as deployment of an arterial DMS, would also be completed at this stage of the process. Any needed interagency operating agreements would also be finalized during this step.

Step 9, deployment, comprises the construction of infrastructure, signing interagency agreements, and “turning on” needed software or communications equipment. There could be many factors involved with a multi-agency, multifaceted deployment, so patience and dedication is necessary to ensure a successful project.

Step 10, operations and maintenance, is perhaps the most important in the process. Stakeholders whose primary responsibility will be to activate and operate operations plans should be involved early in the process of developing operating plans and procedures. These individuals will not only provide valuable insight into operations and maintenance processes, but also have a clear understanding of the roles and responsibilities of operations and maintenance personnel during the various scenarios. They will also be able to ensure that plans are operating at maximum efficiency and reliability.

2.4.4 Continuous Improvement

The continuous improvement process, reflected in step 11, is never ending. As the system is being operated and maintained, it must be continually monitored. The monitoring process determines whether the actual performance of the system matches the goals and objectives of the project. If the system is not solving the problem identified in Step 1, then modifications should be made to better address the problem. This is, in effect, another cycle of problem identification, identification of improvement strategies, evaluation, prioritization, design, deployment, operations, maintenance, and so on. More detail is given in section 3.13 on when iteration through the process is necessary, and to which step in the process iteration should occur. Without such a process, the corridor (and the overall system) will fail to perform at optimum effectiveness and efficiency.

2.5 Summary

This chapter presented a broad view of the planning-level activities recommended for the successful development of CFA operations. The planning process was examined at a regional level and then at a corridor-specific level. It is only after understanding these levels that meaningful corridor sensitivity and analysis can be initiated. The CFA framework introduced in this chapter, is described in more detail in the next chapter. Utilizing a consistent framework insures a repeatable, stepwise process. Thusly, process, appropriate technologies, and deployable solutions are the primary focus for the remainder of this document.

3 A FRAMEWORK FOR COORDINATED OPERATIONS IN A CORRIDOR

3.1 Purpose

The purpose of this chapter is to expand on the corridor-level framework recommended for planning, developing, and operating plans and procedures to support coordinated operation of traffic on freeways and arterials. This chapter assumes that the necessary regional-level planning has been completed, and now the region is ready to begin planning for coordinated operations on specific corridors. Upon completing this chapter, the reader should have a thorough understanding of the issues and processes associated with achieving coordinated operation of freeways and arterials on a specific corridor through implementation of the steps in the CFA framework.

3.2 Introduction

The previous chapter made the case that the chances for success in coordinating the operations of freeway and arterial streets improve when first taking a broad, regional view of solving some of the coordination and institutional issues between agencies. One of the results of this regional-level planning process is the identification of corridors that have operational problems that would benefit from CFA operations. The regional-level planning process provides sufficient information to move forward to the detailed corridor implementation planning process, which is the focus of this chapter.

Adhering to a process ensures that all planning considerations are addressed and the potential for realizing the noted benefits of this framework are maximized.

A process roadmap, or framework, was developed to aid agencies and regions in planning, developing, and operating CFA operations for an individual corridor. Figure 6 displays this corridor-level CFA operations framework. The 11-step process may at first glance seem complex or unnecessary. However, adhering to a process ensures that all planning considerations are addressed, and the potential for realizing the noted benefits of this framework are maximized:

- The steps in the framework cover the entire life cycle of a project, from planning to design to operations. All these steps need to be considered by someone at some point when developing and integrating technical plans. Rather than making this an ad hoc process, the framework's complexity can be made less burdensome by making the steps explicit and understandable to all stakeholders and by allowing all stakeholders to have a chance to participate in the process.
- The framework was designed for overcoming both institutional and technical issues. Initial emphasis is given to first resolving institutional issues. The best way to overcome institutional barriers is to create a systematic process that can be integrated into existing institutional processes. This framework provides a systematic process agencies and regions can follow. Guidance was given in the previous chapter on fitting a corridor management process into existing institutional structures.
- The cyclical nature of the framework ensures that solutions developed meet the goals of the project and mitigate the problem; stakeholders can confirm that the investment in the corridor

is warranted. Also, lessons learned by monitoring and evaluating field conditions can be used to fine-tune corridor implementation plans and can be applied to additional corridor management efforts.

- The framework is easily scalable based on the complexity of the corridor and required strategies. For smaller, less complex corridors, some steps may not need to be formally addressed. For example, a formal evaluation of operations strategies may not be necessary when there is only one feasible strategy. When all stakeholders agree a particular step does not need to be addressed, then stakeholders can move easily to the next step in the process.
- Following a formal process with consensus by all affected stakeholders will help maximize the chances for securing funding for corridor implementation plans and procedures.

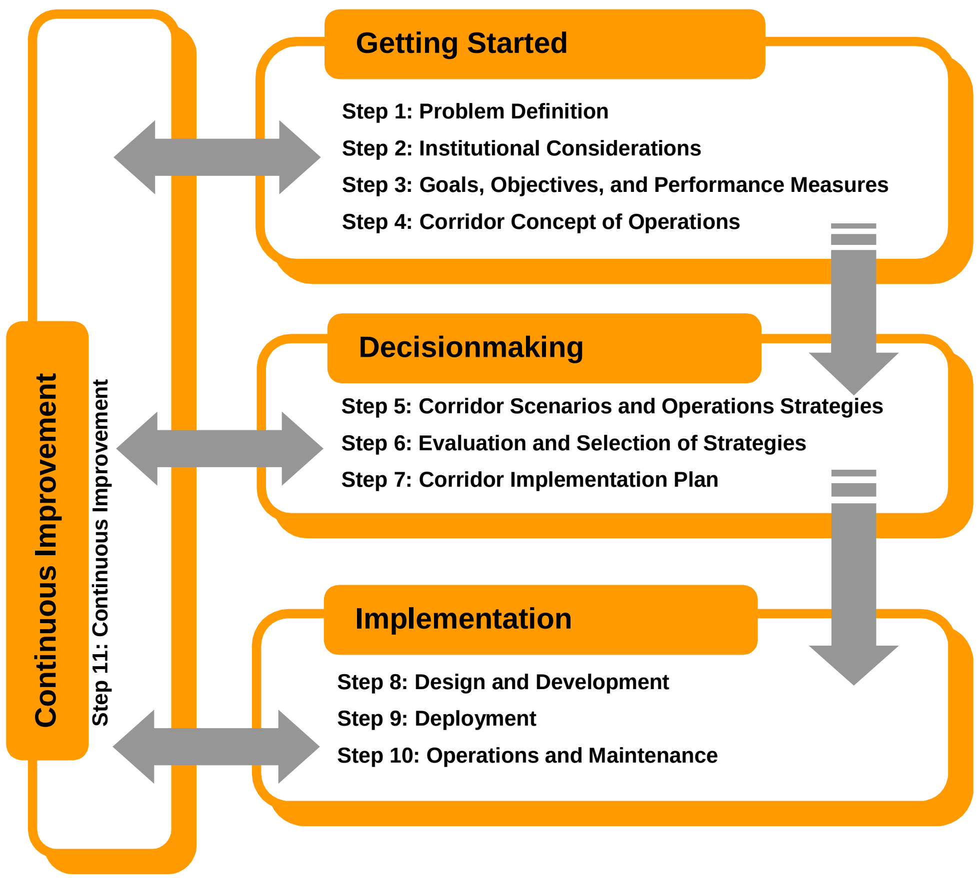


Figure 6. Chart. The coordinated freeway and arterial (CFA) operations framework.

The remainder of this chapter discusses each of the 11 steps in the CFA operations framework in more detail.

3.3 Step 1: Problem Identification

The first step is to define the problem. A problem may be identified either through a formal performance monitoring process, which may be part of a regional planning process, or as the result of an obvious operational problem such as traffic backing up onto a freeway due to an improperly timed arterial signal.

The definition of the problem in the broadest sense begins at the regional planning and coordination stage. The regional planning process provides the institutional framework necessary to sustain the corridor planning process. At the regional level, problems are identified at a minimal level of detail as part of a planning and programming function. At the corridor level, discussed in this section, a more detailed level of problem identification is undertaken.

The cause of a problem may be easy to identify at the regional level, such as the lack of traffic signal coordination between two adjacent jurisdictions. However, at the corridor level, problem definition may require more extensive analysis, especially when the congestion is widespread, to determine the true bottlenecks in a system experiencing extensive congestion. While it is easy to measure and identify symptoms of problems, the key is to identify the root causes of congestion in the corridor.

There are four types of problems that are particularly amenable to coordinated corridor operations:

- Incidents.
- Work zones.
- Special events.
- Day-to-day/recurring operations.

Incidents on freeways are the most readily addressed form of freeway congestion. Traditional actions like motorist service patrols that focus on quickly removing incidents, directly mitigate the effects of incidents. However, incidents may have significant secondary effects in major travel corridors, resulting in diversion to arterial streets which, if unprepared for the influx by unadjusted signal timing or other factors, can result in sprawling congestion on major thoroughfares.

More significant corridor problems are also likely to result from major construction projects in work zones that require closed lanes, detours, or other modifications to roadway usage patterns. Special events can generate large traffic volumes, often at what would otherwise be off-peak times, creating congestion due to suddenly increased volume and, perhaps, unusual traffic patterns as large numbers of vehicles attempt to reach the same destination at the same time. The resulting corridor congestion can often cause significant delays to travelers who are not involved in the special event. The benefit of coordinated operations is that travelers will avoid the delays caused by special events.

Day-to-day operations, while of little note, are perhaps the most sensitive to the iterative process of continued fine tuning to achieve optimum benefit. Issues related to these four specific problem types will be discussed in chapters 5.

Initially, processes may not be in place to identify problems based on performance measurement systems (e.g., freeway and arterial performance measurement systems using detection and data archiving). Problems will be identified by more ad hoc systems, such as travelers registering their concerns with public agencies; however, public agencies often discard problems brought to their notice as being outside their jurisdiction. Problems initially identified at the local level should also be provided to regional-level agencies for consideration.

Finally, what one stakeholder sees as a problem may not be viewed as a problem by other stakeholders. For example, some local jurisdictions may object to accommodating freeway diversion traffic. However, lack of an initial consensus does not mean a solution cannot be reached. The goal of this phase of the process is to create an environment where mutual problem identification is possible as the first step towards resolution. The next critical step is developing the framework to work through the solutions. The institutional framework must provide a level playing field where all stakeholders—all parties who have an interest in a safe, efficient transportation corridor—explore issues and find win-win solutions. Coordination cannot take place when one or more participants are placed in what they perceive to be a situation where they will be obligated to contribute to a solution which is either inconsistent with their agencies' goals or contradicts their agencies' interests.

3.4 Step 2: Institutional Considerations

> An overarching structure is necessary to bridge the seams between the various agencies and even functions within agencies.

It is necessary to establish an institutional structure for the specific corridor being addressed in the coordinated operations framework. The institutional structure can be ad hoc or formal depending on the current state of coordination in the region and the complexity of the undertaking. Ad hoc arrangements tend to work best when long-term relationships between entities already exist or when the effort emerges from a specific project of limited duration. Formal agreements are used when either the complexity of the endeavor or the long-term nature of the undertaking require that the effort be implemented with formal agreements. There is no single best practice because of the unique nature of each region. The important point is to realize that an overarching structure is necessary to bridge the seams between the various agencies and even functions within agencies.

Mechanisms for creating institutional structures may include personal relationships among leaders and staff members of key operating agencies and neighboring jurisdictions who recognize common problems and opportunities and agree to work together to improve corridor performance. These structures may evolve from or into a broad-based regional partnership among public and private sector interests across multiple jurisdictions.

A formal organization can be legislatively established as a regional authority, or it can be established by a memorandum of understanding as a virtual organization. An example of a formal organization is metropolitan New York's Transportation Operations Coordinating Committee (TRANSCOM℠), which was formed within the Port Authority of New York and New Jersey. TRANSCOM is a coalition of 16 transportation and public safety agencies in the New York, New Jersey, and Connecticut metropolitan region that provides a mechanism to facilitate collaboration and coordination among a variety of existing organizations, but does not replace them. Each existing organization has a specific, unique mission as well as a legal basis for existence and funding. The role of a formal organization is to provide a legitimate basis for collaboration and a mechanism to fund that collaboration.

Virtual organizations may be easier to establish than formal organizations and can rely on member organizations for corporate functions such as procurement, project management, and staffing. A virtual organization may look like a single entity to external observers, but behind the scenes, it will often be comprised of several different agencies and groups working together to produce and deliver specific products and services. An example of a successful virtual organization is AZTech™. AZTech is a partnership of more than 75 public and private organizations led by the Maricopa County Department of Transportation (DOT) and the Arizona DOT whose goal is to use ITS to improve management of traffic and travel in the Phoenix metropolitan region. The partnership is able to share information through an integrated traffic management and information system consisting of cameras, traffic detectors, DMSs, CCTV, and personal communications devices designed to provide real-time travel information to travelers and traffic managers alike.

> The role of a formal organization is to provide a legitimate basis for collaboration and a mechanism to fund that collaboration.

To be effective, the collaboration and coordination must be linked to the regional transportation planning process. Often, what passes for collaboration is directed primarily or solely toward installing a project, solving a problem, or preparing for a special event. For corridor collaboration and coordination to work, it must be part of an ongoing, intentional, focused effort to improve system performance by identifying needs and opportunities and collaborating on strategies and solutions that lead to strategic investments.

There is no one institutional structure that will meet the needs of all local circumstances. It is necessary to bring together the appropriate stakeholders and understand their individual needs and capabilities as well as their authority relative to the collaboration. While there is not one best structure, solutions can be found to virtually all limitations that any one agency may have in achieving collaboration and cooperation.

3.4.1 Identify Corridor Stakeholders

The success of a corridor initiative depends on participation by an appropriate set of stakeholders. Involving appropriate organizations at the early stages of the decisionmaking process facilitates their buy-in.

Corridor stakeholders' interest in improved operations will vary dramatically. In areas that have implemented substantial traffic management systems, the stakeholders may have an existing working relationship. As a result, these areas usually have operations management committees that provide a natural forum in which to discuss corridor traffic management.

Other areas require more significant education and outreach efforts to assemble and motivate potential stakeholders. Educating the right people is important. Frequently education and outreach efforts target management levels in an organization where decisions are made to commit valuable personnel that support the corridor traffic management development effort. Without management support, it is difficult or impossible for those with a working knowledge of operations in the area to participate in corridor traffic management.

It is often best to start with a core stakeholder group and then add participants to the core group over time. Too many stakeholders at the beginning can hinder the development process and discourage people with limited vested interest in corridor traffic management. Alternatively, it is also important to understand that it is difficult to get buy-in when stakeholders are brought into the process at the late stages.

If it is decided to limit the number of participants to a core group initially, set a timeframe to add others. Table 4 provides a list of stakeholder organizations whose participation would be desirable and which may provide representatives to the group.

It is also important to focus stakeholder participation appropriately. For example, both planners and system operators may participate in the process, but with substantially different contributions. System operators may be more interested in the operational concepts, functional requirements, and interface definitions, while the planners may have more substantial input into identifying transportation needs and services and project sequencing. Other individuals with specialized knowledge will be needed to assist in development of the list of agreements. As the "stakeholder roster" is developed, consider the various areas of expertise that are required and use your stakeholder resources selectively. Different stakeholders should be engaged in different parts of the process, consistent with their expertise and interests.

Table 4. Candidate stakeholder organizations or agencies.

Organization or agency type	Example organization or agency
Transportation Agencies	◆ State DOT. ◆ Local agencies (city and county). ◆ Department of public works. ◆ Federal Highway Administration (FHWA). ◆ Toll/turnpike authorities. ◆ Bridge/tunnel authorities.
Transit Agencies/Other Transit Providers	◆ Local transit (city/county/regional). ◆ Federal Transit Administration. ◆ Paratransit providers (e.g., private providers, health/human services agencies). ◆ Freight movers associations. ◆ Intermodal facilities.
Public Safety Agencies	◆ Law enforcement. ~ State police and/or highway patrol. ~ County sheriff department. ~ City/local police departments. ◆ Fire departments. ◆ Emergency medical services. ◆ Hazardous materials teams. ◆ Emergency response services.
Other Agency Departments	◆ Information technology (IT). ◆ Planning. ◆ Telecommunications. ◆ Legal/contracts.
Activity Centers	◆ Event centers (e.g., sports, concerts, festivals, ski resorts, and casinos). ◆ National Park Service. ◆ Major employers. ◆ Airport operators. ◆ Intermodal transfer facilities.
Travelers	◆ Commuters. ◆ Residents. ◆ Bicyclists/pedestrians. ◆ Transit riders. ◆ Others. ◆ Commercial vehicle operators.
Private Sector	◆ Traffic reporting services. ◆ Local television and radio stations. ◆ Travel demand management industry. ◆ Telecommunications industry. ◆ Private towing/recovery business.

In addition to having appropriate stakeholders, it is necessary to understand their perspectives and issues. One group may focus on minimizing traffic disruptions caused by emergency workers, and overlook the need to protect the personal safety of the responders. However, by hearing all perspectives, problems can often be recast into win-win solutions. Better traffic management becomes improved emergency worker safety and less exposure to potentially dangerous secondary traffic accidents caused by poor traffic management.

The following is a categorical description of potential stakeholders and a representation of their perspectives:

Users are the primary customers of the transportation system. Users include motorized transportation (e.g., motorcycles, automobiles, trucks, light and heavy rail, buses) and nonmotorized transportation, such as walking and bicycling. These customers are interested in safe, reliable, and predictable trips from their origin to their destination. They are generally not interested in the details of how the system operates, except when they encounter a system failure or disruption that influences the convenience or reliability of their trip. Additionally, users want real-time, accurate travel information to guide them on their trip.

Decisionmakers (e.g., elected officials, agency heads, and so forth) develop legislation and policies addressing the funding, implementation, and management of the surface transportation network. They need to understand society's needs and allocate available resources to best satisfy those needs. They also want to know the effects of their allocations.

Responders, such as police, fire, and other emergency services, represent a "special user" category. They use the transportation network as part of their critical missions and often have decisionmaking and operational responsibilities for the network, particularly during traffic incidents, special events, and emergencies.

Practitioners (e.g., agency managers, planners, designers, implementers, operators, and maintenance staff) are responsible for implementing the transportation projects and day-to-day management and operation. They are the providers who supply the many functions and services that require collaboration and coordination. They use the resources provided by the decisionmakers to provide travelers with transportation services, travel modes and options, and information that meet the users' needs. These practitioners represent many different types of transportation agencies, including Federal, State, county, city, transit, and regional organizations.

3.4.2 Corridor Champions

The action steps necessary to establish a corridor traffic management program include not only identification of stakeholders but also identification of champions.

A champion is an individual who believes in the program and is willing to put in the effort necessary to make it happen. Although a small project may not require high-level champions, the presence of a champion who commands significant resources (staff and funds) is most desirable.

Champions are generally visible because they are proactive in the field of management and operations of transportation systems. A champion must be a stakeholder so that he or she has a vested interest in the outcome. But there is no rule saying that there can only be one champion; indeed, it is beneficial that more than one champion be identified from different agencies or stakeholder groups, including:

- Transportation agencies (traffic, transit, toll authorities, and others) that support the project because it meets their operational needs.
- Public safety agencies that can bring aboard other public safety stakeholders.

Champions need to have, in addition to an interest in the outcome, particular skills that will aid them in breaking down institutional barriers and establishing understanding and respect among the stakeholder group. These skills include:

- Understanding of the subject.
- Knowledge of local transportation systems and their operation.
- Vision for collaboration, partnership, and coordination.
- Ability to build consensus among individuals with varying priorities.
- Executive-level access to resources.

3.5 Step 3: Goals, Objectives, and Performance Measures

Once the institutional structure is established, the stakeholders next identify the goals, objectives, and performance measures for the corridor. A goal is defined as a broad statement of the long-term outcomes of the program, such as:

- Seamless traffic flow across jurisdictional boundaries.
- Enhanced mobility through readily available information.
- Safe and efficient movement of goods.

Such goals enable all entities affected by coordinated operations to agree in simple layman's terms as to the purpose of the coordinated operations. Moreover, the development of goals should be a bottom-up process with input coming from the stakeholders. The goal development process provides the opportunity to bring all the stakeholders to the table early in the overall CFA process, leading to a continuing dialog. Goal setting also helps establish priorities and ensures that the coordinated operations program is fully responsive to participants needs. Establishing goals sets the stage for the development of objectives and performance criteria.

The next step is to determine specific objectives. Objectives detail how the goals will be achieved. Objectives are generally measurable because they are precise and quantifiable. An example of a measurable objective might be a reduction in incident-caused congestion by 25 percent.

Table 5 illustrates the relationship between goals and objectives. The establishment of goals and objectives allows stakeholders to reach consensus on what corridor management is attempting to accomplish before getting down to specific operations strategies.

Table 5. Example of goals and objectives for corridor operations.

Goals	Objectives[1]
Improve safety	Reduce crash rate. Reduce accident severity. Reduce fatalities.
Reduce recurrent congestion	Improve traveltime. Improve average speed. Reduce vehicle hours of delay.
Reduce nonrecurrent congestion	Improve traveltime. Improve average speed. Reduce vehicle hours of delay during incidents. Improve incident response time.
Improve travel reliability	Reduce variation in daily traveltime. Reduce variation in daily average travel speeds.

[1] Typically expressed as a quantitative change, such as percent reduction.

Performance measures are needed to assess the success of efforts to collaborate and coordinate and to identify areas where improvement is needed. The first step related to performance improvement is finding a general consensus that performance measures are needed if corridor performance is to improve. Given this consensus, performance measures relevant to system-users must be developed and accepted as meaningful methods of assessing both the short-term and long-term operation of the corridor. Because corridor operations can be an evolving process that undergoes changes in institutional relationships, technology applications, and policy and procedures, the performance measures themselves may change over time.

The performance measurement process is also an important part of the broader need for continuous improvement. Traffic operations are, by their very nature, a continually changing environment. As development takes place or traffic patterns change, system performance will also change, requiring a reevaluation of current operations. The performance measures provide the mechanism for quantifying the operation of the network and should also be used to evaluate the effectiveness of implemented traffic management strategies and to identify additional improvements. Vehicle-hours of delay would be an example of a congestion-related performance measure.

There is not a single performance measure or a set of performance measures to meet all needs. It is therefore necessary for the stakeholder group to evaluate the strengths and weaknesses of alternative measures to meet the varying needs of each approach. The following are some characteristics of good performance measures:

- Clearly understood.
- Measurable.
- Sensitive to modes (person-based).
- Time-based (traveltime or speed, not volume-to-capacity ratio).
- Link- or trip-based (to provide system monitoring).
- Sensitive to time period (e.g., spreading of peak period, at least hourly, not daily data).
- Not too difficult or costly to collect.

- Can be forecast into the future.
- Sensitive to the impact of congestion mitigation strategies (on people and/or goods).

Past definitions of congestion have fallen into two basic categories—those that focus on cause and those that focus on effect. Performance measurements clearly require a definition that addresses the effects, or symptoms, of congestion. Since traveltime or delays are the typical measures, congestion represents traveltime or delay in excess of that normally incurred under light or free-flow travel conditions.

As stated, traveltime or difference in traveltime can be a basic measure. It can be used to compare door-to-door traveltimes by different modes. In addition, travel rate (e.g., minutes per mile) can be used to account for link-specific differences in the transportation network.

Moving to a corridorwide operations approach makes it essential that the performance measures be consistent with the goals and objectives of the process in which they are being employed. It is also important to consider how the performance measures may be used including policy, planning, and operational situations.

3.6 Step 4: Corridor Concept of Operations

The corridor concept of operations is a formal document that provides a high-level, user-oriented view of operations in a specific corridor. It is developed in part to help communicate this view to the other stakeholders and to solicit their feedback. The corridor concept of operations provides a description of the current system, operating practices and policies, and existing capabilities. It lays out the program concept, explains how the corridor system is expected to work once it is in operation, and identifies the responsibilities of the various stakeholders for making this happen. The goals, objectives, and performance measures of a proposed operation are also documented. The process of developing a concept of operations for a corridor should involve all stakeholders and serve to reinforce the goals and objectives developed in step 3; to provide a definition of how functions are currently performed, thereby supporting resource planning; and to identify the interactions between organizations. Figure 7 schematically shows all of these issues and questions addressed in a concept of operations.

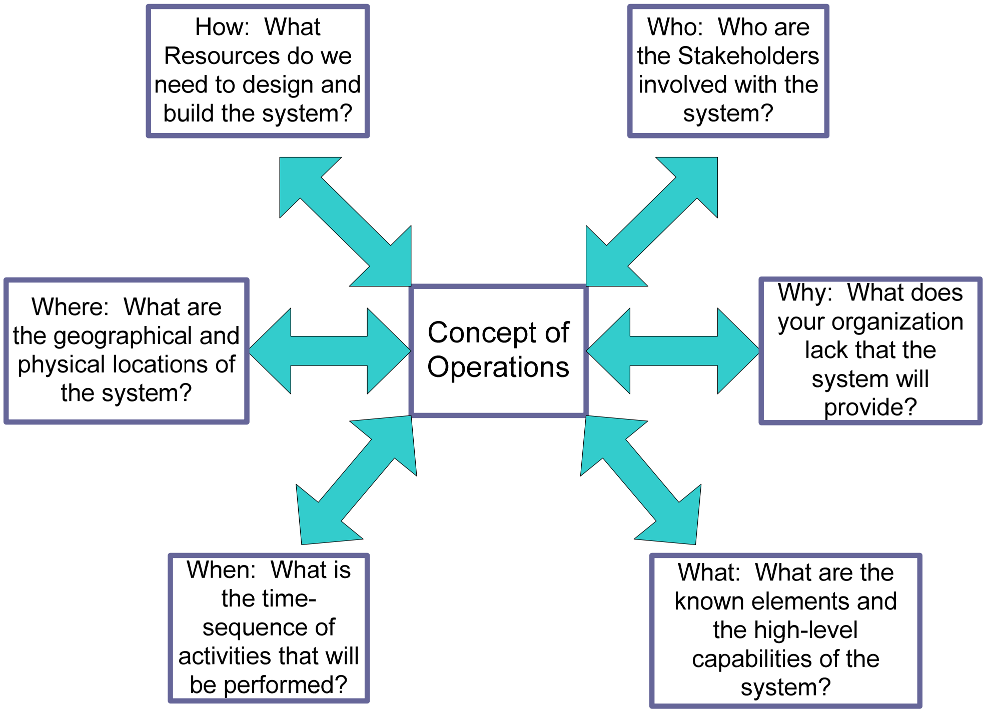


Figure 7. Chart. Questions addressed by a concept of operations document.[12]

By definition, a concept of operations does not delve into technology or detailed requirements of the program. Rather, it addresses operations scenarios and objectives, information needs and overall functionality, details of where the program should be deployed, how users will interact with the various elements of the program, and performance expectations. The concept of operations must also address the "institutional" environment in which the corridor operations program is to be deployed, operated, and maintained. This environment includes all the potential stakeholders and their respective needs and perspectives, the relationships between the coordinated operations program and the policies/procedures of affected public agencies and private entities, and the necessary coordination (working relationships and agreements) between the stakeholders.

The major goals of the concept of operations include:[12]

- **Stakeholder identification and communication**. The concept of operations document should facilitate discussion and assist participants in finding a middle ground associated with system design, development, and operation.
- **High-level system definition**. Stakeholders must understand what it is the system is being designed to achieve. This definition will specify the major entities within the system, flows of information among both major internal entities and entities external to the operation, the high-level capabilities of the system, and the primary daily activities of the system.
- **Foundation for detailed system descriptions**. Detailed descriptions of the system begin with a high-level requirements document. Although the concept of operations is not a requirements document, a good concept of operations will provide enough information to develop a high-level functional requirements document.

- **Definition of major-user classes and user activities**. Stakeholders will be made aware of the different types of users of the system and activities those users will perform. Everyone who uses the document will be able to understand who is performing what task and in what order.

The most important aspect of this phase is that the questions of who, what, where, when, why, and how are answered. Of lesser importance is the exact format of the final concept of operations document, which should vary to some degree depending on the complexity of the system(s) and resources available to document the issues covered during this stage. While there is no standard outline for a concept of operations document, there are a number of core elements that a good concept of operations should cover that could be used as a high-level outline for the final document. These core elements include:[(12)]

- **Establish scope**—provides a summary of the entire concept of operations, including documentation of the goals, objectives, and performance measures for the corridor identified previously.
- **Identify reference resources**—identifies resources critical to the development of the concept of operations. For corridor operations, this includes documenting the traffic management system designs, telecommunications, ITS and devices, related concept of operations documents, operations procedures, and existing traffic operations (delays, congestion levels, traffic volumes, and so forth) on the individual roadways in the corridor to be coordinated. If there is no description of current ITS and devices, then an ITS systems inventory is needed. Guidance on completing such an inventory is described in the appendix.
- **Develop a user-oriented operational description**—describes how the concept of coordinated operations in the corridor will operate from a system-users perspective and how it will impact the way users will view the corridor. This portion describes the vision of coordinated operations in the corridor, including how the envisioned system satisfies the goals and objectives for the corridor.
- **Establish or identify operational needs**—identifies the operational, institutional, policy, procedural, or technology gaps of agencies that need to be filled to meet the operational system described in the previous step. The needs or requirements to fulfill the operational system may overlap agency boundaries within the corridor and, as such, a clear description and understanding is needed of who has responsibility for operating and maintaining the systems or infrastructures.
- **Provide a system overview**—provides an overview of how different system parts relate to each other and who is responsible for each part. This section takes the operational description given above and shows the interfaces between the different components of the system.
- **Describe the operational and support environment**—describes the environment, or “world,” in which the corridor operations plans will be carried out. The facilities, equipment, hardware, software, personnel, operations procedures, and additional support that together make the current corridor operations possible are documented here.
- **Develop operations scenarios**—develops high-level operations scenarios that are likely to happen in the corridor. For example, if the corridor is focusing on incident management, then a number of scenarios could be developed based on the location, severity, and duration of the incident (e.g., one scenario could be a fatal crash on Interstate 90 during the p.m. peak). Developing such scenarios allows for adequate operations plans and procedures to be prepared at a later stage for a number of common scenarios.

Chapter 4 presents examples of how these core elements can be incorporated into a corridor concept of operations for corridors that are dealing with problems related to incident management, work zones, special event management, and day-to-day operations.

3.7 Step 5: Corridor Scenarios and Operations Strategies

The corridor concept of operations can be thought of as "a vision of *what* we want to do," while step 5 can be thought of as "a vision of *how* we want to do it." This step takes the corridor concept of operations to a more comprehensive level by developing more detailed corridor scenarios and then identifying specific operations strategies to address these scenarios.
The first part of this step takes the description of operations scenarios developed in the corridor concept of operations to a more detailed level. It is important to develop a range of operations scenarios to an adequate level of detail that can be used to determine which operations strategies are needed. These detailed scenarios need to represent the range of conditions that could occur in the corridor.

Table 6 displays examples of how the high-level scenarios developed in step 4 can be taken to a more detailed level in step 5. The detailed corridor scenarios should be developed with the assistance of, or at the least the concurrence of, the stakeholders. Key considerations in the development of scenarios include:

- **Event**—the nature of the event that is triggering the need for action (e.g., crash, sports event, work zone).
- **Location—**the location of the event. An incident on a minor arterial will require different operations strategies than an incident on a major freeway.
- **Time**—the time of day and week that the event occurs. An incident during the p.m. peak will likely require different operations strategies than a midday incident.
- **Duration**—how long the event occurs. A work zone that closes lanes for 1 week will require different operations strategies than one that has a 1-year duration.
- **Severity/Impact—**how severe the event is and what impact it has on its surroundings. The severity/impact is a function of the four previous considerations. For example, a minor rear-end crash on an arterial during off-peak conditions will have far less impact than a fatal crash on a freeway during the p.m. peak.

Table 6. Developing detailed corridor operations scenarios.

Opportunity for Coordination	High-Level Scenario (From Concept of Operations)	Detailed Scenarios
Incident Management	Fatal crash on I–90 freeway during p.m. peak	• Fatal crash on I–90 between Exits 5 and 10 in westbound direction. • Fatal crash on I–90 between Exits 5 and 10 in eastbound direction. • Fatal crash on I–90 between Exits 10 and 15 in westbound direction. • Fatal crash on I–90 between Exits 10 and 15 in eastbound direction.
Work Zone Management	I–90 freeway lanes closed during construction	• I–90 left two lanes closed during p.m. peak hours. • I–90 left two lanes closed during off-peak hours. • I–90 right lane closed during p.m. peak hours. • I–90 right lane closed during off-peak hours.
Special Event Management	Sports event creates queues on freeway blocking exits to local businesses/neighborhoods	• Freeway queue blocks Exits 5 through 7 for 30 minutes. • Freeway queue blocks Exits 5 through 7 for more than 2 hours. • Freeway queue blocks Exits 5 through 10 for 30 minutes. • Freeway queue blocks Exits 5 through 10 for more than 2 hours.
Day-to-Day Operations	Freeway bottleneck causes vehicle diversions onto parallel arterial during p.m. peak	• Minor diversion traffic (< 500 vehicles per hour (veh/h)) on arterial between 1st and 5th Streets. • Major diversion traffic (> 500 veh/h) on arterial between 1st and 5th Streets. • Minor diversion traffic (< 500 veh/h) on arterial between 5th and 10th Streets. • Major diversion traffic on arterial (> 500 veh/h) between 5th and 10th Streets.

Once the more detailed corridor scenarios have been developed, then specific operations strategies can be identified that will help mitigate the impacts of the scenarios. Having available the range of possible scenarios will be helpful in identifying potential operations strategies. During this step, strategy identification will be at a conceptual level. Strategies should be identified based on input from the corridor stakeholders. Desirably, the identified strategies are those that will:

- Help solve the problems defined in the detailed corridor scenarios.
- Be approved by corridor stakeholders.
- Meet the goals and objectives for the corridor.
- Be consistent with the operational description and overview provided in the corridor concept of operations.

- Make the most of the existing systems (hardware, software, telecommunications, and so forth.) and procedures on the corridor to help minimize additional requirements.

In the next step, the identified strategies will be evaluated more rigorously to select the best possible strategies for the corridor. The types of strategies that are appropriate for coordinated operations on a corridor can be grouped into three categories:

- Traveler information.
- Traffic management and control.
- Shared information and resources.

The difference in perspective for the strategies above is they are viewed from a corridorwide perspective. The following discussion in this section provides an overview of the range of strategies available for improving coordinated operations on a corridor.

3.7.1 Traveler Information

Most regions provide traveler information by one or more traveler information media, but often the information is not coordinated in a corridorwide perspective. Traveler information that is focused solely on a freeway or arterial streets can have either positive or negative effects on the entire corridor. For example, a DMS that suggests using alternate routes due to a freeway incident can potentially have a negative impact on a parallel arterial if appropriate traffic management and control plans do not support potential motorist rerouting in response to the information. Thus, it is easy to see the need for a corridorwide view of traveler information.

In this day of advanced communications technologies, there are a multiple ways to disseminate information among travelers, including:

- Web pages.
- Pagers/personal data assistants (PDA).
- Telephones/511.
- DMSs (fixed and portable).
- Commercial radio broadcast.
- Commercial television broadcasts.
- HAR.
- Citizens' band (CB) radios.
- Dynamic route guidance signs (sometimes referred to as trailblazer signs).
- Kiosks.

Figure 8. Photo. Sample DMS message.

The list of ways to communicate traveler information reflects both formal and informal sources of information. Informal sources include the use of CB radios by truckers. Formal sources include DMSs (figure 8) and private sector traffic information providers that broadcast radio traffic services. By expanding the quality and extent of information provided, travelers can implement their own rerouting plans or defer their trips. Either way, the result is improved system performance.

A coordinated view of traveler information has two benefits. First, it does not provoke a negative impact on the system by focusing information on only one part of the system (i.e., the freeway or the arterial). Second, it focuses on traveler information as a system approach to maximizing corridor performance. During peak traffic times, traveler information may cause motorists to delay or even cancel trips, reducing demand. During off-peak times, traveler information may make the system more efficient by encouraging the use of less active portions of the transportation system, which has the capability of absorbing excess demand from the portion of the system experiencing congestion.

Critical aspects of information include the time it reaches travelers (pretrip, en route), the type of information (condition, guidance), the extent of the information (link-based, corridor-based), and the method of dissemination (Web site, radio, HAR, DMSs, trailblazer signs). The more system oriented the information, the better decisions travelers can make.

In addition, the further in advance information can be provided, the more likely a desirable outcome will result. If travelers receive information before leaving home or work, alternative routes are significantly more often used than when travelers are already caught in traffic. A coordinated traveler information strategy would ideally use a single metropolitan area Web site and contain both freeway and arterial travel information. Estimated traveltimes could be provided for alternative routes, along with information on events along all routes. During the middle of the day, information on work zone activities could be provided on a corridor traffic map indicating the nature and location of work zones.

Improving the nature of information provided is also important. Traditionally, because of the lack of coordination between operating agencies, traveler information was largely advisory and only related to the agency owning the DMS. By developing agreed upon operations plans, more specific guidance information can also be provided to help travelers take specific actions, such as taking a diversion route around a freeway incident.

One particular issue to decide is whether to provide route guidance as part of the traveler information system. Dynamic route guidance around particular incidents, work zones, or other causes of congestion is particularly beneficial to motorists when taking a corridorwide perspective. However, providing route guidance is difficult for a number of reasons. Among the issues to consider are the availability of real-time information on both the original route and alternate routes, the amount of capacity available on alternate routes, the infrastructure needed to provide dynamic route guidance (DMSs, trailblazer signs, static signs, and so on), the potential response of motorists to the guidance (e.g., a large percentage of motorists unfamiliar with the surroundings may not be willing to change routes), and the impacts on neighborhoods and local businesses. Once a decision is made to provide dynamic route guidance, choosing specific alternate routes can also be difficult. A survey of public agencies revealed the top 10 criteria used when selecting alternate routes: [13]

- Proximity of alternate route to affected roadway.
- Ease of access to/from alternate route.
- Safety of motorists on alternate route.
- Height, weight, width, and turning restrictions on alternate route.
- Number of travel lanes on or capacity of alternate route.
- Congestion induced on alternate route.
- Traffic conditions on alternate route.
- Number of signalized intersections, stop signs, and unprotected left turns on alternate route.
- Traveltime on alternate route.
- Pavement conditions on alternate route.

A coordinated traveler information strategy includes shared use of information systems. For example, a freeway DMS that typically provides traffic information on the freeway could also provide information on congestion on nearby streets caused by incidents or special events. Real-world examples are evident in the Phoenix, AZ, and Washington, DC, metropolitan areas where DMSs located on arterials adjacent to freeways provide congestion information on the freeways, giving motorists the opportunity to avoid the congestion before entering the freeway. Without a broad view of traffic management, the DMS does not achieve its maximum potential as a corridorwide traveler information system.

Overall, achieving a corridor approach to traveler information dissemination requires a broader look at the available systems and the interconnections necessary to implement the corridor information program. Issues that may need to be addressed include center-to-center communication and shared control of traveler information systems such as Web sites and DMSs. A coordinated traveler information program may require the development of cooperative agreements. A cooperative agreement is a formal statement of recognition and commitment by the participating agencies regarding their roles and responsibilities in the operations of the corridor. Such details are finalized in step 8 of the CFA operations framework.

3.7.2 Traffic Management and Control

Traffic management and control strategies can be divided into three categories:

- Coordinated traffic signal timings.
- Lane-use adjustments.
- Access control.

3.7.2.1 Coordinated Traffic Signal Timings

Traffic signals are operated by the responsible local jurisdiction or its designee. However, the boundaries of these operating agencies often do not constitute logical break points in a traveler's journey; therefore, one simple means of improving corridor operations is to develop timing plans jointly in a way that reflects the users' systemwide view of travel.

The simplest opportunity to coordinate operations is expanding traffic signal timing issues beyond individual agency boundaries. This can be accomplished in many different ways depending on the specific situation. An example of this would be in an area where a city agency controls all the traffic signals approaching an interchange, and the State operates the two traffic signals at the interchange. The State traffic signals could be added to the city system for coordination purposes by extending the traffic signal interconnect if the agencies have compatible equipment. Such an arrangement does not require one agency to give up control; it is only necessary to allow another agency to provide the necessary coordination functionality. The technical issues involved in such coordination include establishing the necessary communications infrastructure and forming agreements on the coordination timing parameters. Institutional issues could include development of formal agreements, if necessary, and procedures to address how the two agencies resolve any operational and maintenance problems that may arise.

The means for implementing cross-jurisdictional traffic control can vary from a simple agreement to operate a common time reference, cycle length, and offset, to more sophisticated integrated systems. The more complicated the timing strategies, the more sophisticated the traffic control system needs to be, but simple solutions are also possible in many cases. For example, peak-hour coordination can be achieved easily by using pre-arranged timing plans with a common reference time. Preplanned incident response plans can be implemented in a number of ways, including via simple telephone calls to the collaborating agency. Another option would be to grant limited control access to the collaborating agency, especially when one agency has 24-hour/7-day-a-week operations, and the other does not.

Another boundary between subsystems occurs between freeway control systems and arterial control systems. These boundaries can cause operational problems because of uncoordinated day-to-day operations or as a result of nonrecurring congestion affecting normal traffic. As noted previously, any effort to alleviate congestion on one system without taking into account the impact of diverted traffic on other systems in the corridor can have a significant negative impact.

In systems without coordination, it is possible to have a situation where traffic signal control on an arterial favors arterial coordination and ignores traffic exiting the freeway. As a result, there is no information on the impacts of the arterial signal timing on freeway operations. However, a more integrated system would provide feedback to the arterial control system about excessive queues spilling back on the freeway and provide the option to adjust signal timing accordingly to alleviate the backup.

Another example of subsystem interaction is ramp metering. Ramp metering considered in isolation from adjacent signal timing can adversely affect both ramp metering and the traffic signal operations. If the traffic signal discharges traffic onto the ramp in large groups because of long cycle lengths, the meter may have to go to less restrictive metering to discharge the queue, reducing the effectiveness of the ramp metering (figure 9). If restrictive ramp metering backs up traffic onto the arterial, arterial operations may suffer, negatively impacting the overall system performance.

The types of strategies used to coordinate signals effectively within a corridor include local, areawide, diversion, and congestion strategies.

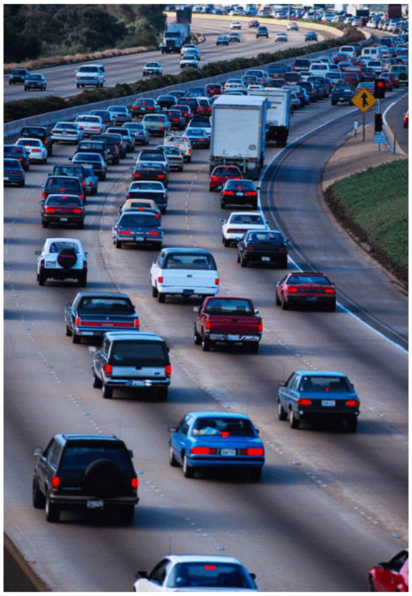


Figure 9. Photo. Uncoordinated arterial signals can cause reduced effectiveness of ramp metering on freeways.

Local Coordinated Strategy. This mode of operation implies the need for a close and responsive interaction between the ramp meter controller and the traffic signal controller. The ramp-metering rate should be adjusted based on the current traffic signal timing at the interchange. Signal timing may also be modified based on current ramp metering rates, whichever is more critical at that time.

Areawide Integrated Strategy. This is a traffic-responsive strategy that sets metering rates based on corridor flow rather than local conditions at the interchanges. The areawide strategy also requires frequent adjustments in traffic signal timing plans as well as ramp metering rates to react to short-term stochastic changes in traffic flow.

Diversion Strategy. The diversion strategy is designed to handle incidents by assigning special timing plans to both arterial traffic signals and ramp meters at locations affected by the diversion strategy.

Congestion Strategy. When traffic demand exceeds capacity in a portion of the corridor, the objective of the traffic control strategy will be to manage the spread of congestion rather than the demand. The goal is to minimize the adverse effect that the congestion has on overall system performance by controlling the location of queues.

3.7.2.2 Lane-Use Adjustments

Lane use is often set up based on peak-hour traffic and is prescribed by static signing. This approach generally meets routine needs, but is not responsive to changing traffic conditions. Dynamic lane assignment signs may be an appropriate treatment for locations with variable traffic as well as for areas that suffer congestion due to traffic incidents or special events.

Figure 10 illustrates a dynamic lane assignment location on a freeway frontage road. The location could also be a more typical freeway ramp to an arterial where the normal operation is a single lane turning right. Under a certain event (e.g., incident, work zone, or special event), the strategy might include converting the right turn to a double right turn. The strategy would be effective, however, only if the receiving roadway network was timed to accept the extra traffic caused by the event. This type of strategy could also be used during different times of day to reflect different traffic patterns.

Figure 10. Photo. Dynamic lane assignment on an arterial.

These changes might be routinely implemented based on time of day, so that hourly variations in traffic can be addressed. With the appropriate control systems, dynamic lane assignment could also be used for nonrecurring events to improve corridor operations.

Lane-use control can also be provided on freeways to improve incident management, traffic flow, or to improve merging capacity. These techniques can be used to expedite flow onto or off of freeways as part of a CFA management strategy.

Effective lane use should represent current traffic demands, especially when it is at or near capacity. Lane-use control is not as effective in dealing with average traffic demand in a corridor.

3.7.2.3 Access Control

Access control can include turning restrictions, ramp metering, or even ramp closure. While ramp metering is an example of limited access control, as are turn restrictions, a variety of measures can be taken to restrict access. Gates on either entrance or exit ramps to or from freeways are a means of controlling access. This can be done using traffic control devices that are deployed on a temporary or permanent basis.

CFA management deals with access control to the corridor level. From this perspective, the most important goal is the effective use of available traffic capacity. The success of any access control strategy within a corridor, however, will depend on the scenario being addressed.

3.7.3 Shared Information and Resources

Sharing information and resources across and within agency boundaries takes the concept of a shared, coordinated system to a more comprehensive level of integrated corridor operations. Perhaps the simplest examples of sharing are those that involve information. Information can be shared in a variety of ways from simple telephone exchanges to electronic pager and e-mail notifications. The information to be shared can also vary from the awareness of an incident to notification of the implementation of a specific operations plan.

An example of information sharing would be an incident report from a freeway traffic management system that is shared by way of an e-mail to the city traffic signal control center. The shared information could provide insight into such potential solutions as traffic diversion to parallel routes.

Sharing surveillance cameras among agencies is an example of a shared resource that could allow another agency to gather information. For example, a freeway surveillance camera at an interchange could provide the arterial management agency with information on street conditions without the need to invest in their own camera.

Figure 11. Photo. A freeway TMC collects and shares information from many sources.

Other resources that could potentially be shared include various incident response equipment such as service patrols, wreckers, and portable DMSs. Application of shared resources of information would be most valuable, for example, in the case of a special event where one agency may not have sufficient assets to manage the situation effectively.

Shared operations could allow an agency with a 24-hour/7-day-a-week operation (figure 11) to take preplanned actions using another agency's equipment when the owning jurisdiction is not staffed. Limited operational control might even be given to a nontraffic agency such as the police during hours where the traffic agency does not staff their traffic operations center. The goal is to maximize the public investment by sharing resources to provide the best operation of the system.

3.8 Step 6: Evaluation and Selection of Strategies

Once a number of potential operations strategies have been identified, an evaluation of the strategies ensures that the most appropriate strategies are selected. The evaluation process and criteria should reflect the goals and objectives that were established earlier and can vary from simple to complex. Strategies that require multiple stakeholders are more complex because of competition for resources. As a result, the details of a particular strategy may have profound effects on how a project is ultimately viewed by stakeholders as a group. It is therefore necessary to have a flexible approach to selecting potential strategies and understanding that all parties must be willing to support the strategies to be implemented.

The evaluation required for larger projects may include an assessment of the costs and the benefits of the project. The structure and formality of the evaluation process used to assess the costs and benefits of the alternatives will depend on the complexity and coordination needs of each agency.

In addition to complexity, the appropriate evaluation process should take into account several other considerations, including existing planning processes in the region. The assessment needs to reflect the evaluation and selection process already used by agencies for other types of program development. Some strategies, like coordinating signals across jurisdictional boundaries, may be simple depending on existing equipment and staff resources, and implementation may be accomplished in-house using existing resources to develop and ultimately implement the new plans and procedures. More extensive control strategies can require more comprehensive analysis to justify the expenditures required for design, implementation, operations, and maintenance.

Strategy evaluation may incur a high cost relative to the expense of actual CFA plan implementation and maintenance. For example, large or complex projects may use a traffic microsimulation model, which can require considerable time and resources to use correctly.

Costs of performing a traffic analysis should be considered when estimating the overall costs of a CFA plan for a corridor.

There are various ways to prioritize and select alternative strategies, including many traditional economic analysis tools like benefit/cost ratios. Categories of funding are often created to address specific problems such as safety or capacity. Others use rankings based on weighted evaluation criteria. The criteria should represent the goals and objectives of the local area, with relative importance being reflected in the weights. Criteria could, for example, include improved system performance and improved air quality.

The last element of the evaluation is matching the expected outcomes with the corridor goals and objectives. The evaluation results should be expressed in the same terms as the performance measures developed earlier in the process. These performance measures can be used to determine whether the proposed strategies meet the corridor goals and objectives. While a certain strategy may be ranked the highest in terms of meeting the specified objectives for the corridor, the evaluation should also consider:

- How the strategies can be changed to meet operational objectives more efficiently.
- Whether the strategies are realistic and will be accepted by all corridor stakeholders.
- Additional resources and tools that are needed to fully meet the corridor objectives.

Overall, the evaluation and selection process can be simple or complex, but it should at least apply an appropriate traffic analysis tool, apply valid analysis methodologies, be understood and approved by stakeholders, and ensure the selection of realistic, effective, and efficient strategies that meet the goals and objectives for the corridor. Detailed information on selecting the appropriate traffic analysis tools and applying the tool correctly can be found at the FHWA Traffic Analysis Tools Web site: http://ops.fhwa.dot.gov/trafficanalysistools/index.htm.

3.9 Step 7: Corridor Implementation Plan

Upon selection of the operations strategies for the corridor, the next step is development of the corridor implementation plan. The purpose of the corridor implementation plan is to provide enough detail so that agencies can proceed to developing operations plans and procedures and designing systems and technologies that support the plans and procedures. The corridor implementation plan is a document with two essential functions: 1) it summarizes all work completed up to this point to serve as a reference for all interested parties if strategies are not designed and implemented immediately, and 2) it provides a roadmap for recommended funding and implementation of the individual projects needed to support the corridor operations strategies. To support this second function, the corridor implementation plan should define expectations over time (what is to be accomplished), processes (how it will be accomplished), and resources (investments in time, money, staff, and equipment).

Corridor operations rely on activities and relationships that can occur only if individuals and organizations commit appropriate funding, staff, and possibly equipment. Implicit in this statement is the allocation, and possible sharing, of resources that enables a region’s operators, service providers, and other stakeholders to improve system performance. Operations must be viewed as a resource priority by participating organizations. The corridor implementation plan should address the availability of resources for putting a concept of operations into practice, implementing agreed upon strategies, and sustaining operations on an ongoing basis.

Most funding for operations will come from individual agency budgets. This may involve agreements to share key resources (equipment and personnel) across jurisdictional boundaries or among operators or service providers; agreements on acquisition and procurement that ensure interoperability and standard protocols for communications and data exchange; or potentially, the identification of capital investments in operations-related infrastructure (networks, operations centers, sensors) to be deployed on a regional basis or in conjunction with other capital improvement projects. Funding for such projects requires that operating agencies and service providers have a role in the region's capital planning process. The corridor implementation plan is the vehicle for securing specific project-related funding to implement the corridor operations strategies.

Another value of the corridor implementation plan is that it provides a record of the process. As staffs change, the plan provides the necessary details that allow others to pick up the plan and not have to revisit the steps leading up to the plan. This does not mean that the plan needs to be static. Plans will always need to be updated based on changing circumstances, but even so having a corridor implementation plan will provide the background on how strategies were developed and whether or not they need to be updated.

Overall, the corridor implementation plan is a document that provides complete details on the first six steps of the coordinated operations framework. The exact format of the corridor implementation plan is different depending on the size and complexity of the coordination required; however, an example of the elements that could be included in the corridor implementation plan document includes:

- Goals and objectives for corridor.
- Summary of corridor concept of operations.
- Summary of corridor scenarios and selected operations strategies.
- Phasing of efforts or projects necessary to implement operations strategies.
- Staffing/personnel needs.
- Capital, operating, and maintenance costs.
- Potential funding sources.
- Schedule for corridor implementation.

A corridor implementation plan becomes a real benefit when funding sources are not immediately secured and thus design and implementation will be delayed. In these cases, having a record of the process and results is imperative, as well as providing a roadmap for project funding and implementation. If adequate funds are already secured and agencies are ready to go directly into the design and development stage, a formal corridor implementation plan may not be necessary.

3.10 Step 8: Design and Development

The design and development phase translates each of the various projects included in the corridor implementation plan into workable project plans. This phase consists of two primary components: developing operations plans and procedures to accomplish the selected operations strategies and designing the systems and technologies (hardware, software, telecommunications, ITS and traffic control field devices, etc.) needed to support the plans and procedures. Because this document is not intended to serve as a detailed technical manual on systems design, details such as how to design various ITS technologies and systems is not discussed here. Rather, this section will focus on the development of plans and procedures needed to support the operations strategies identified earlier in the process.

A plan defines what will be done, while a procedure defines how it will be done. The plan should accomplish the operations strategies selected earlier. However, the operations strategies are fairly broad (i.e., arterial signal timing to support freeway traffic diversion); thus, more detailed plans must be developed to define precisely how the strategy will be implemented. In addition, multiple plans will be needed to respond adequately to the range of scenarios that could occur.

For the example of arterial signal timing to support freeway diversion, multiple signal timing plans will be needed depending on the scenario that occurs. Three different signal timing plans could be created to account for light diversion, moderate diversion, and heavy diversion scenarios. Developing each of these plans includes defining what traffic signals will be affected and what changes will be needed (e.g., the signal offsets, cycle lengths, and green splits could all be changed). It is imperative that the plans be developed in advance so agencies can quickly implement the plans in real time based on the scenarios that occur.

Operations plans are needed for each operations strategy selected; therefore, numerous plans could be created for DMS messaging, signal timing, ramp meter timing, dynamic lane assignment, access management, traveler information dissemination, sharing agency information (e.g., State TMC operator shares freeway conditions with city engineer), and sharing agency resources (i.e., State TMC operator controls city traffic signals after regular office hours). As a result, many operations plans will be created for the corridor. One way to organize the operations plans is to combine them into logical groupings based on each scenario. Figure 12 shows an example of how operations plans can be grouped together based on the operations scenarios and strategies.

Figure 13 shows the individual scenarios developed previously in step 5 of the coordinated operations framework further subdivided into subscenarios (i.e., scenario 1 divided into scenarios 1A, 1B, 1C, etc.). Subdividing the scenarios in this manner may be necessary depending on the level of detail required. In the figure, the scenarios were subdivided using an activation matrix, which in this case is a two-dimensional grid of the number of lanes blocked and time of day of the incident. Various criteria can be considered for the activation matrix based on the event, location, duration, time, and severity/impact of the event as discussed in section 3.7.

After developing the operations plans, procedures are needed to define how the plan will be implemented. The procedures define the roles and responsibilities for the plan, or who will do what and when should it be done. Specific steps need to be defined for each plan, including when it should be activated, sequence of steps needed to complete the plan, who is responsible for each step, and when the plan should be deactivated. Using an activation matrix such as that shown in figure 12 is one way to detail when a plan should be activated. Figure 13 shows an example of how procedures can be developed and documented based on the various operations plans.

Recognition of existing procedures needs to be taken into account when developing these new procedures and overlap is discovered between what is currently done and what is proposed. For the example in figure 13, the normal incident management procedures by the State TMC operator were incorporated into the corridor operations procedure.

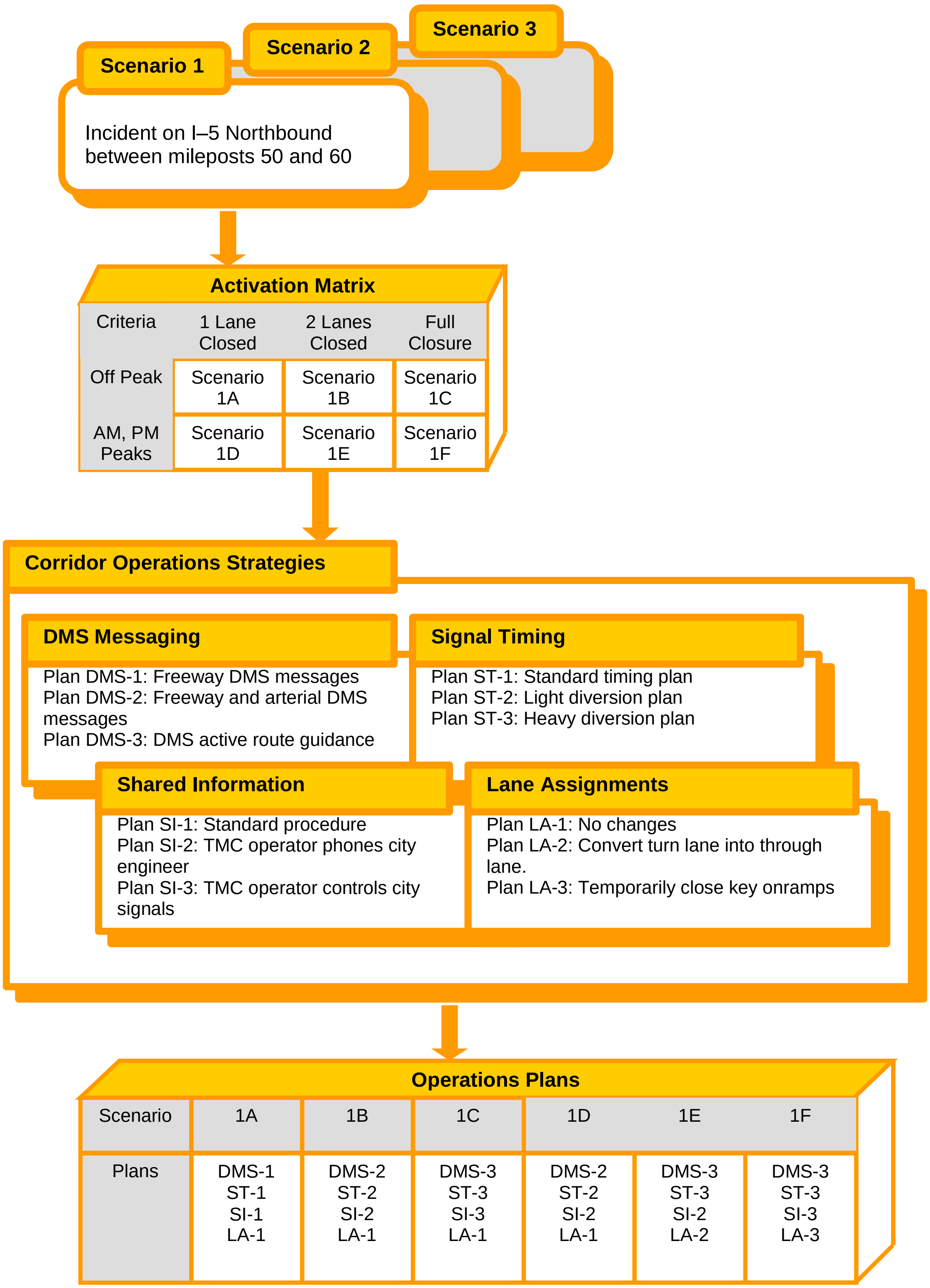


Figure 12. Chart. Example of development of corridor operations plans.

Operations Plans

Scenario	1A	1B	1C	1D	1E	1F
Plans	DMS-1 ST-1 SI-1 LA-1	DMS-2 ST-2 SI-2 LA-1	DMS-3 ST-3 SI-3 LA-1	DMS-2 ST-2 SI-2 LA-1	DMS-3 ST-3 SI-2 LA-2	DMS-3 ST-3 SI-3 LA-3

Operations Procedures

Scenario	Action Steps	Responsibility
1B	1. Verify field conditions match scenario. 2. Begin typical incident management plans. 3. Phone city engineer of conditions (Plan SI-2). 4. Implement DMS messages (Plan DMS-2). 5. Implement signal timing (Plan ST-2). 6. Monitor field conditions and check if different scenario is activated. 7. Deactivate plans when warranted.	1. State TMC operator. 2. State TMC operator. 3. State TMC operator. 4. State TMC operator. 5. City signal engineer. 6. State TMC operator and city signal engineer. 7. State TMC operator and city signal engineer.

Figure 13. Chart. Example of development of corridor operations procedures.

In addition to defining responsibilities for the operations plans, responsibilities should also be defined for those agencies and departments that own physical systems and equipment, whether or not equipment will be shared (and who has control override), and who is responsible for maintenance. Figure 14 shows an example from Portland, OR, where responsibilities were agreed on and explicitly stated in a corridor operations plan.

Agency	Barbur Boulevard				Interstate 5			
	Own	Maintain	Control	Share Data/ Video	Own	Maintain	Control	Share Data/ Video
CCTV								
City of Portland	✓	✓	P	✓			S	✓
ODOT			S	✓	✓	✓	P	✓
VMS								
City of Portland	✓	✓	S	✓			S	✓
ODOT			P	✓	✓	✓	P	✓
CMS								
City of Portland	✓	✓	S	✓	N/A			
ODOT			P	✓				
Ramp Meters								
City of Portland	N/A							
ODOT					✓	✓	✓	✓
Vehicle Detectors								
City of Portland	✓	✓		✓				
ODOT					✓	✓		✓
Traffic Signals								
City of Portland	✓	✓	P	✓	N/A			
ODOT	✓	✓	S	✓				

N/A = Not applicable.
P = Primary control with override capability.
S = Secondary control that may be overridden by primary agency.
ODOT = Oregon Department of Transportation.
VMS = Variable Message Sign.
CMS = Changeable Message Sign.

Figure 14. Chart. Example of identifying field equipment responsibilities.[(14)]

In defining relationships for sharing equipment, it is important to define the boundaries of control before implementing the plans. For example, if one agency has agreed to allow another agency to take control of a CCTV system under specific circumstances, those circumstances must be laid out in the greatest detail possible, delineating both the triggers for handoff as well as the circumstances for returning control to the principle authority. The formality of the definition of the organizational relationships will depend on the complexity of the operations plans and the legal requirements of each organization involved.

Cooperative agreements between agencies (public or private) may be needed to support the plans and procedures developed at this stage. Cooperative agreements can take many forms, such as resolutions, memoranda of understanding (MOU), intergovernmental agreements, or some combination of these. The cooperative agreements should be agreed upon and signed before the actual implementation of the systems, plans, and procedures. More detail on this subject, including guidance and lessons learned on developing cooperative agreements for corridor management, is available in *NCHRP Synthesis of Highway Practice 337: Cooperative Agreements for Corridor Management*.[(15)]

3.11 Step 9: Deployment

The deployment stage consists of the implementation of plans and procedures and the installation of ITS and traffic control devices, including telecommunications hardware and software. Getting the public involved and aware of the project throughout the entire planning and design process is essential. Prior to starting the system, a targeted public outreach campaign should be implemented where motorists' travel through the corridor will be altered by the corridor implementation plans and procedures. Negative media coverage and/or public complaints to local leaders and elected officials have the potential to entirely shut down a corridor operations project, so it is clear that the public, media, agency management, and even elected officials should be educated on how the systems work, how it affects motorists travel, and the benefits of the system to corridor residents and businesses.

The public outreach should be targeted to motorists who drive through the corridor on a regular basis, who live or have a business near the corridor, and who may be effected by the corridor operations plans. Distributing marketing materials, releasing press statements, granting interviews to television stations and other media, and attending neighborhood meetings are all viable methods to help the public understand the new systems and plans in advance of actual deployment.

Special events and work zone projects often have their own public outreach efforts. When implementing corridor operations plans and procedures into these types of projects, the public outreach should integrate information on the corridor operations systems into the overall special event or work zone project outreach campaign.

New systems and technologies should be field tested under a variety of different conditions and scenarios to ensure that the systems will function adequately before actual implementation of the corridor operations plans. Participating agencies and departments should make sure they are internally ready to operate the systems for which they are responsible. Being ready includes ensuring all responsible staff are adequately trained on the plans and procedures and have adequate time and resources to complete their responsibilities. Being ready also includes notifying affected internal staff, including management, of startup dates and how to respond to any questions or complaints from the public (i.e., knowing who the point of contact is for media inquiries).

3.12 Step 10: Operations and Maintenance

Upon deployment of the corridor operations plans and procedures, as well as the new systems or equipment needed to support the plans, it is imperative that agencies use the developed plans and procedures to ensure the corridor operates at peak efficiency. The focus of this entire effort is to create plans and procedures that can be operated on a daily basis, or when triggered by certain scenarios, so operating the corridor should have been adequately planned for and funded by this point.

It is easy, however, for those responsible for operating the corridor systems to lose focus after the interest created during the project deployment fades. Daily activity priorities change as new projects, plans, and procedures become the new "project of the day." To address these issues, it is important that agencies periodically monitor the activities of system operators to check whether the corridor operations plans and procedures are being used as often as they should be and as intended.

A number of operations support tools can also be developed to maximize the efficiency of system operators and the plans and procedures used to operate the corridor. Such operations tools could consist of: [16]

- **Operations checklist**—a convenient, easy-to-use reference for system operators that lists all action steps necessary under each corridor operations scenario. Such a checklist could be based directly on the plans and procedures developed under the plan development in step 8.
- **After hours on-call roster**—a roster available to all operators containing the names and contact information of individuals to call in cases of emergency. Included in the roster should be a schedule of when staff are on-duty and the general types of problems each staff member is able to address.
- **Operations logs**—records of system activity, when the activity occurred, and whether the activity was generated automatically or manually.
- **Agency contacts—**names and contact information for partner agencies affected by the corridor operations plans.
- **Media procedures—**procedures on how to respond to media inquiries, such as when to personally field the inquiry, when to refer the inquiry to other points of contact (e.g., public relations office), and talking points on the corridor operations plans.

In addition to operations, the new systems and technologies deployed to support corridor operations need to be maintained on a regular basis to ensure the systems can be efficiently operated (figure 15). Corridor operations systems may be complex, integrated amalgamations of hardware, technologies, and processes for data acquisition, command and control, computing, and communication. Accordingly, maintenance can be a complex proposition as well, requiring sophisticated approaches and advanced technology. Without adequate consideration of maintenance, inefficiency will begin to develop shortly after implementation of a project.

Figure 15. Photo. Traffic signal maintenance crew at work.

Maintenance of the systems is a necessity to ensure reliability and proper operation, thereby protecting the investment and enabling the system to respond to changing conditions. Failure to function as intended could negatively impact traffic safety, reduce system capacity, and ultimately lead the traveling public to lose faith in their transportation system. Failure of the system also has the potential to cause measurable economic loss and increase congestion, fuel consumption, pollutants, and traffic accidents.

Maintenance considerations must be an integral part of the process to develop a corridor operations program. Considerations for maintenance include involving maintenance stakeholders, developing a high-level maintenance plan (including maintenance and replacement costs in the life cycle analyses), and identifying maintenance functional requirements early in the process. In this manner, the coordinated operations effort and any enabling systems will include the necessary resources, environment, and procedures to maintain the infrastructure associated with the program.

3.13 Step 11: Continuous Improvement

As emphasized in figure 6 in chapter 3, continuous improvement is iterative and should take place throughout the entire life cycle of a corridor operations project, from planning to design to operations and maintenance. Continuous improvement is the process of monitoring the conditions in the field to determine whether the corridor operations plans are meeting the original corridor goals and objectives. If the goals and objectives are not being met adequately, then revisions need to be made to the plans and procedures to meet the goals and objectives.

The continuous improvement step is often overlooked by agencies in all project types. However, it should be considered seriously because it is the only step solely dedicated to ensuring the project is a success. Also, the continuous improvement step keeps the project accountable and certifies the costs of the project are matched with the highest benefits possible.

Continuous improvement is done soon after deployment of the corridor operations systems and on a regular basis thereafter. For example, the effectiveness of the corridor operations system could be checked on a yearly basis. Continuous improvement should be done on a regular basis because of the dynamic nature of traffic conditions, staff turnover, changes in agency direction, and changes in funding and operations priorities. Because of this dynamic nature, operations plans that are highly effective one year may not be the next year.

If it is determined that it is necessary to re-align the corridor operations closer to the original goals and objectives, the corridor stakeholders should first determine how far back in the process they should return. The point in the framework to which the stakeholders should return depends on the nature of the problem and how far apart the actual conditions are from meeting the goals and objectives. Once the framework has been entered again, all the subsequent steps should also be reviewed to determine if they are affected. For example:

- If new agencies need to be involved in the operations plans, then the institutional considerations discussed in steps 2 and on should be revisited.
- If the goals and objectives need to be revised, then steps 3 and on should be revisited.
- If the corridor concept of operations needs to be expanded or revised due to changes in the roadway network, implementation of new systems or technologies, or addition of significantly different operations scenarios, then steps 4 and on should be revisited.
- If new strategies have become possible that could improve corridor operations, then steps 5 and on should be revisited.
- If new funding sources have become available that could affect the sequence of projects supporting full development of corridor operations, then steps 7 and on should be revisited.
- If previously effective operations plans have become outdated or are not being used as planned, then steps 10 and on should be revisited.

Overall, the process of coordinating freeways and arterial streets through the established framework is never completely finished. Not only will new opportunities arise that will need to be addressed within the framework, but refinements to the existing system will also become necessary as time passes. As the system is being operated and maintained, the system must be continually monitored; it is this monitoring process that will inevitably be the catalyst for setting into motion another cycle of the framework. Without such a framework for monitoring conditions and continuously improvement, the corridor (and the overall system) will fail to perform at optimum effectiveness and efficiency as time passes.

3.14 Summary

The reader should now have a thorough understanding of the issues and processes associated with achieving coordinated operation of freeways and arterials on a specific corridor through implementation of the 11-step CFA operations framework. The next chapter will demonstrate how the corridor-level approach can be applied to incident management, work zones, special events, and daily recurring operations. While these four categorical areas of traffic operations represent areas of emphasis, other traffic issues and problems may also benefit from the framework described in this chapter.

4 APPLYING CFA OPERATIONS TO FOUR OPPORTUNITY AREAS

4.1 Purpose

This chapter brings together, as a single process, the concept of corridorwide planning, the use of a logical framework for strategy development, and CFA solution deployment from various perspectives. Relevant, cost effective technologies for a successful CFA operational deployment are assumed as part of the perspective solutions, but CFA supporting technologies and ITS systems are discussed at greater length in chapter 5. The four primary opportunities for coordinated operations identified in chapter 1 include:

- Traffic incident management.
- Work zone management.
- Planned special events management.
- Day-to-day or recurring operations.

Any one or several of the four areas may serve as the launch point for corridor focus and the source generating scenarios and solutions. The remainder of this chapter is devoted to applying the CFA process to each of these four areas. Methodological repetition is to be expected as each category employs the same corridor planning, framework, and enhancing technologies. The backbone of the process is the 11-step CFA framework introduced in chapter 2 (figure 6) and described in more detail throughout chapter 3. This iterative process applies to each category and results in a separate set of action scenarios and strategies.

4.2 Introduction

CFA operations is a mindset. This handbook through chapter 4 has developed that mindset into a process that integrates operating systems and is enhanced by ITS related technologies. This chapter will relate the CFA process specifically to work zones, special events, incident management, and day-to-day/recurring operations. The basic concepts and technologies used for traffic management and incident management in the context of those systems have been covered extensively in many different texts. The same applies to work zone safety and motorist protection during highway reconstruction. Even special event planning has been thoroughly addressed more recently. Any one of the four areas of traffic management can serve as the starting point for developing a CFA approach to regional operations depending on the primary concerns and needs of a particular region. By presenting the CFA process from each perspective, it is hoped that the reader will recognize not only the different perspective but the essential similarity of the CFA mindset, technologies, and shared responsibilities.

4.3 Traffic Incident Management

The basics of traffic incident management are well known. There is significant guidance on the subject of incident management including *Framework for Developing Incident Management Systems,*[17] *Traffic Incident Management Handbook,*[18] *Regional Traffic Incident Management Programs—Implementation Guide*, [19] and the *Freeway Management and Operations*

Handbook.[20] These materials provide many of the details associated with traffic incident management.

Expanding incident management processes to corridors is the goal of CFA operations. While there is no specific formula for the successful development of a coordinated traffic incident management plan, the key is in the expansion of the scope of incident management from a single agency or group of agencies acting in relative isolation to a corridor-level approach. Coordinated operations puts the available operational elements together in an integrated package that focuses on maximum system performance from the users' perspective.

> The key is in the expansion of the scope of incident management from a single agency to an entire corridor.

While it is possible to plan response scenarios for a variety of incident types and locations, it is not possible to plan when and where they will occur. The process is incident-driven rather than planned-for as in the other three categories. This significantly different aspect of incident management warrants more intensive scrutiny. The critical difference is planned events versus unplanned incidents. Corridor incident management, while requiring the same CFA process as the other opportunities for coordination, is treated differently from a technology enhancement point of view. The primary issues in dealing with corridor incident management are *incident detection* and the need for *rapid response.* The prompt detection of an incident, the determination of its impact on the affected facility and other roadways corridorwide, and the execution of a quick, effective response are essential.

> CFA operations are most beneficial under conditions of significant supply variations, such as incidents.

While most traffic incidents impact little more than the travel route upon which they occur, more significant incidents, both traffic related and otherwise, can have corridorwide travel implications.

The impact of major traffic incidents on the movement of traffic within a corridor can be dramatic, causing delays and congestion that overflows onto arterial streets and ramps and even increasing the likelihood of additional crashes. The purpose of this section is to reshape the issue of incident management coordination with a view toward providing a corridorwide perspective on the problem. At the conclusion of this chapter, readers will have an understanding of how to expand their approach to traffic incident management coordination from a single project focus to a corridorwide management perspective.

4.3.1 Problem Identification

Problem identification is the essential first step that sets forth the rationale for exploring alternative courses to reduce the magnitude of a problem. Without a clearly defined problem, it is impossible to implement a solution that effectively alleviates the basic malfunction of the system. The problem definition step also allows the various stakeholders to reach consensus on something they all believe constitutes a problem worthy of joint action. Three issues are especially important in identifying problems that can be solved by coordinated incident management:

- Frequency of incidents by location, time, and weather conditions.
- Duration and severity of incidents.
- Traffic impact of incidents.

> One of the most challenging issues to be resolved among the jurisdictions is the sudden increase of traffic in the surface street system due to diversion from the freeway as a result of an incident.

As the frequency, duration, and impact of incidents increase, corridor incident management becomes more desirable to reduce delay and increase safety. Typical problems include increased congestion on alternative routes or unnecessary delay when alternative routes are available but not effectively utilized.

Incidents will often cause traffic to be diverted off the affected roadway to parallel and other alternate routes. If these alternative routes are not operated effectively for the incident-induced traffic, delays will occur to both diverting and nondiverting traffic.

The diversion may take place based on motorist information on the incident route or by the actions of individual motorists acting on what they believe to be in their best interests. The diversion point and route may lie outside of the jurisdiction experiencing the incident. To properly divert traffic to the roadways best able to handle the alternate volume, multiple agencies may need to coordinate their efforts. What is best for the mobility and the region as a whole may not be realized when diversions take place based on the decisions of individual drivers in response to general incident information or the lack of information.

In assessing current incident response practices from a corridor perspective, the following questions may be helpful in identifying problems that are amenable to coordinated incident management:(19)

- How well does the corridor perform under normal operating conditions?
- How well does the corridor perform under incidents?
- Is there any unused capacity on any of the networks in the corridor? Is this unused capacity effectively utilized under current incident conditions?
- Do mechanisms exist to effectively inform motorists about road conditions on all networks?
- What is the frequency of incidents that result from diversions?
- What incident management tasks does each agency now perform?
- What are each agency's tasks, responsibilities, and priorities?
- Are each agency's task, responsibilities, and priorities well understood among other responders and stakeholders when viewed from a corridor perspective?
- Do any of these responsibilities and priorities conflict? What is the nature of the conflict? How can agencies involved in coordinated operations cooperate to resolve the conflicts?
- Are agencies' tasks ever redundant? Can coordinated operations free up resources?
- Are there gaps in delivery of corridor incident management as agency services are now configured?

4.3.2 Institutional Considerations

The three basic principles of developing institutional relationships were presented in chapter 3. They are:

- Establish a structure.
- Identify corridor stakeholders.
- Identify corridor champions.

Incident management is an area that involves multiple agencies and disciplines, and that must be executed in real time. It therefore requires the clear delineation of roles and responsibilities, which can only be accomplished if an appropriate structure is developed to sustain the effort. The type of structure will depend on the local circumstances and, if possible, should build off existing relationships and interactions.

A unique aspect of incident management is the diverse group of individuals or agencies involved in it. The complexity of this involvement grows in corridor incident management because both the number of agencies engaged and the coordination issues among them increase significantly. The following are the types of individuals and agencies commonly involved in incident management:

- Law enforcement.
- Fire and rescue.
- Emergency medical services (EMS).
- Transportation agencies.
- Towing and recovery service providers.
- Media.
- Information service providers.
- Coroners and medical examiners.
- Hazardous materials teams.

> Take advantage of attention focused on major events (e.g., international sporting events, weather events, earthquake) to help organize and build support for a formal incident management program.

These are potential stakeholders in a corridorwide incident management program. To mobilize them into an effective coordinated incident management program requires a concerted effort to bring them together in new ways that help them perceive the benefits of corridorwide coordination.

It is necessary to have in place some degree of local incident management before initiating corridorwide coordination.[21] When no incident management program exists, the first step would be to develop a local program. If one agency or jurisdiction has an incident management program, start from that point and identify a broader group of stakeholders and build either new or expanded relationships that will benefit corridorwide coordination.

Another challenge is the identification of champions for expanding incident management to a corridor-level program. The champions' support is necessary to secure an initial commitment of resources in the form of staff and funding to begin the program development process.

To achieve the desired outcome, it is necessary to consider the legal and policy environment in which coordinated incident management is carried out. Four questions that may be helpful in determining this environment include:[19]

1. What are the legal limits to the incident response roles that agency personnel can perform? (e.g., can an agency leave its jurisdiction to aid another jurisdiction?)
2. To what extent do real or perceived legal constrictions pose an obstacle to coordinated incident management?
3. What is the financial liability of agencies, agency personnel, and the public with respect to joint incident management?
4. Can or should statutes be changed to facilitate coordinated incident management?

> Having a neutral meeting space and staff are important for creating an equal playing field and enhancing trust among participants; but meetings alone are not enough. At the Greater Houston Transportation and Emergency Management Center (TranStar), physical co-location of multiple organizations, working side by side on a daily basis, established trust and created an understanding among the agencies of each other's activities, needs, and resources that would not be possible from meetings alone.

Perhaps the best example of an organization initially formed to address incident management problems across jurisdictions is TRANSCOM, as described in section 3.4.[22] A series of debilitating incidents in 1986 caused problems on routes adjacent to the incident and led to the recognition of the interdependence of facilities and the establishment of TRANSCOM. Here, the Port Authority of New York and New Jersey operated as the champion of the effort, providing leadership and seed funding. Since then, the organization has evolved and taken on a broader role in regional traffic management coordination.

4.3.3 Goals, Objectives, and Performance Measures

The goals for corridor incident management are established before working on the detailed strategies for the corridor incident management program. This allows the partners to define broadly what they are willing to do before defining where and how they will do it. By starting with broad goals, the partners can define what aspects of corridor incident management they believe they can undertake. This is an important step because not all parties may see goals the same way. It is easier to understand conflicts at the goal level because they are general in nature.

For example, one goal might be:

> *To mitigate the corridor impact of major incidents on travelers by efficiently using freeway and surface street capacity during major incidents.*

A broad goal such as this provides an opportunity for stakeholders to express differences. The goal suggests there are opportunities for improvement in incident response on both the arterial and the freeway system and that corridorwide action should be limited to major incidents, leaving lesser events to the individual agencies. If the arterial management agency is opposed to using arterials during incidents, it will become apparent during the drafting of a goal. At this point, however, it is not necessary to determine whether there are specific areas for which use of alternative routes is unacceptable, just whether the concept is supported in principle.

The next level of detail is objectives. Specific objectives might include:

- Assess severity of corridor incidents within 5 minutes.
- Inform corridor users of incident within 5 minutes.

- Implement diversion plan within 10 minutes.
- Provide clearance resources through coordinated response with 15 minutes.

These objectives help shape expectations of what is and is not reasonable from the perspectives of the partners. In formulating goals and objectives, the following corridor-based questions should be considered:

- What factors influence corridor incident management? How can they best reflect the corridor goals and objectives?
- What are the corridor's greatest unmet needs with respect to incident management?
- How can corridor incident management goals and objectives be framed such that they reflect the mission, roles, and priorities of all the corridor incident management team members?
- Are there political factors (e.g., certain stakeholders that will be opposed to diverted traffic) that need to be addressed?

Typical incident response performance measures (generally measured in minutes) to be used for incident management include:

- Detection time.
- Response time
- Clearance time.
- Time-to-traveler notification.
- Travel delay time.
- Throughput reduction.
- Related secondary incidents.

It is also possible to estimate reductions in delays based on the frequency, location, and duration of incidents. However, this requires more extensive analysis than would be typically undertaken.

Corridor incident management is not significantly different from agency incident management. However, in developing a corridor program, the coordinated response may be limited to more significant incidents. It is also useful to understand that excess capacity is more likely to occur during off-peak conditions. For example, a major truck accident at night may be more effectively addressed by an alternative route because the volume of affected traffic and the volume of traffic on alternative routes are likely to be less.

4.3.4 Corridor Concept of Operations

The corridor concept of operations is a formal document that provides a high-level, user-oriented view of operations in a specific corridor. It is developed in part to help communicate this view to the other stakeholders and to solicit their feedback. The corridor concept of operations provides a description of the current system, operating practices and policies, and existing capabilities. It lays out the program concept, explains how the corridor system is expected to work once it is in operation, and identifies the responsibilities of the various stakeholders for making this happen. The goals, objectives, and performance measures of a proposed operation are also documented. The process of developing a concept of operations for a corridor should involve all stakeholders and serve to build consensus in defining the goals and objectives; to provide a description of how functions are currently performed, thereby supporting resource planning; and to identify the interactions between organizations.

The basis of the corridor incident management concept of operations is the development of high-level problematic issues, which warrant corridor-level incident response. These issues are developed from the defined problems identified in the first step in the framework. Those problems that are identified and whose mitigation is consistent with the corridor goals and objectives would be candidates for mitigation. Those problems that merit mitigation would be developed into high-level problematic issue statements.

Problematic issues represent the initiating event for mitigation of the effects of incidents. At the concept of operations stage, problematic issues are high-level and do not focus on specific locations. One such issue would be a major incident on a freeway that would activate diversion plans involving traveler information, revised traffic signal control, and the initiation of a coordinated agency response.

At this stage, the cooperating agencies answer the questions of what (not how) they would be willing to do in the corridor in regard to coordinated operations in response to an incident. General strategies would include:

- Provide traveler information.
- Establish traffic management and control.
- Share information and resources.

For example, a high-level problematic issue might be an incident on a busy parallel arterial street. The general strategy might be to use existing freeway DMSs to alert freeway drivers to the incident so they may choose to stay on the freeway and/or seek an alternative route. Another general strategy might be to provide special arterial signal timing when major incidents occur on the freeway.

The development of a concept of operations will allow the participating agencies to agree on what they wish to accomplish and to lay the framework for how that will be done. For example, does the traveler information only describe the nature of the problem or does it provide recommended courses of action? This is an example of an issue the agencies have to work out before moving to the more detailed level of discussion. This step sets the general ground rules for coordinated response.

As part of the development of a concept of operations, consider the following points:

- Does stakeholder consensus exist to support coordinated incident management?
- If not, does it exist for other types of situations such as special events or major construction and maintenance operations?
- If so, could success in the other situations be used to develop a coordinated incident management program within the region?
- If stakeholder consensus must be established, who will be the champion and organize a workshop or forum to demonstrate the benefits?
- What is the level of stakeholder commitment to contributing personnel and funding resources?

- What policy changes, if any, are needed to implement a coordinated incident management program (such as quick clearance legislation, liability protection, and so forth.)?
- What organizational structure will be established for the day-to-day incident management program?

As discussed more fully in section 3.6, the concept of operations document that results from this development process could include sections on the following topics:

> The key to successful concept of operations development is remembering that this step involves the "who, what, when and where" of incident management.

- Scope.
- Resources.
- A user-oriented operational description.
- Identification of operational needs.
- A system overview.
- Description of the operational and support environment.
- Development of operations scenarios.

The concept of operations defines the general scenarios that will be used to address the identified problems and is consistent with the corridor goals and objectives. Activation criteria and the types of response, specific scenarios, and strategies will ultimately be worked out in the design and development step. The key to successful concept of operations development is remembering that this step involves the "who, what, when and where" of incident management. The corridor plan will determine how these details will be implemented.

4.3.5 Corridor Scenarios and Operations Strategies

Once the concept of operations is agreed to, scenarios and potential strategies need to be refined. Specific questions need to be addressed, such as:

- In what segments of highway and under what conditions are strategies to be implemented?
- What are the potential strategies that might be implemented to mitigate each scenario?

The concept of operations scenarios need to be developed for specific locations where corridor incident management would be implemented. For example, freeway and arterial segments where the frequency of incidents causes significant corridorwide congestion need to be identified. This identification process is done best with the involvement of all the corridor partners to incorporate the widest possible perspective of the problem and to develop a sense of engagement among the implementing partners.

The process of selecting scenarios is somewhat iterative with the strategies to be implemented. For example, if strategies include alternative routes, the scenarios need to reflect the logical points at which diversions might be implemented.

Strategies are specific actions to mitigate one of the scenarios associated with a corridor incident. Several strategies may be required to achieve the desired improvement in system performance. The strategies may also vary by the severity of the incident.

Individual agencies might consider the following examples of candidate strategies to achieve improved corridor operation:

- Notify potentially affected agencies of incidents.
- Provide traveler information via resources such as DMS, HAR, and the media.
- Advise affected motorists to use an alternate route.
- Advise motorists to use a particular alternate route.
- Implement traffic signal timing adjustments.
- Provide mutual-aid sharing of in-field incident response teams.
- Implement access control strategies (e.g., lane closures, turning restrictions, lifted high occupancy vehicle (HOV) restrictions, and so forth).

Shared resources represent one of the potential major benefits of coordinated operations, especially during major incidents. Most agencies cannot provide sufficient staff and resources to deal with unusually large incidents; however, through shared resources, collaborating agencies can make available many more resources than they could individually provide. Since a major incident often has substantial spillover effect, shared resources are a win-win proposition for all stakeholders involved.

At this point the strategies are still general ideas of how agencies can work together, but are being focused on specific segments of roadway. In the next step, the strategies are analyzed in more detail to identify practical considerations as well as costs and potential benefits. The current objective is to consider taking traditional strategies beyond agency boundaries to improve corridor operation. What is possible technically and what is possible practically? The answers will depend on many local factors. The important point is to begin the dialogue among partners to determine what is possible.

4.3.6 Evaluation and Selection of Strategies

The process of selecting specific strategies is an iterative process involving the stakeholders in assessing both the costs and the benefits of the strategies and the various agencies' ability to implement them. A strategy may be perceived to be positive initially, but a more detailed analysis may show it to be counterproductive. A strategy may be technically feasible, but beyond the resources available or inconsistent with other community values.

As the stakeholder group considers specific strategies, the following issues will ultimately come under discussion:

- Roles, responsibilities, and procedures.
- Infrastructure needs and costs.
- Operating and maintenance resources and costs.
- Analysis of numerous alternative strategies and selection of the best one(s).
- Ability of candidate strategies to meet the goals and objectives for the corridor.

Each of the agencies must be comfortable with the strategies and be capable of implementation. The degree of sophistication of the strategies will depend on the current capabilities of the agencies and the degree to which the agencies desire to invest in technology and/or staffing to achieve better operations.

The evaluation of strategies may vary from qualitative to quantitative methods. Integrated traveler information may be evaluated qualitatively because the impacts are difficult to assess and the potential for problems minimal. A strategy to divert traffic from the freeway to a parallel arterial should involve adequate quantitative analysis to avoid creating a larger problem than the one being resolved. In some cases, more sophisticated tools such as simulation models may be required to determine the feasibility and appropriateness of a strategy.

The process of selection may be simple or complex depending upon the nature of the problem being addressed and the need for quantification of benefits. In some cases, the strategies may be more dependent upon consensus among the stakeholders than analytical analysis.

The following are some possible items to consider before diverting traffic either from a freeway to an arterial, or from an arterial to a freeway:

- Is there sufficient signage to ensure travelers do not get lost?
- Is there sufficient trailblazing on the alternate route?
- Does the arterial have the capacity to handle the diverted traffic? Can it, with signal timing changes?
- Can signals be changed easily from a remote location? Is there sufficient arterial surveillance capability to closely monitor the diversion?
- Are there effective connectors? Can these be effectively monitored?
- Are there liability issues in suggesting alternate routes?
- Are temporary turning or parking restrictions needed on arterial routes? If so, is it possible to deploy manual resources to erect appropriate signing and/or implement such changes safely and in a timely manner?
- Are there permit or utility operations that have been deployed without prior notice?
- Is there roadwork in place along the diversion route and, if so, can it be removed quickly?
- Are there any special events along the diversion route which may hinder traffic?
- Are there schools or hospitals on the alternate route?
- Are there major employment centers or shopping malls on the diversion route?

In planning the operational strategies to be used during incidents, there are questions which should be considered, such as:

Is the incident on the freeway or the arterial street?

> It may be preferable for safety reasons not to designate roads containing schools, hospitals, parks, or residential areas as alternative routes as they may have speed restrictions or speed control devices installed (e.g., speed humps).

There are a number of differences depending upon where the incident occurs. If the incident is on the freeway and traffic is diverted to the arterial street, the local agency operating the arterial needs to be aware of the diversion and should take steps, such as a survey of the arterial street, to assure traffic is hindered as little as possible. Adjustments to signal timing, removal of temporary roadwork, and other steps can also facilitate traffic diversion. If the incident takes place on the arterial street and traffic is diverted to the freeway, there are probably fewer considerations, but notifications still need to be made and adjustments, such as changes to ramp metering, may have to take place.

What time of day and on which day of the week did the incident take place?

An incident occurring on a weekend will have a different response from one taking place on a weekday. For example, schools along the alternate route will not be open on Saturdays and Sundays, but traffic to a shopping district will be heavier. The time of day will also have an impact: incidents during peak periods will cause even greater congestion than is typically experienced. Available resources, especially staffing, will vary depending upon the time of the incident.

What capacity loss does the incident present?

An incident which occurs in the early morning hours and shuts down one lane of a three-lane highway will present a minor loss of capacity and it may not be necessary to implement any coordination between the freeway and arterial street operators beyond notifications. At the other extreme, a full closure of either the arterial street or the freeway may force a diversion between the roadways.

What is the cost of various coordination efforts?

Most actions, beyond notifications, carry some cost to the agencies responsible for carrying them out. For example, if a city must deploy police officers to direct traffic manually at diversion points or through intersections, there is a significant cost for supplying that labor. Issues of who pays for what should be worked out ahead of time so that concerns about cost do not delay implementation of plans during an incident.

What resources are available?

Knowing ahead of time what resources can be used allows the agencies to improve coordination of their efforts and to determine what level of response is appropriate. Permanent DMSs can be easily adjusted with messages displayed even for incidents of short duration. On the other hand, if portable signs need to be deployed, agency personnel must consider whether the time and effort to retrieve the signs, transport them to the location, and program messages is worth the effort given the expected duration of the incident.

Upon completion of this step of the process, all stakeholders should have a detailed understanding of what strategies are feasible and supported by the corridor agencies. The next step is to package all of the strategies in a corridor implementation plan, which is a formal document that can be used to secure the funding necessary to advance the program to design.

4.3.7 Corridor Implementation Plan

The corridor implementation plan is the final product of the decisionmaking segment of the CFA operations framework. It documents all the steps previously undertaken with sufficient detail to see the project or projects developed for improved corridor operations through implementation.

The corridor implementation plan would include the following elements:

- Goals and objectives for corridor.
- Summary of corridor concept of operations.
- Summary of corridor scenarios and selected operations strategies.
- Phasing of efforts or projects necessary to implement operations strategies.
- Staffing and personnel needs.
- Capital, operating, and maintenance costs.
- Potential funding sources.
- Schedule for corridor implementation.

Multiple scenarios are developed for the the package of operations plans, which forms the basis of the corridor implementation plan. To implement the operations plans requires an assessment of the resources required for the implementation phase of the framework (design, deployment/ implementation, and operations and maintenance). The corridor implementation plan compiles the operations plans and the necessary supporting resources in a complete package that can be used to secure the funding necessary for design, implementation, and operation and maintenance. The plan is also needed to provide documentation for securing the institutional consensus necessary to proceed.

In summary, after the concept of operations, the corridor implementation plan is the second major milestone. It is a formal document that contains sufficient detail to move the plan to the next step, which is design and development, and may contain a number of projects, especially if it is necessary to fund and construct the implementation over a long timeframe. The plan would also indicate priorities among projects, potential funding sources, and cost allocations.

4.3.8 Design and Development

The design and development step initiates the implementation phase of the framework. The design transforms corridor implementation plan concepts into practice and covers many details, including the construction plans necessary to build the supporting infrastructure and the detailed procedures and supporting agreements necessary to operate and maintain the operations plans.

The issues to be addressed in the design phase include:

- Performance requirements.
- Functional requirements (what is trying to be accomplished).
- System architecture (how does the system work).
- Identification and screening of technologies.
- Specifying technologies.

> When more than one agency is involved in the funding and development of a system, a memorandum of understanding (MOU) may be necessary to dictate which agencies are responsible for the maintenance of each component of the system.

The important aspect of the design phase is that it requires selection of the technologies that are necessary to support the operations plans included in the corridor implementation plan. The specifics will be highly individualized because of the variety of ways in which individual agencies work and the amount of sharing of information and control that is acceptable. Under a loosely integrated system, control system changes could be implemented by a telephone call requesting a special timing plan. Under a closely integrated system, an agency with a 24/7 operation might be able to implement preplanned strategies when the agency owning the equipment is not staffed for operation.

The design phase also calls for development of specific details of the strategies to be implemented, similar to those noted in figure 16. This would include details like loading specific messages onto DMSs and creating signal timing plans for coordinated diversion routes. This is where development of plans and procedures are made for each strategy that was selected earlier. These plans are then packaged into a separate operations plan for each scenario. Specific procedures are created for each plan to define roles and responsibilities. See chapter 3 and figure 13 for more information.

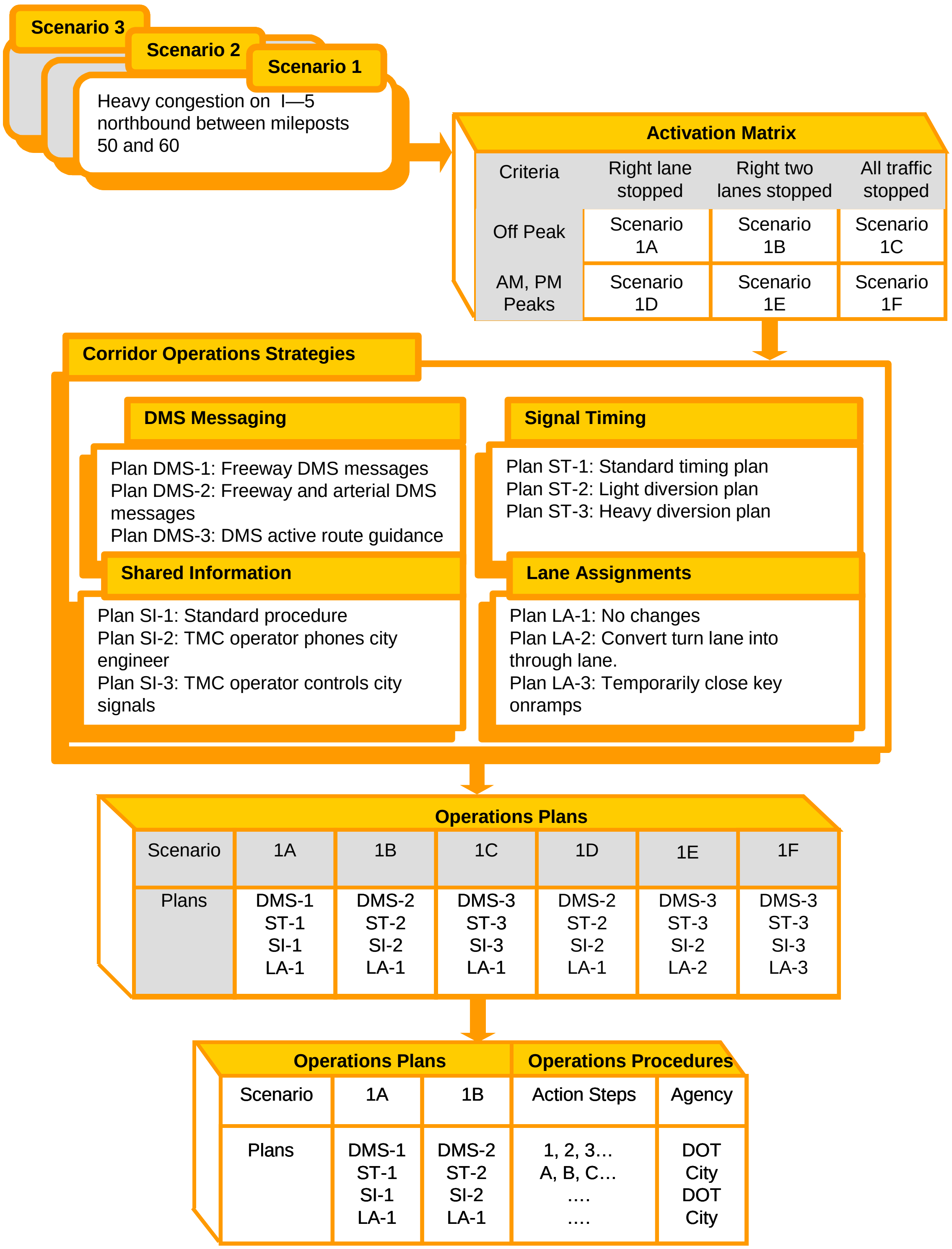


Figure 16. Chart. Example of operations plans and procedures for incident management scenarios.

4.3.9 Deployment

The deployment phase includes activities in preparation for implementation and the various actions necessary to implement the system designed in the previous step.

Some of the following activities may be required prior to implementation:

- Execution of any interagency agreements.
- Execution of any policies such as “Move It” or “Quick Clearance.”
- Procuring other resource staff.
- Training staff.

The implementation process may involve both people and infrastructure. There may be new staff that needs to be hired and trained. As the complexity of the project increases, phasing and timing of the various elements needs careful consideration so that the system components can be deployed and tested in a timely fashion.

In the development of most CFA deployments, it is anticipated that the majority of activities will involve integration and enhancements of disparate monitoring and control systems. Given the assumption of integration, consideration should be given to adopting ITS standards whenever possible in the deployment process.

4.3.10 Operations and Maintenance

Overlooking operations and maintenance often results in serious negative consequences. Without ongoing support for a project, its potential cannot be achieved; therefore, operation and maintenance must become a part of the routine operation of the agencies. To achieve this, it may be necessary to designate an individual to handle the coordination of the unique requirements of shared operations and management of the corridor. Given the irregular frequency of incidents, there may be substantial cost savings in integrating incident management responsibility.

> Assigning full responsibility and authority to the program manager usually facilitates success of a large technical project.

4.3.11 Continuous Improvement

Continuous improvement should be well integrated into the overall process. The performance monitoring system should provide feedback on both the success of individual operations plans and the need for other actions. In addition, regular meetings facilitate ongoing communications. These meetings would address both experiences and lessons learned from coordinated operations and refine existing operations. An annual meeting to review the program more broadly regarding overall operations plans would also be desirable. This is particularly critical for corridor incident management as many of the response strategies are difficut to develop. For example, diversion volume and corresponding signal timings must first be estimated based solely on projected demands. Once the sytem has been in actual operations, these operations plans can be calibrated and upgraded.

4.4 Work Zone Management

It is often the case that a work zone has a ripple effect on transportation within a corridor, particularly when they lie within high-traffic areas or areas that are subject to extreme a.m. or p.m. peak movements. The purpose of this section is to recast the issue of work zone management in the context of the coordinated freeways and arterials framework. At the conclusion of this section, the reader will have an understanding of how to expand their approach to work zone coordination from a single project focus to a corridorwide management perspective.

A view that focuses on maximum system performance from the users' perspective by minimizing the overall effects of the work zone is essential.

The impacts of work zones are not always restricted to the work zone itself. These impacts may be felt in the area in advance of the work zone, in other roadway corridors, within the regional transportation network, and on other modes of transportation. It is important to understand that the types of strategies deployed may change based on the duration of the operation.

Expanding work zone management processes to corridors is the goal of CFA operations. There is no magic formula for development of coordinated work zone management; the key is to expand the scope of work zone management from a single project focus to a corridor management view. A view that focuses on maximum system performance from the users' perspective by minimizing the overall effects of the work zone is essential.

4.4.1 Problem Identification

The following factors help define the work zone problems that should be addressed:

- Type of work zone operation.
- Duration and severity of work zone.
- Impact of work zone on surrounding traffic operations.

Type and duration of work zones can have a potentially significant corridor impact. However, it is also important to understand the potential impact of multiple work zones on each other. Often individual work zone projects would have modest impact on travelers if it were not for another work zone that either compounds the principal delay or affects alternative routes.

The type and duration of work zones affects both the extent of the potential problems and the potential remedies. The longer and larger the work zone, the more likely that mitigation efforts will be cost effective. The *Manual on Uniform Traffic Control Devices* classifies work zone operations as follows:[(23)]

- Long-term stationary— work that occupies a location for more than 3 days.
- Intermediate-term stationary— work that occupies a location for more than 1 daylight period up to 3 days or nighttime work lasting more than 1 hour.
- Short-term stationary— daytime work that occupies a location for more than 1 hour but less than 12 hours.

- Short duration—work that occupies a location up to 1 hour.
- Mobile— work that moves intermittently or continuously.

The important point to derive is that the impact of work zones can vary from large projects that impact an entire city to smaller projects to a daily pothole patching crew on the local freeway. This section focuses on work zone projects that impact both freeway and arterial operations.

In assessing current work zone practices from a corridor perspective, the following questions may be helpful in identifying problems that are amenable to coordinated work zone management:

- Do agencies share information on planned activities?
- What are each agency's practices for work zone management?
- Are each agency's practices and priorities well understood among other stakeholders when viewed from a corridor perspective?
- Do any of these practices and priorities conflict? What is the nature of the conflict? How can agencies involved in coordinated operations cooperate to resolve the conflict?
- Are agency's practices redundant? Can coordinated operations free-up resources?
- Are there gaps in delivery of corridor work zone management as agency services are now configured?

4.4.2 Institutional Considerations

The basic principles of developing institutional relationships were presented in chapter 3. Those principles are:

- Establish a structure.
- Identify corridor stakeholders.
- Identify corridor champions.

Work zone management is an area that involves multiple agencies and disciplines and therefore requires the clear delineation of roles and responsibilities. An appropriate structure must be developed to sustain the effort. The type of structure depends on local circumstances and should build, if possible, on existing relationships using any of the structures described in chapter 3.

To advance a large project from inception through implementation may require the organization of executive, steering, and operation committees that will need to be informed throughout the various stages of the project.

The key stakeholders that need to be involved in work zone operations fall into the following categories:

- State and local political leadership.
- Intra-agency personnel such as planning, design construction engineering, and public information staff.

- Interagency personnel.
  - Law enforcement and emergency management agencies.
  - Local public works departments.
  - Transit agencies.
- Managers of special event venues.
- Major employers and/or traffic generators.
- Media.

To mobilize these individuals and agencies into an effective CFA work zone management program, a concerted effort is required to bring them together in new ways to realize the benefits of corridorwide coordination.

It is necessary to have in place some degree of work zone management to implement a coordinated program. Agencies wishing to assess their work zone management practices may wish to take FHWA's *Work Zone Mobility and Safety Self-Assessment Guide*.[(24)] This tool allows agencies to judge their own programs' achievements and to identify areas for improvement.

If no work zone management program exists, the first step is develop a local program. Assuming at least one agency or jurisdiction has a work zone management program, the next step is to expand work zone management beyond traditional agency or jurisdictional boundaries. The process requires identification of a broader group of stakeholders and either building new relationships or expanding established relationships.

To achieve the desired outcome, it is necessary to consider the legal and policy environment in which coordinated work zone management is carried out. Questions that may be helpful in determining this environment include:

- What are the legal limits to work zone management that agency personnel can perform? (e.g., can an agency leave its jurisdiction to aid another agency in its jurisdiction?)
- To what extent do real or perceived legal constrictions pose an obstacle to coordinated work zone management?
- What is the financial liability of agencies, agency personnel, and the public with respect to joint work zone management?
- Can or should statutes be changed to facilitate coordinated work zone management?

The remainder of this section highlights the unique issues of CFA management, which extends the principle of local work zone management to a larger venue. The first challenge is to identify champions for expanding work zone management to a corridor-level program. The champions' support is necessary to secure an initial commitment of resources (staff and funding) to begin the program development process. It ensure success, champions must emerge or be identified as part of the coalition-building process. The champions guide the project from inception to completion and help navigate through the institutional challenges.

4.4.3 Goals, Objectives, and Performance Measures

Goals, objectives, and performance measures should be developed based on the consensus of the stakeholders to establish a unified foundation for developing CFA operations during work zones. CFA operations specifically for work zones should address the following key goals:

- Maximize worker safety.
- Maximize worker productivity.
- Minimize impacts on travelers.
- Reduce project duration.
- Achieve cost efficiency.

It can sometimes be difficult to reach a balance between these goals. A full roadway closure would achieve four of the five goals, but would generally not be considered because of the inconvenience to the public. However, even full roadway closures are now being considered. An example of implementation of a full lane closure project and can be found at: http://ops.fhwa.dot.gov/wz/workshops/accessible/LaRue_paper.htm.

In addition, special considerations to minimize the impacts of work zone operations on response time by emergency management services needs to be addressed. Once the goals have been established, specific objectives can be defined to reflect the various perspectives of those impacted by work zone activity, such as the traveling public, work zone workers, and the responsible jurisdiction(s). Table 7 is an example of work zone objectives.

Table 7. Example objectives for work zones.

Perspectives	Work Zone Objectives
Traveler	Travel delay no greater than X percent. Maintain normal access for local residents and businesses. Maximum travel times through primary freeway corridor to not exceed X hours.
Workers	No work zone-related fatalities or injuries.
Jurisdiction	Achieve crash rate no higher than exists without work zone. Allow emergency vehicles to access work zone and travel through work zone as quickly as possible.

The determined goals and objectives will influence the work zone sequence and impact the types of strategies considered to improve the CFA. The most important performance measure from the traveler perspective is any delay that the work zone operation will have on their trip. While the public understands that delays are likely from a work zone operation, there is a limit to what will and will not be tolerated.

The development of goals and performance measurement for work zone operations is also an evolving area. Areas for potential goal setting and performance measure are:

- Planning.
- Mobility.
- Safety.
- Throughput.

Planning should address such issues as coordination across agencies, projects, and time, as well as a consideration of work zone implications throughout the project life cycle.

Mobility measures should include a consideration of impacts through the whole life cycle (before, during, and after a work zone) on all modes of transportation (multimodal) throughout the affected corridor (corridorwide). Mobility also addresses the availability of useful and reliable information to travelers and operating agencies and the use of ITS technology to measure performance, provide information, and manage traffic.

Safety measures will promote continuous review of work zone design and management, and the reduction of accidents and fatalities through efforts to maximize work zone safety management. In summary, the goals of an effective CFA work zone project would include maximum safety and minimum disruption to travelers. To achieve such goals, a broad view of the interactions of various decisions, especially those caused by a lack of coordination between agencies, must be considered.

4.4.4 Corridor Concept of Operations

The corridor concept of operations is a formal document that provides a high-level, user-oriented view of operations in a specific corridor. It is developed in part to help communicate this view to other stakeholders and to solicit their feedback. The corridor concept of operations provides a description of the current system, operating practices and policies, and existing capabilities. It lays out the program concept, explains how the corridor system is expected to work once it is in operation, and identifies the responsibilities of the various stakeholders for making this happen. The goals, objectives, and performance measures of a proposed operation are also documented. The process of developing a concept of operations for a corridor should involve all stakeholders and serve to build consensus in defining the goals and objectives; to provide a description of how functions are currently performed, thereby supporting resource planning; and to identify the interactions between organizations.

The formality of a concept of operations will depend on the nature of the work zone activity. Short-term work zones will not usually warrant a complex concept of operations. However, a generic concept of operations may be appropriate for walking through the issues and alternatives associated with short-term work zones. Guidance on best practices which can form the basis for developing a concept of operations may be found at: http://ops.fhwa.dot.gov/wz/practices/best/Default.htm.

Long-term work zones associated with major construction or reconstruction projects requiring months or years to complete warrant the development of a more complex concept of operations. The operations plan provides a package of strategies associated with one or more specific scenarios.

In the case of minor work zone activities (e.g., mobile, short duration, or short-term stationary work zones as defined in section 4.4.1), providing traveler information, scheduling during off-peak hours, and coordinating work zones activities between agencies may be all that is necessary. The development of a corridor work zone Web site can be a simple means to achieving coordinated agency activities and dissemination of traveler information. More extensive work zone activities may necessitate more active traffic management and control as well as more extensive resource sharing.

At this stage, the cooperating agencies should address questions of what (not how) they are willing to do regarding coordination of work zone activities in the corridor. Perhaps the biggest opportunity for improvement of work zone operations is coordination between agencies at the planning stage of work zone projects. Avoiding projects that have overlapping impacts could substantially reduce traveler delay with a very modest investment in resources. Other general strategies to be considered include:

- Traveler information.
- Traffic management and control.
- Shared information and resources.

The development of a concept of operations allows the participating agencies to agree on what they wish to accomplish and to lay the framework for how it will be done. For example, are the agencies willing to discuss their schedules for construction projects? This is an issue agencies should resolve before moving to the more detailed level of discussion.

As part of the development of a concept of operations, consider the following points:

- Does stakeholder consensus exist to support coordinated work zone management? If so, does it exist for both short-term and long-term activities?
- If stakeholder consensus must be established, who will be the champion and organize a workshop or forum to demonstrate the benefits?
- What is the level of stakeholder commitment of personnel and funding resources?
- What policy changes, if any, are needed to implement a coordinated work zone management program (such as legislation regulating short-term work zone activity)?
- What organizational structure will be established for the day-to-day management program?

The concept of operations document could include the following sections:

- Summary of the overall goals of work zone management.
- Description of the corridor and the stakeholders.
- Description of the high-level problematic issues.
- Description of activation criteria.
- Description of types of strategies to be implemented.
- Identification of roles and responsibilities of stakeholders.
- Identification of polices and procedures that require modification.
- Estimate of capital and operating costs.
- Identification of schedule for planning, development, and implementation.

In summary, the concept of operations defines the overall plan that addresses the goals and objectives of work zone management coordination, the high-level scenarios to be addressed, the activation criteria, and the type of response. The concept of operations phase of planning involves the "who, what, when, and where" of work zone management.

4.4.5 Corridor Scenarios and Operations Strategies

The concept of operations provided the high-level scenarios to be addressed and a general discussion of the types of strategies to be implemented to achieve agency support. Once the concept of operations is agreed to, the scenarios and potential strategies need to be refined. Specifically, what segments of highway and under what conditions are strategies to be implemented? What are the potential strategies that might be implemented to mitigate each work zone scenario? The concept of operations scenarios need to be developed into specific locations where work zones would be implemented. For major construction projects, the location would be project specific. For short-term work zones, the scenarios would be more generic, focusing on freeway or arterial sections having similar strategies regardless of a specific work zone location.

The process of selecting scenarios is conceptually linked to the strategies selected for implementation. For example, if strategies include alternative routes, the scenarios need to reflect the logical points at which diversions might be implemented.

Strategies are specific actions to mitigate one of the scenarios associated with a work zone. Several strategies may be required to achieve the desired improvement in system performance and would vary by the duration and impact of the work zone.

Specific examples of candidate strategies that individual agencies might consider to achieve improved corridor operation include:

- Notify affected agencies regarding work zone activity.
- Provide traveler information via resources such as DMS, HAR and media.
- Advise affected motorists to use an alternate route.
- Advise motorists to use a particular alternate route.
- Implement traffic signal timing adjustments.
- Work with corridor employers to investigate potential travel demand strategies (e.g., flextime, telecommuting).
- Expand incident management capabilities for large, long-term projects to preserve remaining capacity.
- Construct temporary park and ride lots to encourage transit alternatives.

At this point, the strategies are still high-level, general ideas of how agencies can work together but focused on specific segments of roadway. In the next step, the strategies are analyzed in more detail to understand practical issues such as costs and potential benefits. The current objective is to consider taking traditional strategies beyond agency boundaries to improve corridor operation. What is possible technically, and what is possible practically? The answers will depend on many local factors. The important point is to begin the dialogue among partners to determine what is possible.

The opportunities for corridor work zone management coordination need to reflect the unique characteristics of incidents. At the corridor level, the two issues that need to be considered are timeframe and significance of benefits relative to the effort.

Short-duration work zones coordination, unless having major capacity reductions, may warrant only the dissemination of traveler information. A coordinated traveler information program can easily be implemented at virtually no additional cost or effort within an agency-specific program.

As the severity (amount of capacity reduction) and duration of a work zone increases, the potential benefits of more aggressive strategies increase.

An example of some operations strategies that might be applied to work zones are shown in table 8. Because work zones vary in duration, it is important to understand the impact of time on the deployment of specific strategies.

Table 8. Example operations strategies for work zones.

Category	Example Strategies
Traffic Management and Control	
Freeway management	Ramp closures. Elimination of weaving areas. Ramp metering timing and coordination.
Arterial management	Access and turn restrictions. Advance signing to improve traffic circulation. Traffic signal timing and coordination. Lane control use adjustments. Road closures. Onstreet parking restrictions. Trailblazer signing.
Traveler Information	
En route traveler information	DMS (temporary and permanent). Trailblazer signing. Pagers, PDAs. CB Radios. Cell phone/511. HAR. Media.
Pretrip traveler information	Internet. Telephone information systems. Public information campaign. Media (radio and television broadcasts). Kiosks.

Table 8. Example operations strategies for work zones (continued).

Category	Example Strategies
Shared Information and Resources	
Incident response	Motorist service patrols. Wreckers. Portable DMS.
Traffic surveillance	CCTV systems. Field observation. Aerial observation. Media reports. Portable traffic management systems.
Information systems	Incident reports. Construction activities. Special event schedules.

Shared resources represent one of the potential major benefits of coordinated operations, especially during major construction projects. Through shared resources, the collaborating agencies can make available more information then they can individually provide. Since a major work zone is often has substantial spillover effect, shared resources are a win-win proposition.

4.4.6 Evaluation and Selection of Strategies

The process of selecting the specific strategies is an iterative process involving the partners in assessing both the costs and the benefits of the strategies and the various agencies ability to implement the strategies. A strategy may be perceived to be positive, but a more detailed analysis may show it to be counterproductive. A strategy may be technically feasible, but not selected because it is beyond the resources available, or possibly inconsistent with community values.

The following factors can be used to evaluate potential traveler information, traffic management and control, and shared information and resource strategies that can be used to be coordinate freeway/arterial roadways during work zone operations:

- Duration of the operation.
- Capacity impacts.
- Volume of traffic affected.
- Funding.
- Existence of traffic generators.
- ITS deployment that is available (existing or to be installed).

There are some analytic tools that can determine the impact of work zone operations on a roadway and therefore provide some indication on the volume of traffic that might need to be diverted to alternate routes or shifted to alternate modes. An example is QuickZone. Information on QuickZone can be found at: http://www.tfhrc.gov/its/quickzon.htm.

QuickZone is the first tool developed under the Strategic Work Zone Analysis Tools program. These tools are intended to be user-friendly software tools that assist those in the highway community with decisionmaking. QuickZone is a traffic impact analysis spreadsheet tool that can be used for work zone delay estimation. The purpose of QuickZone is to:

- Quantify corridor delays resulting from capacity decreases in work zones.
- Identify delay impacts of alternative project phasing plans.
- Support tradeoff analyses between construction costs and delay costs.
- Examine impacts of construction staging by location along mainline, time-of-day (peak versus off-peak), and season (summer versus winter).
- Assess travel demand measures and other delay mitigation strategies.
- Support development of work completion incentives.

At this point in the process, there is a clear overlap between incident management and work zone operations response planning. There are similar, important review items to be considered prior to diverting traffic from a freeway to a surface street, including whether or not there are permit or utility operations that have been deployed without prior notice; the presence of schools, hospitals, or shopping centers on the alternate route; and the presence of major employment centers on the diversion route. Additional considerations include the question of whether temporary turning or parking restrictions are needed. If so, the question then arises as to whether it is possible to deploy manual resources to erect appropriate signing and/or implement such changes safely and in a timely manner. Additional discussion of strategy evaluation and selection considerations can be found in section 3.8.

While each jurisdiction may have individual characteristics, and it is preferable to have preplanned diversion routes, the following are some possible items to review before diverting traffic from a surface street to a freeway:

- Is the surface street connected to the freeway (preferably at both ends of the diversion) or are there multiple streets involved in the diversion route? Is trailblazing along the diversion route necessary, and if so, is it in place?
- Is there other roadwork in place along the diversion route?
- Are there any special events along the diversion route that may hinder traffic?
- Are there other unusual circumstances along the diversion route (i.e., shopping mall during holiday season, school day ending)?

In planning the operations strategies to be used during work zones, there are questions which should be considered:

What is the cost of various coordination efforts?

Most actions, beyond notifications, carry some cost to the agencies responsible for carrying them out. For example, if a city must deploy police officers to manually direct traffic at diversion points or through intersections, there is a significant cost to supply that labor. Issues of who pays for what should be agreed to ahead of time.

What resources are available?

Knowing ahead of time what resources can be used allows the agencies to coordinate their efforts more effectively and to determine what level of response is appropriate. Permanent DMSs can be easily adjusted with messages displayed even for work zones of short duration. On the other hand, if portable signs need to be deployed, agency personnel must consider whether the time and effort to retrieve the signs, transport them to the location, and program messages is worth the effort given the expected duration of the work zone.

Upon completion of this step, all stakeholders should have a detailed understanding of what strategies are feasible and supported by the corridor agencies. The next step is to package all of the strategies in a corridor plan, which is the formal document, which can be used to secure the funding necessary to advance the program to design.

4.4.7 Corridor Implementation Plan

The corridor implementation plan is the final product of the decisionmaking component of the CFA operations framework. It documents all the steps previously undertaken with sufficient detail to take the project or projects developed for improved corridor operations to the implementation stage.

The corridor implementation plan is the second major product after the concept of operations. It contains sufficient detail to move to the design step and may contain a number of projects, especially if it is necessary to fund and construct the implementation over a long timeframe. The plan should also indicate priorities among projects, potential funding sources, and cost allocation.

A detailed discussion of the elements of the corridor implementation plan and a list of the issues and resources that need to be addressed during its development are in section 3.9 above.

4.4.8 Design and Development

Design and development is the first step in the implementation section of the framework. This is a significant step forward in that it transforms the corridor implementation plan *concepts* into projects that are able to be implemented. It covers many details of implementation including the necessary construction plans to build the supporting infrastructure and specifies detailed procedures and supporting agreements necessary to operate and maintain the operations plans. A detailed discussion of important elements of the design phase can be found in section 3.10 above.

The implementation of the design and development phase can be either separate from the work zone contractual package or incorporated as an early phase. Regardless, the important consideration in either case is the required leadtime to implement the strategies prior to the start of the work zone operations. In some states, design/build procurements are used to consolidate this step and deployment, the next step. The selection of technologies addresses the way the varying phases of construction will impact the use of ITS technologies.

Strategies may also vary by time of day, reflecting both the volume of traffic on the freeway and the conditions on adjacent arterials. Table 9 is an example of a corridor operations plan with activation criteria based on freeway capacity loss, duration of work zone, and the time of day. In this freeway example, letters represent the level of response, which are recommended based on three factors: the time of day the incident occurs, the expected duration of the incident, and the amount of capacity lost on the roadway experiencing the incident. The example shown is fairly complex and could be simplified based on reducing the number of time periods and the number of categories of duration.

Table 9. Example corridor operations plan for freeway work zone.

		Freeway Capacity Loss		
Time of Day	**Duration**	**Low**	**Medium**	**High**
All Day	24 hours (h)/day	N, T, A, M, D1	N, T, A, D1	N, T, A, M, D2
Weekday Daytime Off-peak	0–20 minutes (min) 20 min–2 h 2–4 h > 4 h	N N, T, A N, T, A, D1 N, T, A, D1	N, T N, T, A N, T, A N, T, A, D1	N, T, A N, T, A, D1 N, T, A, M, D2 N, T, A, M, D2
Weekday Nighttime Off-peak	0–20 min 20 min–2 h 2–4 h > 4 h	N N, T N, T N, T	N, T N, T, A N, T, A N, T, A	N, T N, T, A, D1 N, T, A, D2 N, T, A, D2
Weekend Daytime	0–20 min 20 min–2 h 2–4 h > 4 h	N N, T, A N, T, A, D1 N, T, A, D1	N, T N, T, A N, T, A N, T, A, D1	N, T, A N, T, A, D1 N, T, A, M, D2 N, T, A, M, D2
Weekend Nighttime	0–20 min 20 min–2 h 2–4 h > 4 h	N N, T N, T N, T	N, T N, T, A N, T, A N, T, A, D1	N, T N, T, A, D1 N, T, A, D2 N, T, A, D2

N = notification is made to affected agencies.
T = traveler information is provided via resources such as DMS, HAR and media.
A = motorists are advised to use an alternate route.
D1 = motorists are advised to use a particular alternate route.
D2 = motorists are forced onto an alternate route.
Notes: ·It is assumed that different governmental entities operate the surface street and freeway systems. ·A decisionmaking matrix is needed when a diversion to an alternate route is warranted that requires confirmation of available capacity and/or the absence of a planned or unplanned event on that route. · Traveler information systems can be portable or permanent DMSs, HAR, kiosks or Internet-based systems and also include media/traffic service notifications.

While strategies are funded and developed with the specific work zone operation in mind, where possible there should be some consideration to the continued use of these strategies beyond the work zone operation.

4.4.9 Deployment

The deployment phase includes activities in preparation for implementation and the various steps necessary to implement the system designed in the previous step. A full discussion of the considerations required for implementation can be found in section 3.11.

4.4.10 Operations and Maintenance

Operations and maintenance is often overlooked with serious negative consequences. Within an agency, someone must be responsible for coordinating the operations and maintenance of any mitigation strategies. Where possible, the champion should encourage incorporating this activity into an existing TMC or operation. Other considerations in the operation and maintenance of work zone mitigation strategies are as follows:

- Work zone operations are dynamic activities and there must be changes to the work zone sequencing because of unforeseen issues. For a daily pothole repair work zone operation, the trucking firm that is delivering asphalt to the site may have been delayed and arrive late to the site. Unforeseen situations such as this can extend the duration of the work zone operation.

- The potential for incidents within work zones is significant. A quick response to incidents, even minor ones, will reduce motorist delay and help avoid secondary incidents that can be worse than the primary one. In addition, access to emergency services must be coordinated.

- For long-term work zone operations, there should be frequent meetings with the different stakeholders to inform them of the status of the work zone operation, gauge how well the strategies are working, and make any necessary changes.

- Other events that impact the work zone operation include special events within the corridor impacted by the work zone operation, work zone or permit operations on the alternate routes, or incidents that take place along the alternate routes. The development and implementation of an information sharing system will help communicate and coordinate interagency responses.

4.4.11 Continuous Improvement

Continuous improvement should be well integrated into the overall process. As stated in previous sections, the performance monitoring system should provide feedback on both the success of individual operations plans and the need for other actions. In addition, regular stakeholders meetings are an advantageous means of facilitating ongoing communications and exchanging stakeholder experiences with coordinated operations to refine existing operations.

The National Work Zone Safety Information Clearinghouse (http://wzsafety.tamu.edu/) is a reference tool on policies, practices and technologies that have been effectively used to manage work zone operations. This site is updated regularly and is an ongoing source of information.

4.5 Planned Special Events Management

A planned special event is a public activity or series of activities with a scheduled time and location that may increase or disrupt the normal flow of traffic on affected streets or highways. As with work zones or traffic incidents, special events may also have a ripple effect on transportation within a corridor for many reasons. The unsuspecting traveler may encounter unexpected delays, and when alternative routes are not clearly conveyed to travelers, congestion and incidents are more likely to occur. The purpose of this section is to apply the CFA framework to planned special event management in a corridor. The benefits of taking a corridorwide view of special event coordination include maximizing system performance and effectively minimizing the overall effect of the special event on the transportation system within that corridor. At the conclusion of this section, readers will have an understanding of how to expand their approach to special event coordination from a single, local project focus to a corridorwide management perspective.

The impacts of special events may not always be restricted to the immediate event venue. The impacts may be felt on other roadway corridors, within the regional transportation network, or on other modes of transportation.

Expanding the special event coordination processes to corridors is the goal of CFA operations. While there is no single solution for development of special event coordination, the key to success is the expansion of the scope of special event coordination from a venue focus to a corridor management view. Special event coordination takes a corridor view that focuses on maximum system performance from the users' perspective by minimizing the overall effects of the special event.

The guidance from *Managing Travel for Planned Special Events* provides many of the details for developing special event plans and procedures.[(25)]Figure 17 shows the recommended process for managing special events in *Managing Travel for Planned Special Events*. Many of the steps in figure 17 are similar to the 11-step CFA process detailed in this handbook. These similarities will be highlighted in the remainder of this section. Event operations planning, shown in figure 17, is similar to steps 1 (problem identification) through 6 (evaluation and selection of strategies) of the CFA process. Event operations planning involves developing: a feasibility study for the proposed planned special event; a traffic management plan to service event-generated auto, transit, and pedestrian traffic and to mitigate transportation impacts; and a travel demand management plan when forecasted traffic demand levels approach or exceed available roadway capacity.

Training and implementation, as shown in figure 17, is similar to the corridor implementation plan and design and development steps of the CFA process. Training and implementation starts with the development of an implementation plan ranging from a brief memorandum, and concludes with an event management manual. Stakeholders representing the event planning and traffic management teams interact through event simulation exercises that may consist of a tabletop exercise, an event walk-through, or a traffic management plan deployment during a smaller-scale event. These exercises assist participants in identifying potential traffic management plan deficiencies and, in addition, will allow traffic management team members to become familiar with decision criteria and contingency plan details.

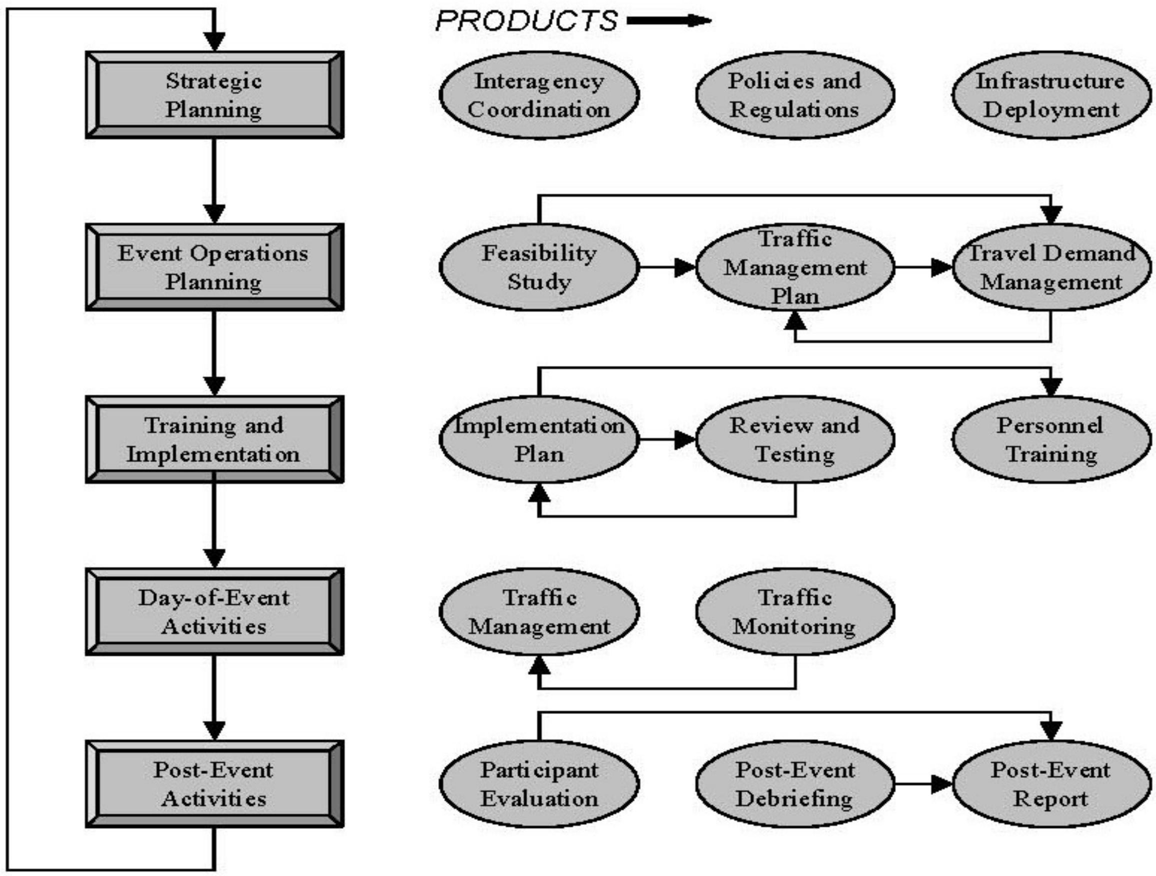


Figure 17. Chart. Integration of planned special event management phases.[25]

Day-of-event activities, as shown in figure 17, are similar to the operations and maintenance step of the CFA process. Day-of-event activities focus on the implementation of the traffic management plan in addition to traffic monitoring. The traffic management team represents a distinct stakeholder group charged with executing the traffic management plan. Traffic monitoring provides traffic and incident management support in addition to performance evaluation data. Timely deployment of contingency plans developed during the event operations planning phase depends on the accurate collection and communication of real-time traffic data between traffic management team members.

Post-event activities, as shown in figure 17, are similar to the continuous improvement step of the CFA process. Post-event activities range from informal debriefings between agencies comprising the traffic management team to the development of a detailed evaluation report. Qualitative evaluation techniques include individual debriefings of traffic management team members, patron surveys, and public surveys. Quantitative evaluation techniques include performing an operational cost analysis and analyzing traffic data collected during the traffic monitoring process.

4.5.1 Problem Identification

Planned special events include sporting events, concerts, festivals, and conventions occurring at permanent multi-use venues (e.g., arenas, stadiums, racetracks, fairgrounds, amphitheaters, convention centers, etc.). They also include less frequent public events such as parades, fireworks displays, bicycle races, sporting games, motorcycle rallies, seasonal festivals, and milestone celebrations at temporary venues. The term “planned special event” is used to describe these activities because of their known locations, scheduled times of occurrence, and associated operating characteristics. Emergencies, such as a severe weather event or other major catastrophe, represent special events that can induce extreme traffic demand under an evacuation condition. However, these events occur at random and with little or no advance warning, thus differing from planned special events.

Substantial technical material exists in the FHWA technical reference *Managing Travel for Planned Special Events*.[25] It presents and recommends various planning initiatives, operations strategies, and technology applications that satisfy the special customer requirements and stakeholder performance requirements driving planned special event travel management. This section summarizes that reference, highlighting the essential elements involved in managing traffic during planned special events. In addition, opportunities for CFA operations will be highlighted.

4.5.2 Institutional Considerations

Because of the high visibility of such events, agencies naturally come together. In addition, because of their unique nature, day-to-day plans and procedures are, by definition, not applicable. The short duration of special events may also make agencies more willing to commit resources because it does not represent an ongoing commitment.

An appropriate institutional structure needs to be developed to sustain the effort. The type of structure will depend on the local circumstances and should build, if possible, on existing relationships, but the basic principles of developing institutional relationships remain the same: establish a structure, identify corridor stakeholders, and identify corridor champions.

Figure 18 presents common stakeholders, representing various disciplines and jurisdictions that play an active role in managing travel for planned special events on a local and/or regional level. The balance of this section describes the potential roles and responsibilities of each identified stakeholder in addition to his or her coordination with other planned special events stakeholders.

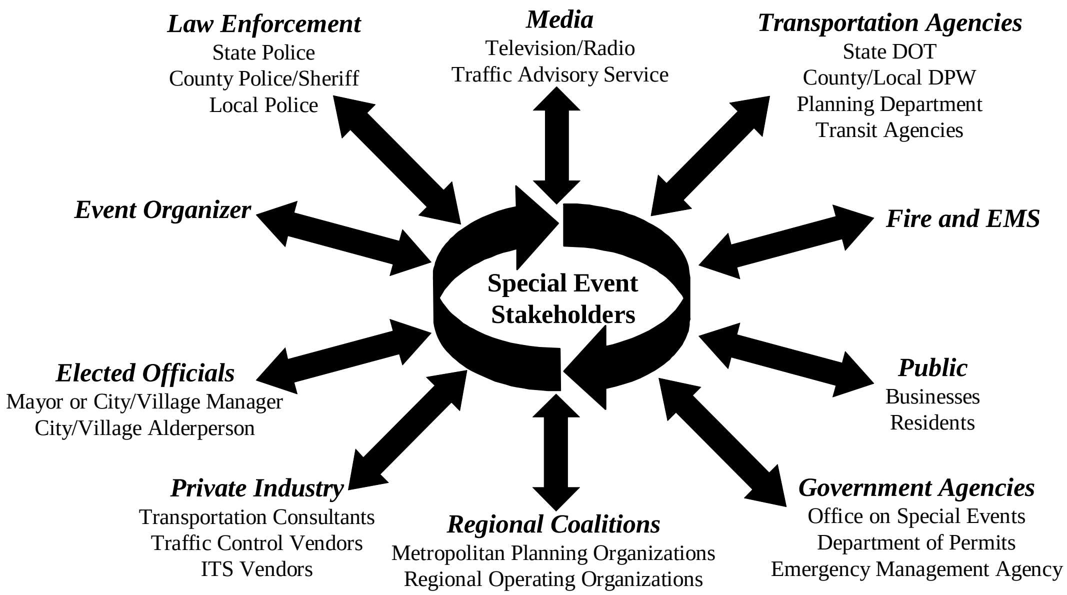


Figure 18. Chart. Stakeholders who may be involved in planned special events. [25]

Law enforcement facilitates the safe and efficient flow of traffic during a planned special event through traffic control and enforcement. Agencies contribute to all phases of planned special events, particularly event-specific advance planning and traffic management. Local and county law enforcement having a traffic operations bureau may take responsibility for developing and executing a surface street traffic management plan. Other potential duties of law enforcement include approving local street closures, approving an event traffic flow plan, approving temporary traffic control deployment, escorting dignitaries to/from the event venue, and enforcing the requirements of a traffic operations agency.

Event organizers initiate the event operations planning phase by notifying stakeholders, through a written request to public agencies or the submission of an event permit application, and assembling an event planning team. The event organizer continually works to maintain interagency coordination to meet milestones in the advance planning process and ultimately gain stakeholder approval of the proposed transportation management plan. The event organizer may hire a private traffic engineering consultant to perform an event feasibility study and prepare a traffic management plan. The event organizer usually funds the deployment of equipment and personnel resources, including reimbursement of public agency personnel costs required to mitigate traffic safety, mobility, and reliability impacts during the day-of-event. However, event organizers for major special events that occur on a regular basis may work together with transportation agencies, law enforcement, and elected officials during the strategic planning phase to develop strategies, including permanent installation of equipment for improved traffic monitoring and control and to better accommodate traffic and transit access to the venue.

Elected officials serve the overall community interest and often have a significant role on an administrative team. Local politicians can establish laws and regulations toward effecting improvements in planning and managing future planned special events. A local mayor or manager may create a special task group to assist event organizers and local agencies coordinate event-planning activities. Local district politicians may advise an event planning team on alternatives to minimize quality of life impacts on residents and businesses represented by the elected official.

Fire and emergency medical services (EMS) advise the event planning team on the provision of emergency access routes to and from the event venue.

The media functions to disseminate pretrip event and associated travel information, in addition to real-time information on traffic and transit conditions during the day-of-event to assist event patrons and other road users. A media representative may participate in a meeting of the event planning team to obtain advance information on proposed temporary traffic control, transit, and travel demand management initiatives. However, the media generally works independently of the traffic management team on the day-of-event.

Private industry satisfies a wide range of public agency needs from the event operations planning phase through the day-of-event activities phase. Traffic engineering consultants may assume the role of a public agency traffic engineer and in turn, develop a transportation management plan and manage either an event planning team, traffic management team, or both. Private traffic control vendors, such as barricade companies, fulfill the duties of a transportation agency maintenance department. ITS equipment vendors contract with transportation agencies to: 1) install permanent equipment such as CCTV cameras, lane control signals, dynamic trailblazers, and parking management systems on surface streets serving a fixed event venue or 2) deploy portable traffic management systems, including portable CCTV, portable changeable message signs, portable HAR, portable vehicle detectors, and portable traffic signals. In some instances, transportation agencies may arrange for an equipment demonstration, at no cost to the agency, to evaluate the performance of a particular technology application during a planned special event.

Regional coalitions interact with both the administrative team and an event planning team regarding major planned special events affecting a regional area. A metropolitan planning organization (MPO) oversees the planning and programming of transportation management strategies. For example, the agency may communicate and seek feedback on temporary travel demand management strategies with commuter groups and trucking companies. An MPO may loan staff to other public agencies in need of personnel to conduct planning and operations activities. The agency may also establish and/or coordinate temporary task forces charged with a particular function, such as event communications. A ROO, as explained earlier in section 2.3, consists of traffic operations agencies, transit agencies, law enforcement, elected officials, and other operations agencies focused on the operation and performance of a regional transportation system.

Government agencies denote nontransportation agencies that generally serve in an administrative capacity. A government office responsible for special events may work in tandem with the event organizer to initiate the event operations planning phase and coordinate event planning team stakeholders. Other governmental emergency management and security agencies may meet with the event planning team to obtain an advance debrief on transportation management plan specifics.

The public represents individual residents, businesses, and associated community groups. Residents and businesses potentially impacted by intense traffic and parking demand generated by a planned special event may interact with event planning team stakeholders during a public meeting. This permits concerned citizens the opportunity to review and discuss proposed traffic and parking restrictions needed to accommodate event traffic.

In summary, the complexity of special events requires a much larger group of stakeholders than other corridor management applications. To achieve corridor level operations, it is necessary to take special event management to a broader level of involvement, which expands the number of stakeholders involved. The large number of stakeholders may require the development of a more multifaceted organization structure to effectively deal with the complexity cause by number of issues and the number of agencies involved.

4.5.3 Goals, Objectives, and Performance Measures

The goals, objectives and performance measures of planned special event coordination should be established before working on the strategies to improve corridor operations. This allows the partners to define broadly what they are willing to do, before defining where and how they will do it. By starting with goals, the partners can define what aspects of corridor special event coordination they believe they can undertake. This is an important step because not all parties may see the goals for special event coordination the same way. It is easier to understand conflicts at the goal level because they are general in nature.

The potential impact of a planned special event is often difficult to predict and measure. However, establishing goals provides the necessary focus to understand what is potentially achievable through corridor coordination. Some candidate goals from *Managing Travel for Planned Special Events* include:(25)

- Achieving predictability.
- Ensuring safety.
- Maximizing efficiency.

Specific objectives include:

- Reducing delay.
- Reducing incidents.
- Reducing non-event traffic demand.

4.5.4 Corridor Concept of Operations

The corridor concept of operations is a formal document that provides a high-level, user-oriented view of operations in a specific corridor. It is developed in part to help communicate this view to the other stakeholders and to solicit their feedback. In essence, the corridor concept of operations provides a description of the current system, operating practices and policies, and existing capabilities. It lays out the program concept, explains how the corridor system is expected to work once it is in operation, and identifies the responsibilities of the various stakeholders for making this happen. The goals, objectives, and performance measures of a proposed operation are also documented. The process of developing a concept of operations for a corridor should involve all stakeholders and serve to build consensus in defining the goals and objectives; to provide an initial, definitive expression of how functions are performed, thereby supporting resource planning; and to identify the interactions between organizations.

The planned special events management concept of operations is the document that creates the high-level understanding of the planned special event management program. The concept of operations represents the initial support for the program and records the agreed upon approaches to be pursued in more depth.

The basis of the planned special events management concept of operations is the development of high-level problematic issues that warrant corridor-level special event response. The issues are presented as scenarios developed from problems identified in the first step in the framework. Problems whose alleviation is consistent with the corridor goals and objectives would be candidates for mitigation developed into high-level issue statements.

Problematic issue statements represent the initiating event for mitigation of the effects of special events. At the concept of operations stage, issues are broad: they do not focus on specific strategies. An example of this level of strategy could be to facilitate access to a special event venue by providing improved traffic management involving traveler information and revised traffic signal control on the major access routes.

At this stage, the cooperating agencies answer the questions of what (not how) they would be willing to do in the corridor to coordinate operations in response during a special event. General strategies could include:

- Traveler information.
- Traffic management and control.
- Shared information and resources.

The general strategy might be to use existing freeway DMSs to alert freeway drivers to the event so they might avoid the venue and seek an alternative route. Another high-level strategy might be to provide special arterial signal timing at the freeway exit to reduce freeway congestion.

The development of a concept of operations allows participating agencies to agree on what they wish to accomplish and to lay the framework for how that will be done. For example, does the traveler information only describe the nature of the problem or does it provide recommended courses of action? This is an example of an issue the agencies should resolve before moving to the more detailed level of discussion.

As part of the development of a concept of operations, consider the following points:

- Does stakeholder consensus exist to develop corridor-based special event coordination? If not, does it exist for other types of situations such as work zones or major construction and maintenance operations? If so, could success in the other situations be built upon to develop special event coordination within the region?
- If stakeholder consensus must be established, who will be the champion and organize a workshop or forum to demonstrate the benefits?
- What is the level of stakeholder commitment of personnel and funding resources?

- What policy changes, if any, are needed to implement special event coordination (such as interagency MOUs)?
- What organizational structure will be established to enable the many agencies to work together effectively?

The concept of operations document often includes the following sections:

- Summary of the overall goals of special event coordination.
- Description of the corridor and the stakeholders.
- Description of the high-level problematic issues.
- Description of types of strategies to be implemented.
- Identification of roles and responsibilities of stakeholders.
- Identification of policies and procedures that require modification.
- Estimate of costs.
- Identification of schedule for planning, development and implementation.

In summary, the concept of operations defines the high-level problematic issues that will be used to address the defined problems consistent with the corridor goals and objectives. The detailed issues and strategies have to be worked out in the development of the corridor implementation plan. The concept of operations phase of planning involves the who, what, when and where of special event coordination. The corridor implementation plan will determine how it will be done.

4.5.5 Corridor Scenarios and Operations Strategies

The main objective of CFA operations during planned special events is to maximize system effectiveness. Traveler information can mitigate demand, influence mode choice, influence route selection, and otherwise improve traveler reaction to negative impacts of the event. Better coordinated control systems increases throughput and minimizes impacts on motorists not attending the special event, but traveling on the roadways in the area.

Table 10 lists example strategies for mitigating the impacts of planned special events on local roadway and regional transportation system operations. In meeting the overall travel management goal of achieving efficiency, these strategies target the excess capacity of the roadway system, parking facilities, and transit. Through travel demand management, event planning team stakeholders develop attractive incentives and use innovative communication mechanisms to influence event patron decisionmaking and ultimately traffic demand.

Table 10. Example strategies for mitigating special event congestion.

Category	Example Strategies
Traffic Management and Control	
Freeway management	Ramp closures. Elimination of weaving areas. Ramp metering timing and coordination.
Arterial management	Access and turn restrictions. Advance signing to improve traffic circulation. Traffic signal timing and coordination. Lane control use adjustments. Road closures. Onstreet parking restrictions. Trailblazer signing.
HOV incentives	Public transit service expansion. Express buses from park and ride lots. Charter bus service. Preferred parking. Reduced parking cost.
Traveler Information	
En route traveler information	DMSs (temporary and permanent). Trailblazer signing. Pagers, PDAs. CB radios. Cell phone/511. HAR. Media.
Local travel demand management	Background traffic diversion. Truck diversion.
Pretrip traveler information	Internet. Telephone information systems. Public information campaign. Event and venue transportation guide. Media.

Table 10. Example strategies for mitigating special event congestion (continued).

Category	Example Strategies
Shared Information and Resources	
Incident response	Motorist service patrols. Wreckers. Portable DMS.
Traffic surveillance	CCTV systems. Field observation. Aerial observation. Media reports. Portable traffic management systems.
Information systems	Incident reports. Construction activities. Special event schedules.
Special Events Management	
Event patron incentives	Pre-event and postevent activities.
Bicyclist accommodation	Bicycle routes and available parking/lock-up.

Shared resources represent one of the potential major benefits of coordinated operations during special events. Through sharing resources, collaborating agencies can make available more information than they might individually provide. Since a major special event is likely to have a substantial spillover effect, shared resources are a win-win proposition.

4.5.6 Evaluation and Selection of Strategies

As discussed previously, the process of selecting the specific strategies is an iterative process involving assessment of the costs and the benefits of the various strategies as well as the stakeholder agencies' ability to implement the strategies. Each of the participating agencies must be comfortable with the strategies and be capable of implementing them.

The candidate lists of strategies must be evaluated from an institutional and financial basis. The following factors can be used to evaluate potential traveler information, traffic management and control, and shared information and resource strategies that can be used to be coordinate freeway/arterial roadways during special events:

- The time of the event.
- The duration of the event.
- Volume of traffic affected.
- Funding.
- ITS deployment that is available (existing or to be installed).

The strategies may also vary by time of day, reflecting both the volume of traffic on the freeway and the conditions on adjacent arterials.

Upon completion of this step of the process, a detailed understanding of what strategies are feasible and supported by the corridor agencies should be shared by all stakeholders. The next step is to package all of the strategies into a formal corridor implementation plan.

4.5.7 Corridor Implementation Plan

The corridor implementation plan is a product of the decisionmaking component of the CFA framework. It documents all the steps previously undertaken with sufficient detail to take the project or projects developed for improved corridor operations through to the implementation phase.

A full discussion of development and contents of a corridor implementation plan can be found in section 3.9 above.

4.5.8 Design and Development

The design effort is the first step of the implementation phase of the framework. It is vital because it transforms the corridor implementation plan *concepts* into projects that are able to implemented. The phrase "design and development" comprises many details of implementation including, if necessary, construction plans to build supporting infrastructure and the detailed procedures and agreements necessary to operate and maintain the operations plans.

The issues addressed in the design phase include performance requirements, functional requirements (what is trying to be accomplished), system architecture (how does the system work), identification and screening of technologies, and specification of technologies. All of these issues are addressed fully in section 3.10, and chapter 5 discusses the types of ITS technologies that can be used in CFA management in greater depth.

Table 11 presents an example checklist for elements to include in a corridor operations plan.

Table 11. Special event operations plan checklist.

Element	Provision
Freeway control plan	Specify maintenance and protection of traffic per the *Manual on Uniform Traffic Control Devices* (MUTCD) guidelines (e.g., location of traffic control equipment, equipment quantities, and safety signs). Indicate ramp control and capacity modifications. Highlight exclusive traffic flows (e.g., unimpeded merge, etc.). Dimension weaving area, acceleration/deceleration lane lengths, ramp length. Indicate potential bottleneck locations for surveillance monitoring.
Street control plan	Show closed road segments. Indicate directional lane control (e.g., alternative lane operations). Show one-way streets. Indicate number of ingress and egress lanes at each venue access point (e.g., parking areas, pickup/dropoff points). Show street use event route. Indicate parking restrictions. Indicate location of command post(s). Integrate with signing plan (e.g., show route trailblazer signs).
Intersection control plan	Specify maintenance and protection of traffic per MUTCD guidelines (e.g., location of traffic control equipment, equipment quantities, and safety signs). Show permitted pedestrian movements and crosswalk locations. Indicate approach lane designations and pavement markings. Indicate traffic control. Highlight exclusive/permitted traffic flows (indicate approach lane and corresponding receiving lane). State special regulations (e.g., turn prohibition, exclusive bus lane, resident/permit only movement). Show approach closures. Indicate parking restrictions. Indicate location of traffic control officers. Indicate location of equipment storage area at intersection.

Table 11. Special events operations plan checklist (continued).

Element	Provision
Signing plan	Show location of permanent/portable changeable message signs. Show location of permanent/portable HAR stations. Indicate CMS/HAR message sets. Default ingress and egress. Contingency scenarios. Show location of temporary static signs and message. Indicate location of dynamic blank-out signs.
Equipment location plan	State number of traffic cones, drums, and barricades required at designated locations. Indicate equipment staging areas (e.g., shoulder, median, intersection corner). Indicate location of equipment storage areas.
Other considerations	Provide plans for both ingress and egress operation. Indicate roadway construction zones. Include table of quantities. Show aerial map. Draw map to scale. Display landmarks.

Source: *Managing Travel for Planned Special Events*[25]

While strategies are funded and developed with the specific special event in mind, where possible, there should be some consideration given to the possibility of overlap, whereby the same strategies can be applied to applications such as incidents or work zone activities.

4.5.9 Deployment

The deployment phase includes all activities preparatory to deployment and the various activities necessary to execute the system as per the design.

The implementation process may involve both people and infrastructure. New staff may need to be hired and trained. As the complexity of the project increases, phasing and timing of the range of elements needs careful consideration so that the system components can be deployed and tested in a timely fashion. More information on this step is contained in section 3.11.

4.5.10 Operations and Maintenance

Because of their short duration, special events typically have fewer issues with operations and maintenance unless the event is recurring within an agency, in which case there needs to be someone responsible for coordination of the operations and maintenance of any strategies.

Special events are dynamic activities and often require adjustments to plans due to unforeseen events. Such unplanned occurrences may extend the duration of the special event, which will require adjustments in staff resources.

The potential for incidents during special events is significant. A quick response to incidents, even minor ones, will reduce motorist delay and help avoid secondary incidents. In addition, swift access to emergency services must be coordinated.

4.5.11 Continuous Improvement

Continuous improvement is a part of the overall process of the CFA Framework. The frequency of special events will influence the degree to which continuous improvement is effective. Ideally, the performance monitoring system provides desirable feedback on both the success of individual operations plans and the potential to improve future activities. Stakeholder meetings can be advantageous as a means of facilitating ongoing communications. At these meetings, stakeholders should discuss experiences with coordinated operations to refine existing operations.

4.6 Day-To-Day or Recurring Operations

Day-to-day or recurring operations generally refer to managing repeated congestion that occurs due to peak period volumes exceeding the available capacity of the roadway(s), creating recurring bottlenecks. The purpose of this section is to apply the CFA framework to day-to-day operations coordination in a corridor. The benefits of taking a corridorwide view of daily operations coordination include maximizing system performance and effectively minimizing the overall effect of congestion-causing factors on the transportation system within that corridor. The section will discuss identification of the types of day-to-day challenges encountered in a corridor and how to determine goals and strategies for dealing with them effectively. Upon completion of this section, the reader should have a good grasp of the factors involved in coordinating day-to-day operations within a corridor.

Coordination of day-to-day operations within a corridor to alleviate congestion involves an expanded view of operations that transcends jurisdictional boundaries or, in some cases, internal agency structures that commonly separate freeway operations from arterial operations. In many States, multiple agencies operate freeways and arterials. State DOTs typically own and maintain the freeway system, and city or county agencies are responsible for arterials. Through coordinated actions, the operation of these separate systems can be made more effective from a user perspective.

Many practices for managing day-to-day operations are well established and have been addressed in other documents such as the *Freeway Management and Operations Handbook*.[20] Some practices, such as coordinating the operation of ramp meters and nearby traffic signals, are still in the early stages of development.

The CFA framework provides the organizational structure for this section, and the following sections reflect the 11-step framework for developing the desired coordinated operations.

4.6.1 Problem Identification

The problem definition for recurring congestion is an issue of identifying bottlenecks and congestion hot spots. The following factors help define the day-to-day problems that should be addressed:

- Signalized arterials crossing jurisdictional boundaries.
- Interchanges with ramp meters and traffic signals that are not coordinated.
- Freeway and arterial traveler information systems that are not coordinated.
- Available resources that are not accessible to other agencies.

While day-to-day problems are typified by organizational seams, such as the separate groups responsible for arterial and freeway operations, there are also day-to-day problems caused by equipment malfunctions or fluctuations in traffic that have systemic effects beyond the immediate location of the problem.

In assessing current day-to-day practices from a corridor perspective, the following questions may help identify problems that are amenable to coordinated corridor management:

- Do agencies share information on operational problems?
- Are signals coordinated across agency boundaries?
- Are ramp meters and traffic signals coordinated?
- Are agency's practices such as Web-based traveler information redundant? Can coordinated operations free up resources?
- Are there opportunities for shared resources to improve operations?

4.6.2 Institutional Considerations

Day-to-day management involves multiple agencies and disciplines and therefore requires an appropriate structure with a clear delineation of roles and responsibilities to sustain the effort. The type of structure depends on the local circumstances and builds from existing relationships, if possible.

To advance a large project, such as a shared traffic management/operations center, from inception through implementation may require the organization of executive, steering, and operation committees that will need to be informed throughout the various stages of the project.

The key stakeholders that need to be involved in day-to-day operations fall into the following categories:

- State and local political leadership.
- Intra-agency personnel such as planning, design construction engineering, and public information staff.
- Interagency such as law enforcement and emergency management agencies, local public works and transit agencies.
- Managers of special event venues.
- Major employers and/or traffic generators.
- Media.

To mobilize these individuals and agencies into an effective CFA operations daily management program, a concerted effort is required to bring these individuals together in new ways. To achieve the desired outcomes, it is necessary to consider the legal and policy environment in which coordinated day-to-day management is carried out. Questions that may be helpful in determining this environment include:[19]

- What are the legal limits to day-to-day management that agency personnel can perform? (e.g., can one agency operate another agency's devices?)
- To what extent do real or perceived legal constrictions pose an obstacle to coordinated day-to-day management?
- What is the financial liability of agencies, agency personnel, and the public with respect to coordinated day-to-day operations management?
- Can or should statutes be changed to facilitate coordinated day-to-day management?

As part of the coalition building process, if a project to coordinate freeway arterial operations is going to succeed, champions must emerge or be identified. The champions are needed to guide the project from inception to completion and help navigate through the institutional challenges. In summary, this step of the process involves expanding the area of day-to-day operations management from an agency focus to a corridor focus. It takes operations management to the next level, a corridor management program, by either broadening existing relationships or establishing new institutional relationships.

4.6.3 Goals, Objectives, and Performance Measures

To gain consensus from stakeholders, goals, objectives and performance measures should be established for the plan that will be developed and implemented to provide better day-to-day coordination of freeways and arterials. Traffic management strategies need to address the following major goals:

- Improve traveler safety.
- Minimize traveler congestion.
- Improve travel reliability.

Once the goals have been established, specific objectives can be defined to reflect the various perspectives of participants. Table 12 is an example of specific objectives.

Table 12. Example objectives for day-to-day operations.

Goal	Objectives
Improve traveler safety	Reduce crash rates by X percent.
Minimize traveler congestion	Travel delay no greater than X percent. Alternative routes to not exceed design capacity.
Improve travel reliability	Maximum travel times through primary freeway corridor to not exceed X hours. Maximum travel times on arterial adjacent to freeway to not exceed X percent higher than the free-flow travel time.

4.6.4 Corridor Concept of Operations

The corridor concept of operations is a formal document that provides a high-level, user-oriented view of operations in a specific corridor. It is developed in part to help communicate this view to the other stakeholders and to solicit their feedback. The corridor concept of operations provides a description of the current system, operating practices and policies, and existing capabilities. It lays out the program concept, explains how the corridor system is expected to work once it is in operation, and identifies the responsibilities of the various stakeholders for making this happen. The goals, objectives, and performance measures of a proposed operation are also documented. The process of developing a concept of operations for a corridor should involve all stakeholders and serve to build consensus in defining the goals and objectives; provide an initial, definitive expression of how functions are performed, thereby supporting resource planning; and identify the interactions between organizations.

The day-to-day/recurring operations concept of operations needs to identify:

- The agencies involved.
- The monitoring and control systems involved.
- The interfaces involved.
- The control objectives to be achieved.

At this stage, the cooperating agencies address questions of what (not how) they would be willing to do regarding coordination of day-to-day activities in the corridor. The general strategies to be considered include:

- Traveler Information.
- Traffic management and control.
- Shared information and resources.

The development of a concept of operations allows the participating agencies to agree on what they wish to accomplish and to lay the framework for how that will be done. For example, are the agencies willing to agree to common cycle lengths in their adjacent signal systems? This is an example of an issue the agencies should resolve before moving to the more detailed level of discussion.

As part of the development of a concept of operations, consider the following points:

- Does stakeholder consensus exist to support coordinated day-to-day management?
- If stakeholder consensus must be established, who will be the champion and organize a workshop or forum to demonstrate the benefits?
- What is the level of stakeholder commitment of personnel and funding resources?
- What policy changes, if any, are needed to implement a coordinated day-to-day management program (such as legislation allowing shared operations)?
- What organizational structure will be established for the day-to-day management program?

The concept of operations document could include the following sections:

- Summary of the overall goals of day-to-day management.
- Description of the corridor and the stakeholders.
- Description of the high-level problematic issues.
- Description of types of strategies to be implemented.
- Identification of roles and responsibilities of stakeholders.
- Identification of polices and procedures that require modification.
- Estimate of capital and operating costs.
- Identification of schedule for planning, development, and implementation.

In essence, the concept of operations phase of planning involves the "who, what, when and where" of day-to-day management.

4.6.5 Refinement of Scenarios and Improvement Strategies

The concept of operations provided the high-level scenarios to be addressed and a general discussion of the types of strategies to be implemented to achieve agency support. Once the concept of operations is agreed to, the scenarios and potential strategies need to be refined. Specifically, on what segments of highway and under what conditions are strategies to be implemented?

The process of selecting scenarios for the concept of operations may be iterative, and the scenarios need to be developed into specific locations where strategies would be implemented. Strategies are specific actions to mitigate one of the scenarios associated with a particular traffic problem, which could vary by time of day. Therefore, several strategies may be required to achieve the desired improvement in system performance. For example, if strategies include running common cycle lengths across jurisdictions, the scenarios need to reflect what cycle lengths might be implemented during what times of the day. The agencies may chose to run common cycle lengths during the a.m. and p.m. peak periods, but run different strategies off-peak. Or, the analysis may conclude that because of the large number of traffic patterns experienced in the area, a more comprehensive approach involving an integrated traffic control system is necessary.

Specific examples of candidate strategies that individual agencies might consider to achieve improved corridor operation include:

- Coordinated traffic signal timing across jurisdictions.
- Development of a shared traffic signal control system.
- Coordination of ramp metering and traffic signal timing.
- Provision of transit priority across jurisdictional boundaries.
- Shared cameras to improve corridor operation.

At this point the high-level strategies—general ideas of how agencies can work together—are focused on specific segments of roadway. In the next step, the strategies are analyzed in more detail to understand practical issues such as costs and potential benefits. The current objective is to consider taking traditional strategies beyond agency boundaries to improve corridor operation. What is possible technically, and what is possible practically? The answers will depend on many local factors. The important point is to begin the dialogue among partners to determine what is possible. Table 13 is an example of the types of strategies that might be applied.

Table 13. Example strategies for day-to-day operations.

Category	Example Strategies
Traffic Management and Control	
Freeway management	Ramp closures. Ramp metering.
Arterial management	Lane control. Alternative lane operations. Road closures. Onstreet parking restrictions. Trailblazer signing. Parking management systems.
Intersection traffic control	Access and turn restrictions. Advance signing to improve traffic circulation. Traffic signal timing and coordination.
HOV incentives	Public transit service expansion. Express buses from park and ride lots. Charter bus service. Preferred parking. Reduced parking cost.
Traveler Information	
En route traveler information	Changeable message signs. HAR. Media. Static signing. Destination signing.
Pretrip traveler information	Internet. Telephone information systems. Public information campaign. Event and venue transportation guide. Media.

Table 13. Example strategies for day-to-day operations (continued).

Category	Example Strategies
Shared Information and Resources	
Incident response	Motorist service patrols. Wreckers. Portable DMSs.
Traffic surveillance	CCTV systems. Field observation. Aerial observation. Media reports. Portable traffic management systems.
Information systems	Incident reports. Construction activities. Special event schedules.

Shared resources represent one of the potential major benefits of coordinated operations. Through shared resources, the collaborating agencies can obtain more information and make available more information than they can individually. Since day-to-day congestion frequently has the largest ongoing impact on operations, shared resources is a win-win proposition.

The next section will discuss how strategies can be packaged to achieve day-to-day coordinated corridor management. The packaging is an iterative process of evaluating the potential benefits and the costs of implementing.

4.6.6 Evaluation and Selection of Strategies

A strategy may be perceived to be positive, but a more detailed analysis may show it to be counterproductive. During the process of selecting the specific strategies partners assess both the costs and the benefits of the strategies and the various agencies' ability to implement the strategies. A strategy may be technically feasible, but not selected because it is beyond the resources available or inconsistent with community values.

As the strategies are being considered, the following issues will ultimately have to be considered as the strategies are being evaluated:

- Roles, responsibilities, and procedures.
- Infrastructure operating and maintenance needs and costs.
- Implementation priorities and schedule.
- Updating process.

Each of the agencies must be comfortable with the strategies and be capable of implementation. The degree of sophistication of the strategies will depend on the current capabilities of the agencies and the degree to which the agencies desire to invest in technology and/or staffing to achieve better operations.

The evaluation of strategies may vary from qualitative to quantitative. Providing integrated traveler information may be evaluated qualitatively because the impacts are hard to assess and the potential for problems minimal. A strategy to upgrade traffic signal control systems will require extensive analysis to determine the costs and the benefits. In some cases, more sophisticated tools such as simulation models may be required to determine the feasibility and appropriateness of a strategy. Information on the benefits and costs of different strategies may be found on the FHWA Web site at: http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13772.html.

The analytic tools that can determine the impact of day-to-day traffic operations on roadways are too numerous to discuss in this document. However, information is available from the FHWA Office of Operations' Web site: http://www.ops.fhwa.dot.gov/trafficanalysistools/toolbox.htm.

In planning the day-to-day operations strategies, there are questions which should be considered, such as:

- What is the cost of various coordination efforts?
- What resources are available?

The process of strategies selection may be simple or complex depending upon the nature of the problem being addressed and the need for quantification of benefits. In many cases, the strategies will be more dependent upon consensus among the stakeholders than analytical analysis.

The candidate list of strategies is further evaluated from an institutional and financial basis. For example, while it might be desirable to upgrade the traffic signal system, the cost to implement may be prohibitive. An approach using existing equipment may be less flexible, but will nevertheless be beneficial.

The following factors can be used to evaluate potential traveler information, traffic management and control, and shared information and resource strategies that can be used for day-to-day coordination of freeway and arterial roadways:

- Capacity impacts.
- Volume of traffic affected.
- Funding.
- ITS deployment that is available (existing or to be installed).

Upon completion of this step, a detailed understanding of what strategies are feasible and supported by the corridor agencies shall be realized. The next step is to package all of the strategies in a corridor implementation plan, which is the formal document, which can be used to secure the funding necessary to advance the program to design.

4.6.7 Corridor Implementation Plan

The corridor implementation plan is the product of the decisionmaking component of the CFA operations framework. It documents all the steps previously undertaken with sufficient detail to take the project or projects developed for improved corridor operations to implementation. A full discussion of the corridor implementation plan and its contents can be found in section 3.9.

Some issues that need to be addressed in the corridor implementation plan for day-to-day operations include:

- Designation of responsibilities (who is allowed to change signal timing, close ramps, etc.).
- Initial funding and resources (agency personnel, consultant, and contractor) needed for design.
- Funding and responsibility for construction, if required.
- Responsibility and funding for operation and maintenance.
- Overall schedule for deployment projects.
- Evaluation criteria (performance measure).

4.6.8 Design and Development

The design step is the beginning of the implementation part of the framework, serving to transform the corridor implementation plan concepts into projects that are able to be implemented. A full discussion of this topic can be found above in section 3.10.

The next step is packaging the strategies into an operations plan. An example of packaging various strategies into an operations plan was shown previously in figure 16.

4.6.9 Implementation

The deployment phase includes activities in preparation for implementation and the various steps necessary to implement the system designed in the previous step. A comprehensive discussion of the implementation phase can be found in section 3.11.

4.6.10 Operations and Maintenance

Operations and maintenance are often overlooked with serious negative consequences. Without ongoing support for a project, its potential will not be achieved. Operations and maintenance must become a part of the routine operation of the agencies. In addition, someone may need to be designated to handle the coordination of the unique requirements of shared operations and management of the corridor.

Within an agency, there needs to be someone responsible for coordination of the operations and maintenance of any mitigation strategies. Where possible, the champion should encourage consideration of incorporating this activity as part of an existing TMC or operation.

4.6.11 Continuous Improvement

Continuous improvement should be well-integrated into the overall process. Ideally the performance monitoring system provides feedback on both the success of individual operations plans and the need for other actions. In addition, regular stakeholders meetings would be advantageous as a means of facilitating ongoing communications. At these meetings, stakeholders discuss experiences with coordinated operations in order to refine existing operations. It would also be desirable to meet annually to broadly review the program and overall operations plans.

The best means of determining the effectiveness of the day-to-day corridor management program is to establish a performance monitoring system. A number of resources are available from FHWA (http://www.ops.fhwa.dot.gov/perf_measurement/index.htm). By continually monitoring performance, problems are more easily identified.

4.7 Summary

This chapter has demonstrated how the CFA operations framework can be applied to incidents, work zones, special events, and day-to-day operations. As a result of this discussion, the reader should recognize that taking a corridor perspective through the framework presented can improve freeway and arterial operations under various congestion-causing problems. The next chapter discusses supporting technologies and ITS elements.

5 SUPPORTING TECHNOLOGIES AND ITS ELEMENTS

5.1 Purpose

This chapter provides an overview of the categorical technologies needed to share information in a timely manner and coordinate freeway and arterial operations. In no way is this chapter a definitive thesis on the issue of ITS technologies. At best it is a sampling of what is a needed and dynamic aspect of traffic control for corridor management. In many respects, coordinating traffic operations on a corridor is the embodiment of the ITS philosophy, which is "to enhance existing transportation systems operations through the application of new and emerging methods and technologies."[26] Upon completion of this chapter, the reader should have a basic understanding of the electronic infrastructure and system interfaces that are available to support the proactive management of travel within a freeway corridor. In essence, the reader will learn about the technology that supports the goals of CFA operations. But technology must not only support better operations, it must also be cost effective. Technology assessment should therefore drive the needs of the application(s).

5.2 Introduction

CFA is about process and technology. The process for coordinating freeway and arterial operations described in chapters 3 and 4, set the stage for coordinated operations such that regional stakeholders might optimize vehicular throughput associated with incidents, work zones, special events, and day-to-day operations. This chapter describes some of the software and hardware tools available to permit CFA operations. The concepts of ITS promote new methods and devices, making technology more transitional than the process. Therefore it is hoped that the reader will look beyond the methods and devices currently used in their particular region. As discussed in section 5.4.1.1, advanced sensor technology integrated with CCTV surveillance and new approaches to their use offer considerable advantages in timely recognition of traffic incidents and the variable nature of traffic volumes.

5.3 Information Sharing

This document places considerable emphasis upon interagency cooperation and communication and thinking in terms of region and corridor instead of agency or municipality. One of the essential outputs of a cooperative working agreement is sharing information. While the purpose of this chapter is to present technology enhancements for sharing information, consider one relatively low-tech device: the telephone, provides a very high level of information sharing. With only a telephone, agencies can take the first step toward corridor management operations if the proper planning, as described throughout this document, has taken place. But sharing information is not enough. Sharing information must lead to effective cooperation in the context of corridorwide thinking and action. The corridor must be treated as a dynamic, interconnected system.

Sharing information must lead to effective cooperation in the context of corridorwide thinking and action. The corridor must be treated as a dynamic, interconnected system.

The direct communication between different agencies and municipalities sharing historic traffic count information, growth trends, accident data, upcoming work zone repairs, etc., is the “ice-breaker” for more sophisticated data sharing. Human interaction, trust, and mutual benefit are the underpinning of even the most sophisticated electronic data-sharing network.

On both freeways and arterials, means of collecting data to facilitate coordinated operations may already be in place. Detection and surveillance, for example, are often part of many freeway and arterial control systems. While such systems are intended to serve the agency and the facility upon which they were installed, they can, with little modification, be interconnected for purposes of information sharing. The objective of using technology in a CFA environment is to gain real-time information that can be acted upon so that incidents and activities in the dynamic traffic stream are altered or corrected before they become major problems.

Figure 19 shows the three principal parts of the logical system that drives successful coordination:

- Travelers (users).
- Freeway systems.
- Arterial systems.

Coordination is about sharing data or information that is useful to others, as demonstrated in figure 19. This is important because in many States, multiple agencies operate freeways and arterials. State DOTs typically own and maintain the freeway system and some major arterials, and city or county agencies are responsible for most arterials and some secondary arterial roads. Through coordinated actions, the operation of these separate systems can be made more useful from a user perspective. To achieve this result, information needs to be shared effectively. Data collection and sharing can be accomplished through a variety of ITS technologies.

Travelers can get information on arterial and freeway traffic conditions through a variety of means, many of which they already rely upon. DMSs, HAR, and radio traffic reports can all be used to advise drivers of conditions as they travel. Pretrip information can be made available via the Internet or by phone. Automated systems can also be tied to in-vehicle navigation units to provide dynamic route guidance.

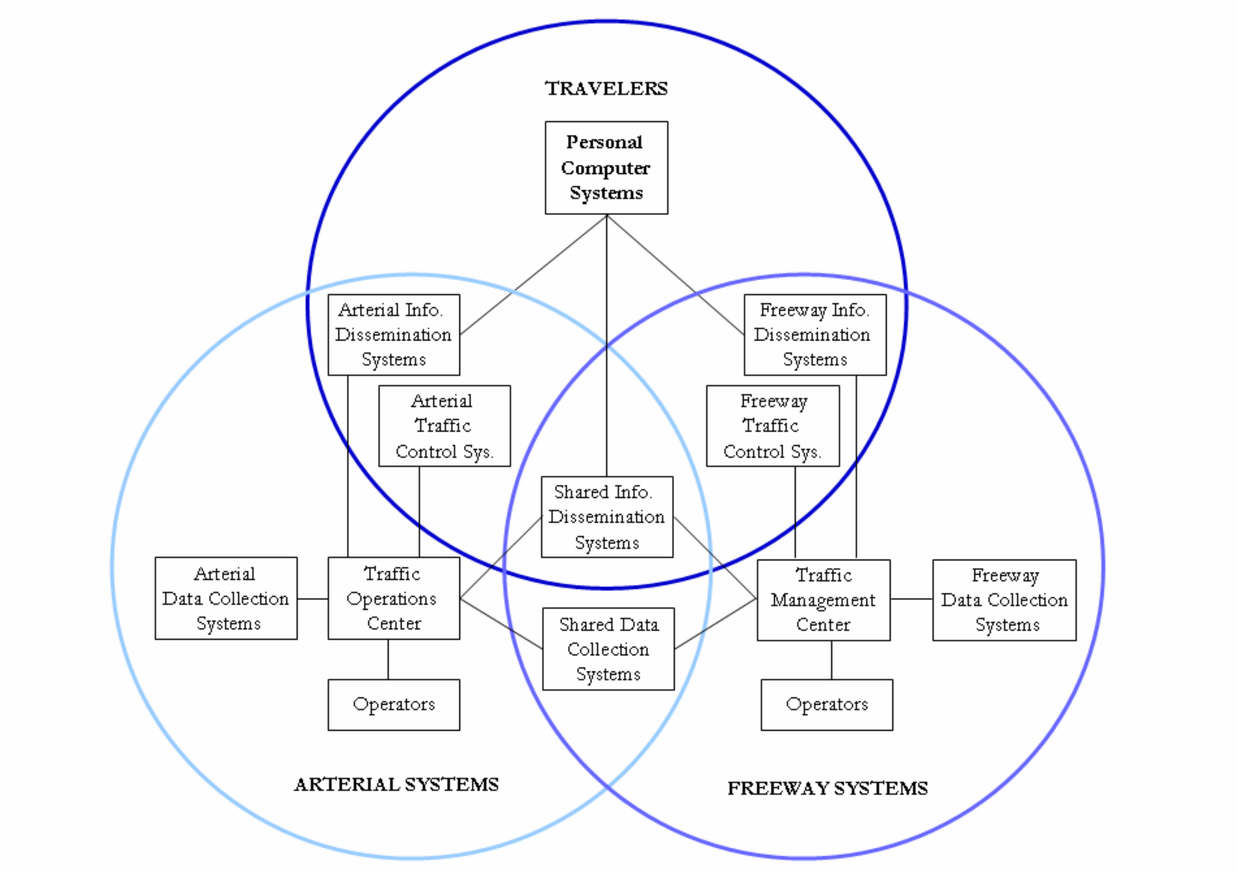


Figure 19. Chart. Traveler interface with technology systems.

5.4 Technology and ITS Elements

Technology plays a role in any CFA plan. The level of ITS deployment on a region's freeways and arterials is not the main driver in developing CFA solutions. What is more likely to drive the CFA process is whether the solution is dependent upon the existence of an already-deployed technology or is only enhanced by that particular technology. As an example, route diversion strategies based upon daily peak period traffic flows can be developed with historical traffic data alone. Such a strategy could be significantly enhanced by real-time data from an array of sensors and surveillance cameras but the strategy deployment is not wholly dependant upon the technology. Conversely, incident management strategies that require immediate identification and verification of incidents at critical links in the roadway system, e.g., bridges, tunnels, and high security locations, will require technologies to be deployed for the solution to work. ITS elements that may support CFA operations can be grouped as follows:

- Traffic data collection systems.
- Traffic control systems.
- Information dissemination systems.
- Communications networks and systems.
- Data analysis systems.

The following sections describe these infrastructure elements and their role in CFA deployment. The appendix details a recommended procedure for the actual performance of such an inventory.

5.4.1 Traffic Data Collection Systems

The primary source of traffic flow information is the traffic sensor; however, several additional data collection systems have been developed primarily for ITS applications. These data collection systems can be used to gather traffic information on both freeways and arterials. There are several different types of data collection systems of varying age and capability already in place in any urban (and increasingly suburban and rural) setting. Examples of traffic data collection systems include the following five areas:

1. Traffic sampling sensors.
2. Motorist call-in systems.
3. Automated Vehicle Location Systems.
4. Surveillance cameras.
5. Road weather information systems.

5.4.1.1 Traffic Sampling Sensors

Traffic sensor (detector) is an all-encompassing term for the generic device used by the traffic engineering community to measure traffic flow. Traffic sensors play a primary role in CFA data sharing and in CFA-shared operations. As previously noted, a variety of technologies can do much the same thing: namely, detect traffic. Some technologies require pavement intrusion, and some are mounted overhead. The real difference in sensors lies in their capabilities. There are only two kinds of traffic sensors: the static or, more commonly, point measurement, and the dynamic sensor, measuring flow characteristics. This important distinction is misunderstood or ignored by many even in the transportation community. Sensors of one type or another are essential to virtually every CFA solution involving traffic monitoring and control on freeways and arterials.

Some examples of existing detector technology commonly found in freeway and arterial traffic control applications include:

- In-pavement wire magnetic induction (loop detector).
- In-pavement magnetometers.
- Microwave/radar.
- Acoustic.
- Laser.
- Digital Image (CCTV).

Traffic sensors can be as simple as point measurement detectors (loops) or as sophisticated as dynamic vehicle tracking sensors that are capable of measuring multiple traffic parameters of an individual vehicle or a collective group (vehicle queue) within a traffic stream. Depending on the detector type deployed, the detector can potentially measure the following traffic parameters:

- Speed.
- Acceleration and deceleration).
- Traveltime.
- Vehicle location.
- Volume.
- Stopped time (arterials).
- Vehicle classification.
- Occupancy.
- Queuing.
- Stopped Vehicles.
- Density.

FHWA has been promoting the development of more advanced traffic sensors since the mid-1970s. By the mid-1980s, digital image sensors based on CCTV that could track individual and collective groups of vehicles in a traffic stream were being developed.

The availability of cheap, robust CCTV equipment has allowed sensors based on this technology to be cost competitive with other sensor technologies. The sensor itself is simply software and therefore can be located anywhere the electronic CCTV image is available, such as a TMC. More information on traffic sensors is available in the FHWA *Traffic Detector Handbook*.[(27)]

5.4.1.2 Motorist Call-In Systems

For many years motorist call-in boxes have been placed along freeways primarily to aid stranded motorists. Over the past decade newer and more reliable technologies have assumed the role for most of the call-in boxes. Often the technology replacing the call-in box does not have as its primary mission "helping stranded motorists." Cell phones are an obvious example of a technology that assists a stranded motorist in securing assistance. Such new technologies often bring additional and better ways for transportation officials to monitor and control traffic. As the population of cell phones with motorists in the traffic has increased, so has the reliability of anonymous signal tracking to monitor general route traffic flow parameters. Live calls from motorist in the vicinity of an incident or reporting traffic congestion have increasingly proven reliable tools as the number of cell users increases.

5.4.1.3 Automated Vehicle Location

There are a variety of reasons why it is important to determine the whereabouts of a particular vehicle. One of the obvious needs is tracking explosives, toxic chemicals, and hazardous nuclear waste to insure public safety. Specific duty-cycle-vehicle fleets such as transit buses, emergency vehicles, and delivery vehicles operations also benefit from knowing the specific location of fleet vehicles. At present, several technologies permit such tracking; e.g., global position systems (GPS) and radio transponders. The ease, cost effectiveness, and multiple uses of GPS suggest that this technology will continue to become pervasive in many and varied fleet monitoring operations. Using the tracking points of fleet vehicles immersed in the traffic stream permits real-time monitoring of traffic system conditions. While this would not be the only means of monitoring a CFA solution, it serves as a powerful overview of the systemic situation.

5.4.1.4 Surveillance Cameras

Today, surveillance cameras and CCTV systems are reliable and cost effective. They provide transportation systems operators with a live visual image of traffic conditions and to some extent weather conditions. Surveillance cameras have been used in security systems for several decades and increasingly, in the past decade, for remote infrastructure monitoring. The digital image of surveillance cameras serves as the input for most advanced dynamic sensors. Therefore, a single technology deployed along the roadside can serve as a visual monitor of traffic conditions and the digital source to measure the dynamics of the traffic stream. Such a dual capability can be an essential component in several CFA solutions.

5.4.1.5 Road Weather Information Systems (RWIS)

Weather conditions can be a major factor in the performance of the traffic stream. In some situations however, weather is a critical component of safe traffic stream performance. A variety of weather reporting stations have been deployed for many years in locations where changing conditions are a significant hazard to public safety. One of the earliest systems was installed along the New Jersey Turnpike to detect the presence of rapid fog formation. Using variable message signs and variable speed limit signs motorists are informed and directed when conditions warranted. The concepts of RWIS has expanded as a result of ITS awareness, and deployments now include a variety of sensors and pavement monitoring systems permitting system operators to gauge the need for roadway salting and snow plowing ahead of actual icing conditions on the pavement surface. The AZTech system mentioned earlier in this document employs an RWIS to monitor for wind conditions and dust storms. A variety of CFA strategies might be predicated on weather-related conditions.

Some of the data collected by RWIS may include the following road-weather related information:

- Pavement temperature.
- Humidity.
- Wind speed.
- Air temperature.
- Pavement moisture.
- Precipitation.

Transportation department dispatchers can use this information, for example, to anticipate the occurrence of icing on roadways and bridges and in turn, dispatch road crews to place de-icing chemicals.

5.4.2 Traffic Control Systems

Examples of traffic control systems commonly used on freeways include:

- Ramp meters.
- DMSs.
- Reversible lane/HOV lane/express lane systems.
- Lane controller signals.

- Dynamic speed control.
- Lane restriction by vehicle classification.

Ramp metering systems are typically controlled locally with ramp detector data inputs and a central system connection for manual overrides and turning the system on or off. More robust systems employ algorithms with freeway mainline and arterial detector data inputs to optimize traffic on all systems and achieve appropriate impacts on the arterials and freeways.

Freeway lane controllers typically use a green down arrow above a lane to indicate the lane is open and a red X above a lane to indicate a closed lane. Lane controllers can be used on freeways to indicate that a lane is closed ahead, often due to construction or an incident. Freeways that allow vehicles to travel on the shoulder during peak periods often use lane controllers to indicate that the shoulder is clear for use, which enables operators to immediately close the lane with a red X if the shoulder becomes blocked.

Lane controllers are also used on reversible lane freeway systems to guide motorists. Reversible lane freeway systems (i.e., express lanes) are often located in the middle of a freeway with limited entrance and egress points, and they are sometimes dedicated to HOV access only. Reversible lanes are often used on bridges as well to manage directional traffic flow. Reversible lane systems on freeways are most often controlled manually for safety purposes to ensure that the facility is free of vehicles prior to reversing the lane(s) direction. Most agencies follow a standard peak hour schedule for reversing the travel lanes, but implement schedule changes to accommodate traffic from special events, construction, and even major incidents.

Examples of traffic control systems commonly used on arterials include:

- Intersection traffic signals.
- Interconnected traffic control systems.
- Lane controller signals.
- Reversible lane/HOV lane systems.

Although traffic signal control systems are mostly or fully automated, their means of control vary from time-of-day control to actuated control to traffic adaptive control systems. Connection to a central control facility enables operator awareness of traffic conditions. It also enables traffic management while allowing the operator to interrupt system control and manually override traffic signal systems to improve operations if it becomes necessary to respond to the effects of special events traffic, construction, and incidents.

Lane controllers and reversible lane systems on arterials are used and operated in a similar fashion to freeway reversible lane operations. However, arterials typically do not have separated facilities for reversible lanes. This enables use of automation to control the systems because motorists can merge into adjacent nonreversible lanes when the lane controllers switch lane operations.

5.4.3 Information Dissemination Systems

All pretrip information dissemination systems require the general public to perform an action to obtain traveler information. Pretrip information dissemination systems include:

- Traffic radio.
- Internet.
- 511 telephone traveler information service.

The only en route information dissemination systems which do not require motorist action to obtain traffic information are DMSs and static signs with flashing beacons. DMSs allow operators to disseminate any information to the traveling public, although it is limited by the amount of time drivers have to read the information. The static sign with flashing beacon implementation is limited to only providing one static message to motorists of a condition, such as "Traffic Congestion Ahead When Flashing."

En route systems may include:

- Traffic radio.
- HAR.
- 511 telephone traveler information service.
- Personal devices.
- DMSs.

All of the pretrip and en route information dissemination systems can be used to inform motorists of travel conditions on both freeways and arterials.

5.4.4 Communications Networks and Systems

ITS infrastructures rely heavily on communications networks. Hard wire and/or wireless networks are necessary for all CFA operations applications; they typically employ a transmitter at the device end and receiver at a communications hub or control center to enable communications between and among field and control center systems.

The final ITS infrastructure element is communications systems, which include systems that enable communications between centers. In fully integrated systems, the communication system might make use of control center software and communications networks to:

- Enable all stakeholders to view any information that may be pertinent to their operations.
- Alert the appropriate stakeholders of incidents within their jurisdictions and/or incidents that may affect operations within their jurisdictions.
- Operate their own traffic control systems and field devices owned by other agencies in accordance with the restrictions allowed by the system.

Distributed control centers without system integration may make use of common communications means, such as telephones and the Internet, for transmitting information between stakeholders. Communications systems enable CFA operations agencies and their systems.

5.4.5 Data Analysis Systems

Traffic data analysis systems most often reside on central system software at a traffic control center, but they can also reside locally in a field cabinet with software residing on a processor or controller. Data analysis systems for freeways are considerably different from those for arterials. Although the concepts may be the same, the data analysis systems are different because of the differences in arterial and freeway operations and traffic patterns.

Data analysis systems can be categorized as one of the following:

- Systems that analyze outputs from traffic data collection systems for inputs to traffic control systems.
- Systems that analyze outputs from traffic data collection systems to alert control center operators to a traffic condition.
- Systems that analyze outputs from traffic data collection systems to create an input to information dissemination systems.

Data analysis systems typically become more robust as the number of data elements analyzed increases, whether the increase is in the type of data elements or the number of data elements.

Examples of data analysis systems include:

- **Incident detection algorithms**—control center software modules that analyze detector data outputs and alert operators of traffic conditions that are indicative of an incident.
- **Parking management systems**—use detector data output as input to local or control center software to either determine the number of remaining available parking spaces or simply determine whether the parking lot is full, with a system output to information dissemination devices of parking availability.
- **Ramp metering control systems**—can apply local or central data analysis and control and provide varying levels of data analysis ranging from a low-technology system that only analyzes ramp detector input to locally control the ramp meter all the way up to a robust system that analyzes ramp detector data, upstream and downstream freeway mainline detector data, and arterial detector data with control center software that controls ramp meters to optimize freeway and arterial operations.
- **Traveltime computation and analysis systems**—select the appropriate inputs to information dissemination systems, such as DMSs, Internet traffic flow maps, and automated traveltime information on 511 telephone information service systems.

5.4.6 ITS Architecture and Standards

The National ITS Architecture provides a common framework for planning, defining, and integrating ITS. It reflects the contributions of a broad cross-section of the ITS community (transportation practitioners, systems engineers, system developers, technology specialists, consultants, etc.). The architecture defines:

- The functions (e.g., gather traffic information or request a route) that are required for ITS
- The physical entities or subsystems where these functions reside (e.g., the field or the vehicle).
- The information flows and data flows that connect these functions and physical subsystems together into an integrated system.

Each State and MPO is required to develop its own ITS architecture modeled on the National ITS Architecture in order to participate fully and effectively in the program and be eligible for Federal funding. More information on developing an ITS architecture can be found at http://www.ops.fhwa.dot.gov/its_arch_imp/index.htm.

From its inception in 1996 to the present, the ITS Standards Program am has had a primary focus on the development of *open, nonproprietary* communication standards and protocols that facilitate the integration of ITS devices and networks. To accomplish this challenging mission, the ITS Standards Program collaborates with seven national standard development organizations to coordinate and accelerate the development of ITS standards. Collaborating allows the ITS Standards Program to tap into existing standards development processes, thus eliminating the need to create new procedures. Collaborating also facilitates the engagement of industry experts who help inform the technical discussion of volunteer committees, of consultants who capture the working group's intent when writing the standard, and of public sector transportation professionals who bring an invaluable perspective on real-world ITS implementations.

The ITS standards are used at the intersection between both similar and different types of ITS devices and components. The standards define how the components exchange information and work together to deliver the user services desired by State and local agencies from their defined systems.

The evaluation found that standards allow the "interconnections" to be open to all of the elements — open to any device, vehicle, center, or traveler to connect to and receive or transmit data to any other element in the system. Standards also define how the data is formatted so they are unambiguously recognized by all the other elements in the system. More information about ITS standards can be found at http://www.standards.its.dot.gov/default.asp.

5.5 Summary

CFA operations require some element of each categorical technology described in this chapter. In the most basic systems, data input can be as simple as a police officer's observation of a traffic blocking incident or as sophisticated and dynamic as an array of roadway sensors monitoring all traffic parameters and immediately noting any anomaly to a TMC. As well, the most basic way to get a message to the motorist is through simple posted signs. Enhancing simple, basic signs are technologies such as HAR, DMS, and GPS navigation systems. In developing and deploying technology elements associated with CFA, several main points should be considered:

- Technology needs should be chosen through consensus of the stakeholders.
- Technology needs should be driven by specific CFA strategies chosen through the 11-step CFA framework.
- Operations and maintenance needs of new technologies must be considered.

The key element in the CFA process is information sharing. The modifier is timeliness, or how quickly the information needed to make a decision. The need for speed will dictate how much and what type of technology is necessary to optimize traffic flow on the corridor in question. The next chapter provides examples of CFA operations.

6 EXAMPLES OF CFA OPERATIONS

In certain respects this last chapter takes the reader back to the beginning of this document because its focus is to reaffirm the benefits of a corridor mindset of looking at transportation issues. The chapter presents two very different examples of CFA operations. The first example showcases a real-world application of the CFA operations framework. The second example uses a hypothetical major incident and the resulting operations both with and without CFA strategies in place.

6.1 Example 1: Developing Incident Management Route Diversion Strategies in Northern Virginia

The following example focuses on the planning and analysis required to develop relatively simple, low-tech coordination between freeway and arterial operations in a heavily traveled suburban area. The example is based in Springfield, VA, a suburb of Washington, DC. In this case, many of the institutional issues are less complex than typical coordinated operations given that the same agency, the Virginia Department of Transportation (VDOT), is responsible for freeway and arterial operations in this area. This example uses the CFA operations framework detailed in chapter 3.

6.1.1 Problem Identification

In the heavily congested Northern Virginia region, VDOT is responsible for operating the vast majority of roadways. The agency operates a freeway management system, the Northern Virginia Smart Traffic Center (NVSTC) and an arterial signal control system, the Northern Virginia Smart Traffic Signal Systems (NVSTSS). While each system is well suited to manage traffic on their respective portions of the surface transportation network, there is little technical integration between them. A key way that VDOT has worked to integrate freeway and arterial operations in the region is to use the NVSTSS to select appropriate timing plans to best accommodate diverting freeway traffic when alerted by the NVSTC. To date, however, VDOT generally selects an existing timing plan (i.e., a.m. peak, p.m. peak, off-peak) as opposed to a plan specifically designed to accommodate diverting freeway traffic. Despite this practice, VDOT traffic engineers expected that improved integrated operations can be realized by developing timing plans better tailored for diversion.

To address this problem, VDOT selected a particular freeway/arterial diversion that is among the most frequently used in the region for a case study. This diversion is designed to accommodate southbound I–95 traffic in the vicinity of the Springfield Interchange (known as the “Mixing Bowl”) where I–95, I–395 and I–495 meet in Fairfax County, VA. As seen in figure 20, southbound South Van Dorn Street to westbound Franconia Road comprise VDOT’s designated incident diversion route in case of freeway lane(s) closure due to traffic incident, construction, or special event.

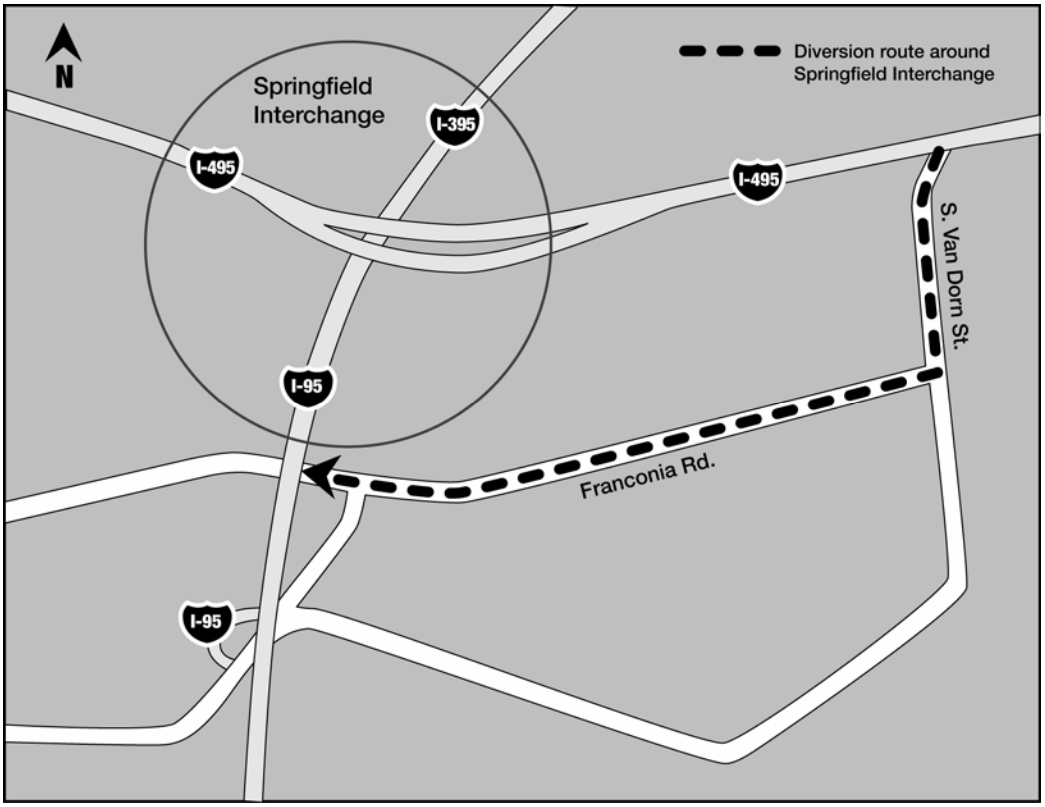


Figure 20. Drawing. Map of project area (black arrow shows the forward direction of diversion route.)

The route is approximately 4.0 km (2.5 mi) long. Traffic signal controls along the diversion route are not coordinated as a single system. The four traffic controllers on the Van Dorn Street are coordinated and are within one zone. The signal controller at the Van Dorn Street and Franconia Road is uncoordinated. The first four traffic controllers on the Franconia Roads along the diversion routes are coordinated and belong to a separate zone. The remaining controllers are also coordinated but are in a different zone.

The problem identified by VDOT engineers is to develop the best timing plans for use on arterials when freeway diversion occurs, making the best use of resources afforded by the NVSTC and NVSTSS.

6.1.2 Institutional Considerations

In this scenario, both the arterial and freeway systems are operated by VDOT. This greatly simplifies the challenge of coalition building. For many years, VDOT has worked to break down artificial barriers between different operating units of the organization. For example, the managers of the NVSTC and NVSTSS both report to the same individual within the agency. However, beyond organizational structure, the key aspect to coalition building is a commitment to continued communication between operators of the NVSTC and NVSTSS.

6.1.3 Goals, Objectives, and Performance Measures

There are multiple, and often conflicting, goals associated with this form of freeway and arterial coordinated operations. The goals are as follows:

- To maximize throughput of diverting vehicles.
- To minimize traveltime of diverting vehicles.
- To minimize delay for motorists in the diversion zone system.

Clearly, these goals are conflicting. As one gives more and more green time to the diversion movement, side street traffic suffers greater with each delay. Careful attention to the balance of these goals was important to VDOT in considering this form of integrated operations.

Performance measures selected to measure achievement of the goals and objectives were simply traveltime and throughput.

6.1.4 Corridor Concept of Operations

The concept of operations needs to identify:

- The agencies involved.
- The monitoring and control systems involved.
- The interfaces involved.
- The control objectives to be achieved.

The existing freeway (NVSTC) and arterial (NVSTSS) management systems are to be used in a coordinated manner to affect a freeway diversion route in response to freeway congestion. The system to be used is basically a low-tech implementation of a specific diversion route, and optimizing the system for the diversion. It primarily involves improved traffic signal timings.

The proposed strategy is totally on the State highway system, minimizing the need for stakeholder consensus building. The amount of resources required to develop, operate, and maintain is minimal. No policy changes are required.

As part of the development of a concept of operations, the following points were considered:

- Does stakeholder consensus exist to support coordinated day-to-day management?
- If stakeholder consensus must be established, who will be the champion and organize a workshop or forum to demonstrate the benefits?
- What is the level of stakeholder commitment of personnel and funding resources?
- What policy changes, if any, are needed to implement a coordinated day-to-day management program (such as legislation allowing shared operations)?
- What organizational structure will be established for the day-to-day management program?

6.1.5 Corridor Scenarios and Operations Strategies

Alternatives that VDOT is considering to address this problem include both new timing strategies and modest geometric changes. In addition, new designs must be compared to the current operations strategy to assess if they result in significant improvements that warrant full development.

First, it is important to describe the capabilities provided by the NVSTSS. The system controls more than 1,000 signalized intersections in the region using a centralized, computer-based traffic signal control system. The system allows traffic signal operators to monitor traffic flows at intersections through a graphical user interface, to update signal timing plans in real time, and to maintain a database of signal timing plans and traffic data. Thus, the system will fully support the development of customized timing plans to dynamically activate when freeway to arterial diversion is necessary.

Currently, when a major crash occurs on a freeway, the NVSTC relays the location and severity of the crash to an NVSTSS operator. Then, the NVSTSS operator checks traffic conditions along the diversion route and updates signal timing plan accordingly. The current practice is to use the peak timing plan corresponding to the direction of the diversion. In the Van Dorn/Franconia diversion considered in this case study, the p.m. peak timing plan is implemented.

The primary alternative considered is a signal-timing plan optimized to accommodate diverting traffic flow. In this case, all 10 intersections of the diversion route are coordinated. The next section will detail the approach used to design this plan. In addition, based on experience and field inspection, a simple geometric change was considered as an alternative. Currently, the I–495 exit to the diversion route (southbound Van Dorn Street) consists of three lanes (one exclusive left turn, one exclusive right turn and one left and right turn shared lanes). An alternative was to modify this facility to include one exclusive left turn lane and two exclusive right turn lanes to better accommodate diversion.

Combining the issues discussed above results in three alternatives for consideration:

- Alternative 1: the p.m. peak period signal timing plan (a ‘do nothing’ alternative).
- Alternative 2: the diversion optimized signal-timing plan without I–495 exit changes.
- Alternative 3: the diversion optimized signal-timing plan with I–495 exit changes.

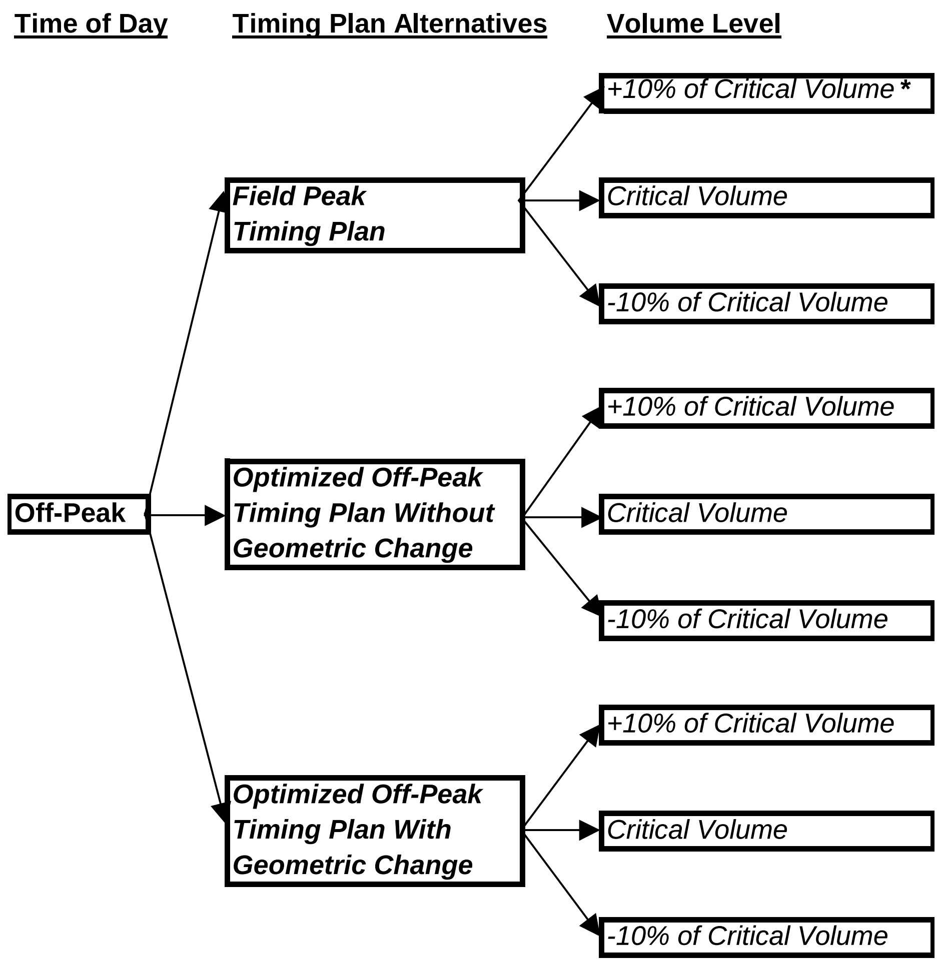
6.1.6 Evaluation and Selection of Strategies

The scenarios considered were weekday off-peak period and p.m. peak period. These were chosen to examine diversion during already congested conditions (p.m. peak) when it is likely that little excess demand from the freeway can be serviced by the arterials and during uncongested conditions (off-peak) when it is expected that arterial diversion is more feasible.

The “base” projected diversion volume is assumed to be the additional volume resulting in a volume to capacity ratio of 0.95 at the critical intersection (in this case, the intersection of the I–495 exit and Van Dorn Street). Based on this definition, the base diversion volume that could be accommodated during off-peak was 1,670 vehicles/hour, and 100 vehicles/hour during p.m. peak conditions. Immediately, one will see that this clearly illustrates that very little benefit can be realized from diversion during the p.m. peak, given the already congested conditions of the arterial diversion route. However, this illustrates the potential benefits of using the route during off-peak.

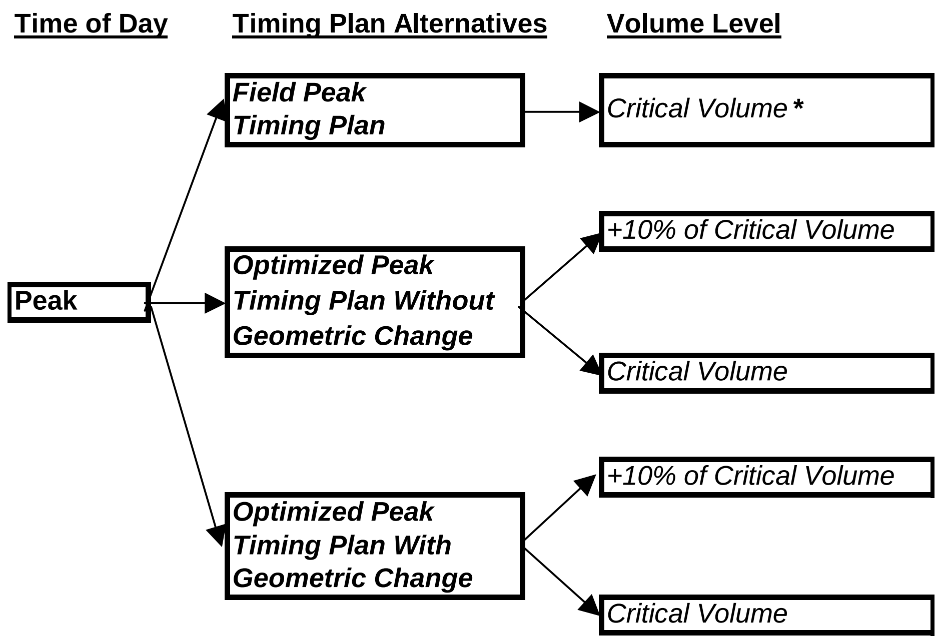
To investigate the sensitivity of the alternatives to variations in diversion demand, the evaluation was conducted at the projected diversion volume, and at levels 10 percent greater and less. However, given that the projected additional feasible diversion demand is so low during the p.m. peak, the negative 10 percent scenario was not considered.

All the alternatives for the weekday off-peak period are illustrated in figure 21 and all the alternatives for the p.m. peak period are illustrated in figure 22.



*** *Critical Volume* is the critical intersection's critical movement's demand at the volume to capacity ratio 0.95.**

Figure 21. Chart. Off-peak strategy alternatives.



*** *Critical Volume* is the critical intersection's critical movement's demand at the volume to capacity ratio 0.95.**

Figure 22. Chart. Peak strategy alternatives.

The design and evaluation process required the collection of large amounts of data and careful attention to model calibration. While it does require significant staff or consultant resources, the process results in a design that is well understood before field implementation. The process involved to develop and evaluate the alternatives can be categorized into three major tasks:

- Acquiring and manipulating field data.
- Developing timing plans using a traffic signal optimization software program.
- Evaluating performance using a traffic micro-simulation software program.

The results of the simulation testing are categorized as follows:

- The "forward" direction of the diversion route (i.e., the experience encountered by diverting motorists).
- The reverse direction of the diversion route.
- The side street traffic (i.e., all other motorists in the system).

The average traveltime was plotted against the cumulative throughput for each alternative. It revealed that a customized timing plan for diverting traffic is warranted during off-peak conditions only in the forward direction of the diversion route.

The three alternatives were analyzed in the forward direction of the diversion routes during the weekday off-peak period at critical volume condition and revealed the following:

- An optimized timing plan during congested conditions will do little to improve diversion performance.
- A customized diversion-timing plan without changing geometry is the preferred alternative in terms of traveltime savings and delay reduction.
- Although the throughput is slightly higher if the geometric change is in place, the average traveltime and delay are higher also.
- The average traveltime for the alternative 1 is highest while the alternatives 2 and 3 are comparable.

The three alternatives were analyzed in the forward direction of the diversion routes during the p.m. peak period at critical volume condition and revealed the following:

- The current design, use of the p.m. peak period timing plan, is a less attractive alternative with a greater average traveltime corresponding to a lower throughput of vehicles.
- As may be expected, the reverse and side streets performance are better using the p.m. peak timing plan, but the values for the reverse direction are comparable.
- In effect, diversion exacerbates the overall traffic more than helping during the p.m. peak period.

The analysis showed that alternative 3 works the best during the p.m. peak period. The throughput of alternative 2 compared to alternative 1 is 44 more vehicles at a traveltime saving of 7 seconds and 5 seconds less delay. Thus the optimized timing plan with or without geometric change is not much better than the p.m. peak timing plan. Again the field p.m. peak timing plan provides a more favorable performance measure for the reverse and side streets. The analysis showed that diversion during the p.m. peak should be avoided, as almost no relief to freeway traffic will be provided while increasing arterial delay.

6.1.7 Corridor Implementation Plan

The corridor implementation plan for this particular scenario is simple: incorporate the newly developed diversion optimized timing plan into the centralized signal control system, and then train operators to use it during off-peak periods.

A longer range corridor implementation plan that VDOT expects to develop after this project is to analyze all freeway diversion routes and develop optimized timing plans to improve this form of freeway and arterial integration.

6.1.8 Design and Development

The design of the preferred alternative, a custom diversion-timing plan for use during off-peak periods, is essentially complete following the signal timing optimization analysis. This can be implemented within the centralized signal control system.

Based on the results of the evaluation, a design modifying lane-use restriction at the intersection of the I–495 exit and Van Dorn Street is not warranted. The small level of benefits seen in some scenarios simply does not call for the effort required to design this change.

6.1.9 Deployment

Given the capabilities of NVSTSS's system, implementation of this new strategy is very simple. The new timing plan need simply be stored for use when warranted.

However, an important step to implement new timing plans is to validate the plans' effectiveness in the field. VDOT's NVSTSS devotes significant resources to data collection and field monitoring when a new timing plan is implemented. This is done to identify unexpected problems associated with the plan and then make minor adjustments. This is necessary because any model, no matter how detailed, is a simplification of the real world. Rarely can they capture every nuance that may impact the performance of a timing plan.

Unfortunately, field validation of the optimized diversion-timing plan is more difficult than "traditional" plans. For example, the a.m. peak occurs every weekday morning. This allows VDOT to gather forces and equipment to plan for the validation effort. On the other hand, VDOT can rarely plan for when a diversion to take place during off-peak periods. This makes it more difficult to adjust the plan based on field observations.

6.1.10 Operations and Maintenance

Operation of the proposed design is based solely on effective communications between NVSTC and NVSTSS operations staff. This will ensure that the plan is implemented (and replaced) as soon as warranted.

Maintenance needs relate primarily to monitoring changing traffic demands in the region. As time progresses, and development patterns change, traffic patterns will be different than those used to develop the customized diversion timing plan. As these conditions change, it will be necessary to re-optimize the signal timings.

6.1.11 Continuous Improvement

As VDOT continues to identify and develop timing plans best suited for freeway diversion, it realizes that nothing will remain constant. The plans developed will need to be revisited on a frequent basis. In addition, incident debriefs between NVSTC and NVSTSS staff will be necessary to ensure that communications remain effective and timely.

6.1.12 Example Summary

This example applies the CFA framework to a relatively straightforward freeway diversion to a parallel arterial under congested freeway conditions. While there were minimal institutional issues in this case study, it does demonstrate how the analysis might be undertaken to determine an appropriate strategy.

6.2 Example 2: Leveraging ITS Technologies to Enhance CFA Operations

The above example reinforced the CFA operations process that was detailed in chapter 3. The following example reinforces the focus of chapter 5, the use of technologies to enhance CFA operations. Technologies including legacy systems, existing ITS deployments, and new systems resulting from the CFA planning process are combined in a hypothetical example. This idealized example has been created to simulate a complex urban environment where several governing entities and multiple agencies have partnered to enhance a major east-west travel corridor. The situation is presented as a hypothetical example of what can happen as a result of a major incident without leveraging ITS technologies in a coordinated manner and how the incident can be more successfully handled with good usage and coordination of ITS technologies.

Consider a major urban area situated along a navigable river with multiple east-west bridge crossings (figure 23). The river is also the border between two States and the urban area is actually two different cities in two different States. We are now, in this example, dealing with at least four different governing entities and several more municipal agencies and/or transportation authorities. Such an urban environment may have several basic ITS operating systems with attendant control devices and DMSs that have been deployed along many highways and bridge approaches over the past decade. The only effective way to alert motorists to difficulties on one of the bridge crossings is to share information so motorist alerts can be posted sufficiently in advance to allow diversions in one jurisdiction and warnings of an incident in another jurisdiction.

6.2.1 Major Incident Without Leveraging ITS Technologies

It is a typical weekday, there is a slight drizzle, and traffic is building toward the p.m. peak hour.

> 4:15 p.m.—A minor fender-bender occurs on the eastbound lanes of the Northern Interstate river crossing linking the downtown areas of both cities. A traffic queue immediately starts to build on the eastbound lanes.
>
> 4:20 p.m.—The incident is undetected by authorities.
>
> Eastbound traffic begins to back up to the last exit before the river, and motorists approaching the backup make quick decisions to bail out to the surface streets (Exit 123) and the old six-lane bridge crossing down river several miles.

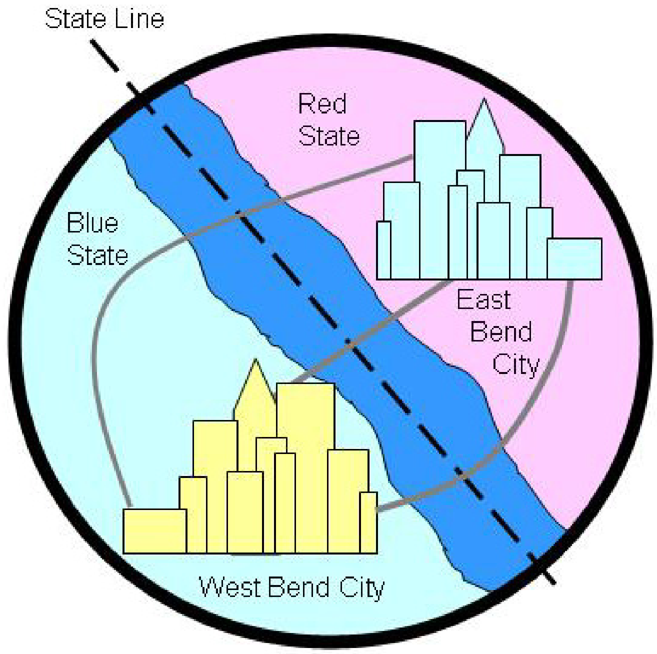


Figure 23. Chart. A major urban area situated along a navigable river with multiple east-west bridge crossings.

4:25 p.m.—The incident is still undetected by authorities.

Westbound traffic, now slowing due to motorists distracted by the incident, experiences a chain reaction collision involving four cars and several injuries. A regional transit bus driver, westbound on the Northern Interstate river-crossing, reports the westbound incident to his dispatcher at the same time the original eastbound accident is reported by cell phone by one of the involved motorists to Red State Highway Patrol who also reports that "no one is injured."

4:30 p.m.—Blue State's ITS TMC has a traffic flow reduction alert alarm going off and one of the TMC operators notes that traffic has slowed considerably at a TMC traffic monitoring location one mile before the Northern Interstate river crossing. A Red State Highway Patrolman contacts his base and reports an accident with no injuries at the same time the Regional Transit dispatcher reports an accident on the bridge with several injuries. West Bend City police dispatch is reporting unusually heavy traffic on city streets and severe congestion eastbound on the old six-lane arterial bridge. This is a particular problem for the West Bend City traffic engineer, who has programmed his new, ITS bridge lane-control signs and movable concrete divider to provide four lanes westbound and two lanes eastbound in accord with "normal p.m. peak hour traffic."

4:35 p.m.—West Bend City police are now hand-directing traffic to undo gridlock that has occurred on the streets approaching the six-lane arterial bridge which only has two lanes open for eastbound traffic. The oldest four-lane river crossing is now receiving the overflow traffic from its six-lane cousin upstream, and traffic is hopelessly backed into

West Bend City where police report several fender benders probably "due to the wet highways." Emergency vehicles arrive at both the eastbound and westbound accident locations.

> Even good intent and a cooperative spirit between governing entities may be inadequate to deal with the most mundane of traffic flow situations unless the processes described in this document have resulted in a deliberate CFA shared operations environment.

4:45 p.m.—The local radio station, receiving information from its "Eye in the Sky" traffic chopper, is now reporting on the major bridge accident on Northern Interstate, jammed traffic regionwide, and suggesting motorists divert to the Southern Interstate. Unfortunately, the Southern Interstate bridge crossing witnessed the beginning of its long-term redecking project last night and is speed restricted with three narrowed lanes of traffic compared to its usual four lanes eastbound.

5:00 p.m.—Situation out of control! Communications ongoing between both city traffic engineers and both State DOTs is unproductive. The Blue State TMC is trying to divert traffic well in advance of the Northern Interstate river crossing via its DMSs but it is too little, too late. The regional transit authority is reporting major delays on many of their downtown lines in both West Bend City and East Bend City.

5:15 p.m.—The "Eye in the Sky" traffic chopper is reporting that traffic throughout the urban region is a mess today; little do they realize that their traffic reports, lacking coordination with those who operate the transportation systems, actually added to the chaos.

In analyzing the scenario described above, the areas where lack of a coordinated response had the most impact can be summarized as follows:

- Information was shared but was neither timely nor coordinated.
- Delays in detecting the incident allowed congestion to spread rapidly.
- Secondary accident with injuries occurred.
- Transit system delayed.
- Appropriate officials in communication were helpless.
- Inappropriate responses by emergency units.
- Police tied up with snarled traffic.
- ITS systems were uncoordinated and unresponsive to incidents.
- Substantial delay-costs to thousands of travelers in the East–West Metropolitan region.
- No benefits from good intentions.

6.2.2 Major Incident With Leveraging ITS Technologies

Now consider that same major urban area where the several bridge crossings are perceived by the multiple agencies and governing bodies as a corridor. The proper planning has been done, a framework has been developed, working agreements and relationships exist, scenarios and response strategies have been created, and operating ITS systems have been upgraded and integrated such that coordinated operations are a routine occurrence.

Once again, it is a typical weekday, there is a slight drizzle and traffic is building toward the p.m. peak hour.

> 4:15 p.m.—A minor fender-bender occurs on the eastbound lanes of the Northern Interstate river crossing linking the downtown areas of both cities. A traffic queue immediately starts to build on the eastbound lanes.
>
> 4:16 p.m.—The incident is detected by the surveillance and data collection cameras that cover 100 percent of this and all bridges in the urban region and is verified at the regional TMC.
>
> 4:17 p.m.—The lane control signs on the bridge immediately configure that lane out of service. Variable speed signs reduce the speed limit both eastbound and westbound on the bridge from 88.5 kilometers per hour (km/h) (55 miles per hour (mi/h)) to 56.3 km/h (35mi/h) in their emergency flashing mode. The DMSs at each bridge approach flash an accident alert. The eastbound DMS notes, "Accident ahead. Right lane closed," The westbound DMS notes, "Accident ahead. All lanes open. Reduce speed."
>
> 4:18 p.m.—The emergency response team is dispatched to remove the damaged vehicles. Preplanned diversion strategies in accord with "reduced eastbound Northern Interstate bridge flow during the p.m. peak hour scenario" are immediately brought online. Traffic eastbound is advised by DMS upstream that an accident has occurred on the eastbound lanes, the right lane is closed, and motorists may exit at Exit 123 and follow signs to the old six-lane river crossing. The surface street traffic signal system in West Bend City is instructed by the TMC to optimize southbound flow at the same time the six-lane bridge transition from its "normal p.m. peak hour operation" of four lanes westbound and two lanes eastbound is revised to allow three lanes in each direction. The regular transition to four lanes westbound and two lanes eastbound is delayed for the duration of the incident.
>
> 4:19 p.m.—The "Eye in the Sky" traffic chopper is reporting "slight delays on the Northern Interstate bridge crossing but it seems to be clearing. We'll fly on down to the bridge redecking on the Southern Interstate to see how the construction traffic is moving even though the TMC folks tell us traffic is moving normally."
>
> 4:30 p.m.—The incident is removed and the lane declared open via lane control signs.
>
> 4:35 p.m.—The incident over, traffic returns to normal. The West Bend City signal system is in normal p.m. peak hour operation, and the old six-lane bridge makes the transition to its normal p.m. peak hour operation.

In analyzing the scenario described above, the most significant successes and their results can be summarized as follows:

- Information was shared in a timely fashion. This was the result of a decision to install state-of-the-art dynamic video sensors monitoring 100 percent of the paved surface on all bridge crossings for data collection and incident detection. Advanced sensor software, located at the regional TMC continually monitored all traffic parameters and provided immediate notice of any stopped vehicle on any of the urban area bridges.

- Coordinated operations through the new "East-West Regional TMC" responded rapidly and effectively. This was the result of a CFA decision to combine functions into a regional operation with preplanned strategies for a host of probable scenarios.
- The preplanned TAP (Transit Alternative Priority) Routes for alternate bridge crossings (stakeholders gave transit priority over passenger vehicles during incidents) were considered but proved unnecessary for this event.
- There was no secondary accident because of the use of integrated ITS systems informing and diverting motorists via DMSs and controlling the traffic stream with lane and speed control signing.
- The traffic surge on diverted-to routes was handled by appropriate ITS systems, including an advanced traffic responsive signal system in West Bend City. When developing the scenarios and strategies, it was decided that, in the best interest of both West Bend City and the greater metropolitan region, movable concrete barriers were not responsive enough on the old six-lane bridge. Instead the bridge received full CCTV surveillance and lane and speed control signing.
- The media have continual access to the TMC, and the "Eye in the Sky" traffic chopper had little or no real impact on the congestion because the incident was resolved so quickly.
- The whole event took place, was resolved, and returned to normal within 30 minutes.
- No notice was taken of the event nor was any credit given to the positive effect of the "CFA corridorwide approach" to traffic management in the east-west Metropolitan region.

While the above example is hypothetical, it is nonetheless an accurate interpretation of what could be done with a well-planned CFA system enhanced with off-the-shelf ITS technologies. Likewise the above example is intended to demonstrate a complex urban environment and the substantial benefits that accrue when multiple ITS deployments work as an integrated urban system. In so doing, it is hoped that the reader will perceive and appreciate simple applications in a broad variety of corridor settings.

6.3 Summary

With its two examples, this chapter reinforces the essential message of this entire document, thinking in terms of transportation corridors. In so doing, the individual facilities within the corridor can be better optimized to serve its region. Essential to this process are technological devices and methods that enhance corridor optimization. The reader is guided to the technical publications referenced throughout this document for detailed information about associated programs and ITS related technologies.

APPENDIX: ITS TECHNOLOGY INVENTORY, NEEDS ASSESSMENT, AND INTEGRATION

It is critical to gather detailed information about the existing infrastructure elements that support coordinated operations during the technology inventory, The inventory is completed to accurately identify locations that are deficient in deployment of data collection, traffic control, and information dissemination systems, as well as their related data analysis and communication systems. Recording details of the existing technology types, brands, protocols, and means of communication will enable engineers to determine whether existing technologies and their components are compatible, interoperable, and interchangeable. Knowledge of the existing systems will define the ability to communicate between them. It will also define future system deployments, because it is essential that new technologies deployed can communicate with, operate with, and be controlled by existing systems.

The level of data collection depends on the degree of complexity of the application and the long-term plans for coordinated operations. The examples given start on the basis of a complex application. The inventory may be less extensive for simpler applications. However, it is better to collect as much information as practical the first time, because requirements often change as systems are developed. A second trip to collect additional information is time consuming, so erring on the side of an excess of information is often a wise investment of time.

Performing an inventory of freeway and arterial data collection systems, traffic control systems, information dissemination systems, and communications networks is best accomplished with an inventory system that is a combination of a database, configuration management software, and geographic information systems (GIS). It is recommended that data input to the inventory system makes use of a form for every piece of equipment inventoried. The inventory of communications networks should focus on collecting information about the types of wireline and wireless networks that are in place, their functions, their available capacity, and their transmission modes to define the ability for future devices to communicate on existing networks, the need for additional capacity on existing systems for future devices, or the need for new communication systems altogether for future devices.

Completing the inventory for field devices, such as detectors, surveillance cameras, RWIS, ramp meters, traffic signals, DMS, and HAR, will require significant time to complete, particularly for systems with significant amounts of deployment with few records of the existing systems. Performing the inventory for central systems, however, should not require as much effort. It will only require the information recorder to gather information about individual systems, such as parking management systems, motorist call-in systems, reversible HOV lane systems, and central data analysis systems, at a few locations.

Ultimately, after populating the inventory system, it will enable a user to:

- View the location of a selected type of system on a map.
- View all systems for a selected area or route on a map.

- View system owning and controlling agency information in list or map format.
- Review quantities and locations of detectors, traffic control systems, and information dissemination systems by type, brand, model number, and/or information input/output in list or map format.
- Review system communications networks information including wireline cable types and locations, wireless device types and locations, and associated field and hub communications equipment types, brands, models, and locations in list or map format.
- Review system interconnections on a network diagram.

Although the inventory system described above is the most comprehensive and useful for assessments, it is rather time-consuming and costly to populate and maintain. Agencies constrained by limited staffing and budgets may only be able to accomplish an inventory that makes use of manual formats or only involves necessary data input without a GIS map.

Performing the inventory for data analysis systems and communications systems is drastically different from that described above because these systems consist of algorithms, firmware, central software, and integration of systems that enable processing, transmission, and receipt of information for CFA operations. These systems may reside in the field or at control centers.

Because there are multitudes of data analysis systems and communications systems that can comprise CFA operations, it is advisable in performing an inventory to first consider all the concepts of operations that were envisioned and then outline the data analysis systems and communications required between control centers to achieve each operations concept. An example data analysis system and communication system inventory process for a coordinated ramp metering concept of operations follows.

Ramp Metering Data Analysis System

Does your data analysis system analyze the following to determine the best metering rates?

- Freeway on-ramp detector data (stop bar, queue, and queue spill back).
- Adjacent freeway detector mainline data.
- Upstream freeway detector mainline data.
- Downstream freeway detector mainline data.
- Midblock arterial detector data.
- Arterial detector data at traffic signal controlled intersections.
- Traffic signal system control data and associated arterial volumes to anticipate queue spillback from the ramp into the intersection.

Is the detector and control system data received often enough? Are you analyzing the most appropriate types of data (i.e., should you receive and analyze speed, occupancy, and volume data instead of only receiving speed data?)?

Ramp Metering Communication System

Can control center operators of the ramp meter owning/controlling agency:

- Observe and adjust ramp metering rates via the central control system?

- Observe traffic conditions at the ramp meter through a surveillance camera at the control center?
- Observe the traffic data elements listed for the ramp metering data analysis system in tabular or map format?

Can the traffic signal control owning/controlling agency and other jurisdictions perform the functions listed above for the ramp meter owning/controlling agency? Can the agencies control the traffic signal operations to give less green-time to phases that send vehicle platoons to the freeway ramp when the ramp is at capacity?

Interagency Freeway and Arterial ITS Infrastructure Needs

Following completion of the inventory of all infrastructure elements, agencies must determine whether they can accomplish their concept of operations for each coordination management operations plan through the existing infrastructure for all desired areas of a corridor. Agencies should consider traffic data collection systems, traffic control systems, information dissemination systems, communications networks, data analysis systems, and communications systems that can be deployed to better CFA operations. If the infrastructure is insufficient, agencies should use the inventory to identify which locations require further infrastructure deployment.

Performing an Infrastructure Needs Assessment

When an agency that operates and maintains arterials performs a needs assessment, they should consider deployment needs on their own road networks and on the freeway networks that will enable the agency to improve operations on their own system via coordination with the freeway. Conversely, an agency that operates and maintains freeways should consider deployment needs on the freeways and on adjacent arterials to improve operations on their own system through coordination with the arterials. Freeway and arterial agencies should work together to complete a needs assessment, particularly when the agencies have a specific coordination applications goal, such as planned special event management coordination. The first recommended step is for each agency to independently answer the needs assessment questions.

The next step is for the agencies to meet to discuss their identified needs and prioritize deployment needs for achieving the coordination goal. The following questions address the process of needs assessment:

- Do you need to replace existing or deploy additional traffic data collection systems for your coordination application?
- Do you need to replace existing or deploy additional traffic control systems for your coordination application?
- Do you need to replace existing or deploy additional information dissemination systems for your coordination application?
- Do you need to replace existing or deploy additional communications networks for your coordination application?
- Do you need to replace existing or deploy additional data analysis systems for your coordination application?

- Do you need to replace existing or deploy additional communications systems for your coordination application?

Specific Infrastructure Needs Assessment Questions

Additional example infrastructure needs assessment questions for specific deployment on freeways and arterials, specifically for recurring and nonrecurring congestions, are included in the following sections.

Freeway System

Recurrent Congestion Infrastructure Needs

- If providing coordinated and seamless motorist information is an objective of the concept of operations, are the existing detection sources, locations and types sufficient to provide speed, congestion, volume, and/or traveltime information on all controlled access facilities within the region? An example may be to consider probe-based surveillance (transponders or cell phone users) technologies to better determine traveltimes in lieu of using algorithms to approximate this information.
- Is there additional information needed from the system, such as vehicle classification information, or is there a need to introduce ramp metering (Note: Ramp metering might be needed to address recurrent congestion or needed on a temporary basis to encourage diversion to parallel arterials during a major construction on the controlled access facility) that requires additional deployment of sensors?
- Is there any additional detection needed at the intersection of freeway exit ramps and major arterials? An example of this would be a point where an exit ramp may be backed up from the intersection. In this case, it might be beneficial to install a sensor on the exit ramp to determine at what volumes this backup occurs and then to allow proactive changes in the signal timing at the downstream intersection.
- Are there fixed time ramp metering operations that are negatively affecting arterial operations? If so, do you want to upgrade the ramp metering operations from fixed time to real time and therefore need additional detection installations?
- Is there any gap in surveillance coverage along controlled access facilities?

Nonrecurrent Congestion Infrastructure Needs

- While ramp metering might not be needed or feasible, it may be worthwhile to install sensors on entrance and exit ramps in preparation for construction and maintenance zones, incidents, and special events.
- Are there any gaps in surveillance coverage along controlled access facilities that might be needed on a short-term basis because of an upcoming special event or construction and maintenance zone operation?
- Is there a need to install lane control signals?
- Does an automated incident recording system exist that would allow information to be automatically shared with other agencies?

- Are certain controlled access facilities to be used as preplanned alternative routes? If so, would it be beneficial to install remote controlled static guide signing to be used real time during major incidents and provide improved motorist information?
- Should additional DMS and HAR be installed to provide better motorist information for special event venues?

Arterial Network

Recurrent Congestion Infrastructure Needs

- If providing coordinated and seamless motorist information is an objective of the concept of operations, are the existing detection sources, locations, and types sufficient to provide speed, congestion, volume and/or traveltime information on all controlled access facilities within the region? An example may be to consider probe-based surveillance (transponders or cell phone users) technologies to better determine traveltimes in lieu of using algorithms to approximate this information. The installation of permanent traffic recording stations might be beneficial on major arterials to better determine periods of capacity or over-saturated conditions. This is especially true if the installation of CCTV devices is not feasible.
- Are all intersections along primary alternative routes to freeways actuated?
- Is there some form of automated surveillance at critical intersections along primary alternative routes to freeways?
- Is it possible to install dynamic signing at major intersections to change geometrics on a real-time basis?
- Is there a computerized traffic signal installed on the primary alternative routes to freeways?

Nonrecurrent Congestion Infrastructure Needs

- Are temporary detectors needed to collect speeds, volumes, occupancy, density, congestion queuing, traveltimes as a traffic mitigation measure during major construction and maintenance zone operations or for special events?
- To manage traffic during major construction and maintenance zone operations, it might be beneficial to install temporary traffic recording stations on parallel arterials to better determine unexpected periods of capacity or oversaturated conditions. This is especially true if the installation of CCTV devices is not feasible.
- Is there a need to install traffic counting sensors at major parking facilities?
- Is there a need to install additional detection to allow the interconnection of a train grade crossing into a traffic signal system to move traffic across the grade crossing in advance of the train approach and only allow traffic movements that do not go toward the grade crossing while train is crossing?
- Are certain surface streets to be used as preplanned alternative routes? If so, would it be beneficial to install remote controlled static guide signing to be used real time during major incidents and provide improved motorist information?
- Can DMS and HAR be installed to provide better motorist information for special event venues?
- Does an automated incident recording system exist that would allow information to be automatically shared with other agencies? Do other municipal agencies such as public works departments and utilities have access to this system?

Prioritizing Infrastructure Deployment

> Future deployments should use technologies that apply national ITS standards to enable future systems integration as legacy systems are replaced.

In most circumstances, budgetary constraints will be a significant factor in making deployment decisions; therefore, agencies should consider all of their deployment needs and associated cost estimates to develop a prioritized deployment list. To develop a complete list of deployment needs, agencies should answer questions similar to those above and complete infrastructure needs forms for each concept of operations they generated for every type of CFA operations application. They can then compare this information to determine which deployment efforts will enable accomplishing multiple goals and to prioritize deployment based on cost effectiveness, immediate needs, and ability to bring systems online. Consider this example. It is determined that 2 ramp meters, 9 ramp detectors, 56 arterial midblock detectors, and 4 CCTV cameras should be deployed for ramp metering efforts for day-to-day management coordination and traffic incident management coordination. CCTV cameras and detectors are also desired for upcoming planned special event management coordination within the same area. If sufficient funds are not available to deploy all of the technologies in this case, the best choice is to implement only the surveillance cameras and some detectors first. If agencies are focusing on a particular CFA operations application, they may want to perform only a needs assessment for that application.

In comparing desired uses of an existing communications network, agencies can determine whether deployments will exceed available capacities, and if so, they will need to prioritize deployment or add capacity to the network.

Another issue that must be considered in assessing deployment needs is the level of compatibility between disparate communication systems. If various agencies operate and maintain technologies that are incompatible, agencies should develop a comprehensive plan to trade out equipment or integrate systems to enable CFA operations. Future deployments must use technologies that apply national ITS standards to enable future systems integration as legacy systems are replaced.

Integration of Interagency Systems

Stakeholders identify and document information they want to share between their field devices and control center systems in a concept of operations document and in accordance with their regional architecture. They must then assess the compatibility and available capacity of existing control center systems, field devices, and communications systems to assess the best means of integrating their systems.

Although the control center system integration assessment will make use of the data analysis and communications systems inventory, it will also involve a detailed assessment of all system components within each center. This includes individual data elements employed in system software, software code, the ability to modify software elements and modules, control center equipment protocols and configurations, video and data networks, control system capabilities, and workstation features. The selection of appropriate systems integration between control centers must incorporate ITS standards, including center-to-center and traffic management data dictionary.

The field device and communications systems assessment will make use of the traffic data collection systems, traffic control systems, information dissemination systems, and communications network technology inventories. Stakeholders will need to review the features of field devices, such as data inputs and outputs, protocols, standards, and means of communications to assess interfacing abilities directly from the field and via control centers. The communications systems assessment will involve reviewing the location of existing wireline and wireless networks and their available capacities, system protocols, and networking parameters to determine whether the existing communications systems can support the desired systems integration.

Following these assessments, the final step will be to develop a deployment and migration plan for deploying communications network components, replacing field devices, updating system firmware, updating existing control center system settings, deploying control center systems, developing new software modules, writing software code to deploy standards, and bringing the integrated systems online to enable CFA operations.

Systems Coordination for Traveler Information Dissemination

While electronics can deliver information from the field to the control center and send it back out to the drivers, the information by itself is of little use without coordination among the many stakeholders. ITS and other electronic systems can play a significant role in this area. Part of the coordination challenge is making sure all the stakeholders get the information they need when they need it. So much information can be gathered that it must be put in context to be of use. This can be accomplished through filtering systems that make certain only the information needed is provided to each individual agency.

Timeliness is also a critical part of systems coordination. Information should be delivered to all stakeholders simultaneously and as soon as it is verified. If one agency is operating with out-of-date information, they may be taking actions out of sync with other stakeholders. Timeliness is also critical to the largest stakeholder group, the traveling public. If information is old and no longer accurate, the value of the system is not only diminished during the incident in question, but for future incidents as well. An example might be information displayed by one agency on a DMS that conflicts with information being broadcast on another agency's HAR system.

Part of the coordination challenge is making sure all the stakeholders get the information they need when they need it.

Accuracy is a third important piece of systems coordination. Control centers need to be able to give stakeholders 100 percent accurate information, even if that information is not 100 percent complete. For example, the control center may know there is a slowdown eastbound at milepost 28.3 without knowing the reason for the slowdown. It must be certain not only that it delivers the information, but that it is understood. ITS can play a role here by providing the information in a consistent, easily understood format, by taking additional steps such as plotting the location on a map and by automatically identifying the surveillance tools that can monitor the incident.

Effectively providing traveler information across agency jurisdictional boundaries within a region requires the integration of the above data to traffic control centers and center-to-center linkages. It is encouraged that a region develops a regional architecture to facilitate the implementation of these system and data interfaces. The result will be a traveler information center/system (virtual or staffed) that disseminates information via:

- Web (fully automated).
- Phone call-in system / 511 (fully or partially automated).
- DMS.
- HAR or other radio means (fully or partially automated or manual).
- Flashing beacons with static sign descriptor alerting motorists to tune in (fully or partially automated or manual).
- Lane control systems.

Communication is needed with the media to support information sharing with stakeholders. Therefore, data and video links to the media may be required. This would allow the media to provide coordinated and accurate information, such as recommending alternate routes around congestion.

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