

EXECUTIVE SUMMARY

Freeways were originally conceived and designed to provide continuous, free flow, high-speed movement of traffic on a limited-access facility. In their original design, little thought was given to providing for the need of traffic management and control systems to maintain a high level of mobility on these facilities. However, as urban areas continued to grow, the freeway system became more congested. The previous approach of constructing more freeway lane-miles to relieve congestion is today often politically and socially unacceptable and economically infeasible. It is incumbent on transportation agencies planning, constructing, operating, and maintaining freeway infrastructure to make the best possible use of available capacity.

Freeway management systems are a primary means by which transportation agencies can manage traffic flow and make better use of the existing freeway system. Freeway management systems make use of control strategies and operational activities such as incident management and information dissemination to 1) keep congestion from occurring in the first place, and 2) lessen the duration and extent of congestion when it does occur.

While the term *freeway management system* was probably not applied to the tasks, early freeway management systems consisted primarily of fixed signs on the roadway providing regulatory and directional information, and police officers handling traffic following incidents. As freeway systems have matured and traffic demands have grown in urban areas over the past half century, freeway management systems have evolved and developed to provide many and varied services.

What Is Freeway Management?

The 1983 *Freeway Management Handbook* defined freeway management as the “. . . control, guidance and warning of traffic in order to improve the flow of people and goods on these limited access facilities.”⁽⁶⁾ Today, the definition of freeway management should be expanded to encompass all activities undertaken to operate a freeway facility in a manner consistent with predetermined goals and objectives of that facility, including those related to impacts on and the influence of surrounding communities and jurisdictions. Certainly, the efficient movement of goods and people continues to be one of the major goals of freeway management. However, legislative mandates, public pressure regarding environmental concerns, adjacent landowner and homeowner rights, and other issues further influence the operation of the freeway system.

In many cases, freeway management requires striking a balance between competing goals and objectives. For example, a goal to minimize recurrent congestion may not necessarily be compatible with a goal to maximize the movement of people and goods on a facility, especially if the goal to maximize people movement is accomplished through the use of high-occupancy vehicle lanes. High-occupancy vehicle lanes require a significant travel time advantage over regular-use lanes to be attractive to travelers using the freeway. In terms of this example, it may be appropriate to allow some level of congestion in the regular-use lanes in order to achieve the best overall operation of the freeway system.

What Is a Freeway Management System?

In general terms, a system is defined as a set of components or elements that could be seen as working together for the overall objective of the whole.⁽⁷⁾ These components or elements may include many different things, depending on the perspective of the person who defines the system. System components can be objects, concepts, processes, or even people. A system has a set of boundaries that define the interactions between system components and the environment. The environment consists of all those factors external to the system that influence the behavior of the system, and that cannot be controlled. Within the system, there are interfaces between the various components, which control how they interact with each other. Finally, the components themselves may be subsystems consisting of smaller elements or components.

A freeway management system, then, consists of the infrastructure elements utilized to accomplish the goals and objectives of freeway management. These things (elements) include field hardware (cameras, dynamic message signs, electronic toll tag readers, etc.), communications equipment, a traffic management center (with associated hardware and software), the people who staff the center, and the policies and procedures established to deal with various transportation-related events that affect the freeway system. The freeway management system comprises several infrastructure subsystems (the motorist information system, the ramp metering system, etc.) that interface with each other to accomplish specific objectives as the need arises.

It is important to recognize that each freeway management system is a unique consolidation of components and interfaces that reflect the location-specific freeway, geographic, and political characteristics and needs of the region. However, most systems can be described in terms of which of the possible functions of freeway traffic management they perform. The following section presents a brief overview of these functions.

History of Freeway Management

Pioneering efforts in “freeway surveillance and control,” as systems were first generally known, took place in Detroit, Chicago, Houston, Los Angeles, Seattle, and Dallas. Highlights of some these early efforts are listed below:⁽⁹⁾

- **1962 Detroit** - Freeway lane control signs and variable speed signs.
- **1963 Chicago** - Demand-capacity/ occupancy metering and surveillance by freeway loop detectors.
- **1965 Houston** - Demand-capacity/ gap-acceptance metering and surveillance by closed-circuit television and freeway loops.
- **1967 Los Angeles** - Fixed time metering and ramp closure.
- **1967 Seattle** - Reversible roadway control and closed-circuit television surveillance.
- **1971 Dallas** - Corridor control integrating ramp metering, frontage road and arterial intersection control with preferential treatment for buses at ramps and intersections.

- **1972 Minneapolis** - Bus bypass ramps at metered ramps.
- **1990** - Introduction of Intelligent Vehicle/Highway System (IVHS) concept including freeway management and related systems.
- **1992** - Federal Highway Administration's introduction of concept of Intelligent Vehicle/Highway Systems (IVHS)
- **1993** - Intelligent Transportation Systems (ITS) concept succession of IVHS to broaden the scope to include other forms of surface transportation.
- **1993**-Initiation of National ITS Architecture Initiative to address common interfaces and protocols for ITS systems.

As systems were upgraded and expanded, they began to be more properly termed "Freeway Management Systems." New and upgraded systems have incorporated many of the basic techniques developed on these earlier systems. The phenomenal developments in computer and communications technology have further enhanced capabilities for various freeway management tasks.

Relationship of Freeway Management to National ITS Architecture

The freeway management concepts of this handbook follow the National ITS Architecture. Quoting from the *1996 ITS Architecture Executive Summary*:

The National ITS Architecture provides a common structure for the design of intelligent transportation systems.

Agencies should seek to ensure that the design of a new or upgrade of an existing freeway management system design uses the National ITS Architecture and applicable National ITS standards.

An outgrowth of the development of the National ITS Architecture has been the concept of intelligent transportation system infrastructure. The term "infrastructure" has been in common use for a number of years to describe the supporting roadways, bridges, water and sewer lines, and other public works structural items that allow movement of persons and goods. It is not the truck or car, it is the roadway and bridge. It is not the water, it is the pipes or conduits that carry the water. A logical extension of the infrastructure concept is its application to flow and delivery of information in Intelligent Transportation Systems.

Many of the functions needed for ITS implementation are already being provided or supported by a broad variety of ITS infrastructure features, which can serve as the building blocks of a full ITS implementation. An ITS infrastructure refers to those portions of ITS-related hardware, software, etc. that today, and increasingly in the future will manage and support transportation-related activities. This is typically happening first in the metropolitan areas, but is expanding to include commercial vehicle and rural needs.

An integrated transportation management system should contain some or all of the following applicable ITS components in a given region:

- Traffic Signal Control.
- Freeway Management.
- Transit Management.

- Incident Management.
- Electronic Fare Payment.
- Electronic Toll Collection.
- Railroad Grade Crossings.
- Emergency Services.
- Regional Multimodal Traveler Information.

Both the implementation of a given component and the integration of the components should use the National ITS Architecture and standards.

OBJECTIVES OF A FREEWAY MANAGEMENT SYSTEM

The goals and objectives of a freeway management system are specific to the social and political desires of the community; however, there are goals and objectives for freeway management systems that are universal across all systems. These include the following:

- To reduce the impacts and occurrence of recurring congestion on the freeway system.
- To minimize the duration and effects of nonrecurring congestion on the freeway system.
- To maximize the operational safety and efficiency of the traveling public while using the freeway system.
- To provide facility users with information necessary to aid them in making effective use of the freeway facilities and to reduce their mental and physical stress.

- To provide a means of aiding users who encounter problems (crashes, breakdowns, confusion, etc.) while traveling on the freeway system.

FUNCTIONS OF FREEWAY MANAGEMENT

Freeway management systems combine personnel, operational strategies, and technologies to control and manage traffic on the freeway more effectively. The following functions can be performed by a freeway management system:

- Surveillance and incident detection.
- Lane use control.
- Ramp control.
- Priority treatment and control for high-occupancy vehicles.
- Information dissemination.
- Incident management.

A brief review of each of these functions is provided below. A more detailed discussion of the pertinent issues affecting planning, design, operations, and maintenance is provided in subsequent modules.

Surveillance and Incident Detection

Traditionally, one of the primary functions of most freeway management systems is to detect traffic incidents that affect the smooth flow of traffic.⁽¹⁰⁾ With surveillance, traffic conditions can be monitored and the location and causes of any operational problems that occur can be pinpointed. As traffic management systems have become increasingly multijurisdictional and multimodal, the surveillance function has expanded to include such considerations as

transit and emergency fleet vehicle locations, weather and pavement conditions, and parking lot status.

Lane Use Control

The function of lane use control is to maximize the efficient use of existing pavement within the right-of-way. Mainline metering, temporary shoulder utilization, reversible lane operations, and large truck restrictions are all examples of lane use control.

Ramp Control

Managing the amount of traffic that can enter or exit the freeway is another function of freeway management systems. Both ramp metering and temporary ramp closures (during peak periods, for instance) are examples of the ramp control function. Controlling freeway access and egress reduces turbulence in freeway flow near the ramps and improves overall freeway operations.

High-Occupancy Vehicle (HOV) Priority Treatments

Another function of freeway management is to provide preferential treatment to buses, carpools, and vanpools on a freeway to generate a travel time advantage for the vehicle occupants and review the number of vehicles on the roadways. These treatments can include special lanes, priority access, and ramp controls for HOV vehicles, special surveillance of those lanes to detect and remove incidents quickly, and occupant restriction enforcement.

Information Dissemination

From a traveler's perspective, information dissemination is one of the most important functions of freeway management. Research

and experience have shown that travelers want and use real-time information about traffic conditions on the freeway and alternative routes; adverse weather and driving conditions; construction and maintenance activities; and special lane use and roadway control measures that are enacted. With current and accurate information, travelers are better able to make mode, departure time, and route choice decisions. A number of existing and emerging technologies are available to facilitate information transfer to travelers.

The Freeway Management System

A freeway management system may be the common interface for multiple transportation agencies in a given region. In the such cases, it is the focal point for receiving, processing, and transferring various types of traffic and transportation data, including digital, video, and voice. Regional multiagency coordination will logically take place in the freeway management center.

Incident Management

Of all the major freeway management functions, incident management probably offers the greatest potential operational and safety benefit to freeway motorists.⁽⁵⁾ Incident management requires the coordinated operation and preplanned use of human and technological resources to restore the freeway to full capacity quickly and efficiently after an incident occurs. Typically, incident management may include other freeway management functions such as the following:

- Control center operation.
- Surveillance.
- Information dissemination.

- Freeway service patrols.
- Ramp control.
- Decision process control strategies.
- Lane use control signals.

Integration with Other ITS Components

As illustrated below, freeway management is just one component of an integrated transportation management system. Freeway management, along with traffic signal control, form the hub of an integrated transportation system. The traffic signal control and freeway management components exchange data with each other, allowing the traffic management strategies on the freeways, the freeway entrance ramps, and the surface street network to act as an integrated system. These data define the actions to be taken by the system when a particular signal timing plan is in effect on the road network, and when a particular sign plan is in effect on the highways. For example, ramp meter timings and traffic signal controls can be coordinated to ensure that queues do not back into intersections. When traffic is diverted off the freeway to bypass an incident, the traffic signals timings can be adjusted to handle the increased flow on the arterials. At the same time, dynamic message signs can be updated along the arterials to give directions on how to return to the freeway beyond the incident location.

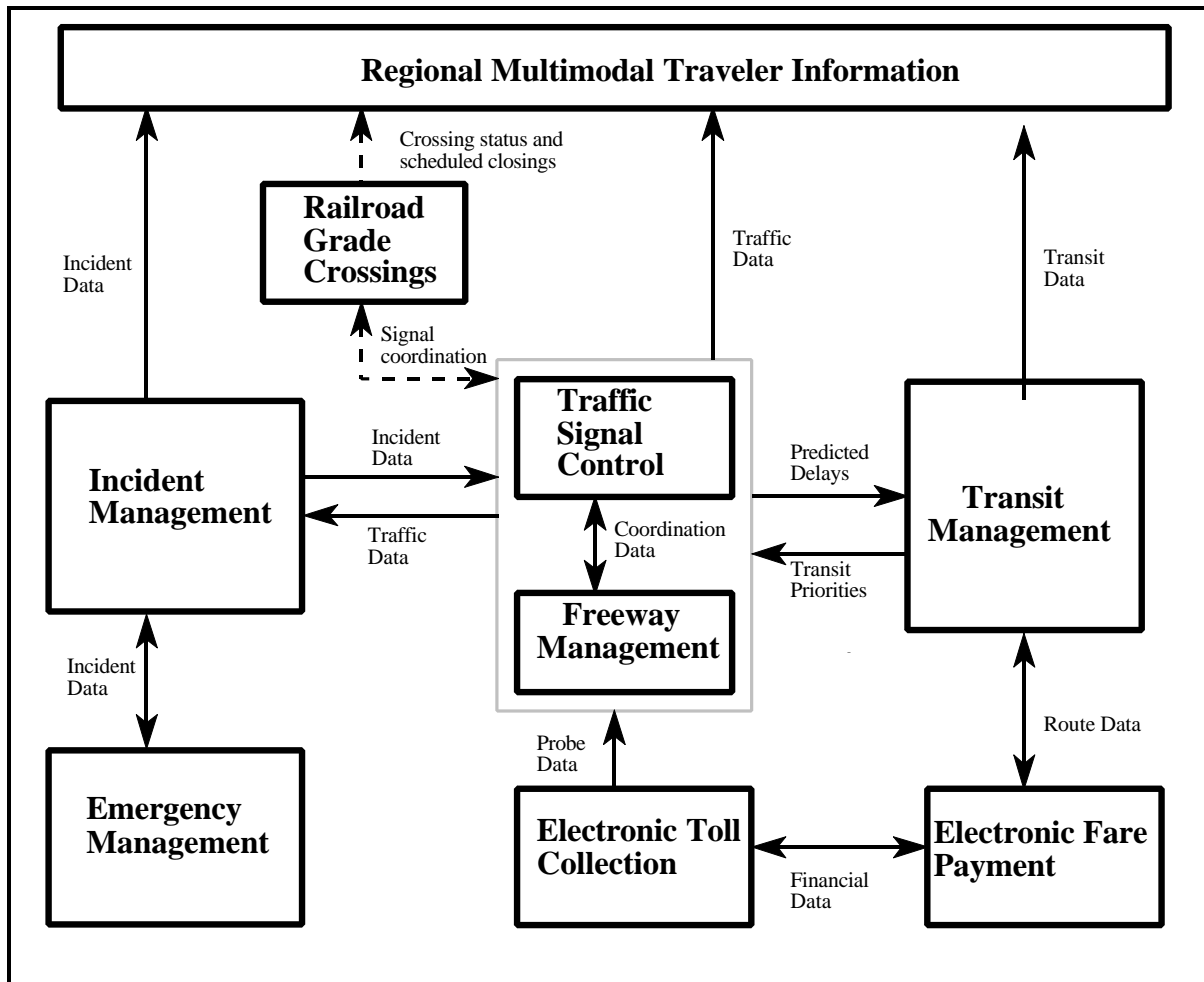
In addition, both the freeway management and traffic signal control components can provide critical information to other components of the transportation system. Both the freeway management and traffic signal control components are responsible for the surveillance, monitoring, device control, and management of the road network. These components provide

information on the status of the roadway system, including link travel times, traffic volumes, and speeds currently flowing on the road and highway network. These data can be passed to the other components in the overall transportation system, such as the incident management and transit management components, and information from these other systems can be channeled through the freeway management and traffic control components. Traffic data can also be output to a regional traveler information system for dissemination to the public for trip planning and other purposes. Because the freeway management and traffic signal control components are monitoring traffic conditions on the roadways, information about predicted delays and incidents can be passed to the transit management component, which in turn can use the information to establish transit priorities and operating strategies, which are implemented by the freeway management and traffic signal control components.

Although it may be possible for some transportation management subsystems to operate in an isolated or independent manner, their operation and functions will affect and be affected by the other transportation subsystems. This will be particularly evident in an urban environment. For optimal efficiency, the various transportation subsystems must operate in a cohesive, integrated manner. Multiple agencies must maintain open communication and cooperation to achieve the goal of a truly integrated transportation system.

FREEWAY MANAGEMENT HANDBOOK

The objectives of this handbook are as follows:



Freeway Management as Part of an Integrated Intelligent Transportation System

- Define the process of planning, designing, operating, and maintaining a freeway management system.
- Provide an overview of the techniques and technologies available for accomplishing the functions of a freeway management system.
- Identify critical issues associated with planning, designing, operating, and maintaining a freeway management system.
- Provide guidance in developing a freeway management system that uses the National ITS Architecture and applicable standards.
- Identify points in the design development process where integration and interface with other systems should take place.

SCOPE OF THE HANDBOOK

This handbook is intended to be a “How To” manual for planning, designing, operating, and maintaining a freeway management system. This manual is directed at a mid-level administrator or engineer for a State or local agency that is responsible for planning, designing, operating, or maintaining all or portions of a freeway management system. As a result, it primarily focuses on the issues associated with each element of a freeway management system. For many of the elements and functions, there are excellent

reference materials that provide detailed information about the technologies and techniques. For example, the *Communications Handbook for Traffic Control Devices* and the *Freeway Incident Management Handbook* provide many technical details on communications and incident management systems, respectively. In those cases where there are other manuals and reference materials to provide technical details, the details have not been reproduced in this manual. Instead, the reader has been provided with references to these materials as a source of more detailed information than that presented in this handbook.

STRUCTURE OF THE HANDBOOK

A modular approach has been used to prepare this manual. Each functional element of a freeway management system is covered in a separate module. Each module presents information specific to the planning, design, construction, operation, and maintenance of that particular functional element. This approach was used when preparing this handbook so that system designers and operators can turn to the modules of interest to them and find all the information pertinent to the planning, design, operation, and maintenance of those specific elements.

In addition, a decision process module has been provided. The decision process module describes the systems engineering approach that can be used to plan and design a freeway management system. The systems engineering approach can be used regardless of whether a system is being designed from scratch, modifications are being made to an existing system, or upgrades are being planned to an outdated system. The decision process module also serves as a model of each of the remaining modules.

The same structure has been applied to each of the modules. Each module contains an overview section that provides some background into the nature of the functional element, and the objectives and scope of the information. The section following the overview section describes a system engineering process for planning, designing, and implementing the functional element within a freeway management system. Another section describes the techniques and technologies commonly used in each functional element. Each module also has a section devoted to covering any special issues that could not be adequately covered in the previous sections. Wherever possible, examples of state-of-the-art facilities are provided in each module. The module concludes with a section listing the references and suggested readings for the module.

OVERVIEW OF FREEWAY MANUAL MODULES

A summary of the type of material to be covered in each of the previously mentioned modules is provided below.

Module 1. Freeway Management Concepts

This module provides an introduction to the handbook including objectives, scope, and structure. Also included is an overview of freeway management concepts as a primer or preface to the 10 modules addressing technical and management issues.

Module 2. Decision Process

The second module is devoted to discussing the process for determining functions and technologies to be included in a freeway management system. It provides the steps to be taken for conducting a system engineering analysis for planning, designing, and

implementing a freeway management system. This module focuses on the issues associated with integrating each of the functional elements to form a comprehensive freeway management system.

Module 3. Surveillance

This module contains information related to planning, designing, and implementing the surveillance subsystem of a freeway management system. Using the structure for the decision process discussed in Module 2, this module provides a process for determining the appropriate elements to be included in a surveillance subsystem. It provides an overview of the various technologies and techniques that are available for performing the surveillance functions in a freeway management system.

Module 4. Lane Use Control

This module focuses on the process for planning, designing, operating, and maintaining systems for controlling the use of the freeway main lanes. This module provides information related to the design and operations of freeway main lane meters, techniques for using the shoulder, and providing reversible lane control on the freeway. It also provides insight into the special issues related to operating and maintaining these control systems.

Module 5. Ramp Control

This module presents information needed to plan, design, operate, and maintain freeway ramp control systems. It provides an overview of the theory and principles of ramp control, including ramp metering and ramp closures. It also presents information on the different types of ramp metering strategies. The module concludes with a section on the special issues associated with ramp control systems, including

maintenance, enforcement, and public perceptions and acceptance of various ramp control strategies. It is intended to complement information in *Ramp Metering Status in North America (1995 Update)*.

Module 6. HOV Treatments

This module presents information needed to include high-occupancy vehicle (HOV) priority treatments in a freeway management system. It provides a summary of the planning, design, and operations issues associated with including an HOV treatment in a freeway management system. It also provides an overview of the decision process for determining which type of priority treatment is appropriate for a specific system. It also discusses some of the special design, operating, and maintenance issues associated with HOV treatments.

Module 7: Information Dissemination

This module describes the process for establishing a cohesive information dissemination subsystem in a freeway management system. It identifies the existing and emerging technologies available to facilitate information dissemination to travelers. It also illustrates how the information dissemination subsystem integrates with the other subsystems of a freeway management system.

Module 8. Incident Management

Module 8 presents information related to the planning, design, operations, and maintenance of an incident management subsystem in a freeway management system. It is intended to illustrate how to develop or enhance the incident management capabilities of a freeway management system. It also provides insight into the key factors and issues to be considered in

planning, designing, and implementing an incident management subsystem. It is intended to complement the material already presented in the *Freeway Incident Management Handbook*.

Module 9. Communications

This module provides insight into the issues associated with planning, designing, operating, and maintaining a communications subsystem in a freeway management system. It focuses on the decision process for determining the appropriate communication technologies for specific freeway management systems. It also provides a summary of existing and emerging communications technologies. It is intended to complement the material already presented in the *Communications Handbook for Traffic Control Systems*.

Module 10. Control Center

This module provides information related to planning, design, operations, and maintenance of the control center. It focuses on both the physical design and

human factor elements associated with freeway management control centers. It also provides insight into how the functions of the freeway management system affect the design and operations of the control center. Special issues such as privatization of operator functions and multiagency control centers are also discussed in this module. It is intended to complement the material already presented in the *Human Factors Handbook for Advanced Traffic Management Center Design* (First Edition).

Module 11. Economic Analysis

This module presents information on some of the economic analyses that can be used in planning and evaluating alternative designs of freeway management systems. Included in this module is step-by-step instruction on how to conduct a life-cycle cost evaluation, a benefit-cost evaluation, and other pertinent economic analyses. This module also provides guidance to the reader on when it is appropriate to use the different types of economic analyses.