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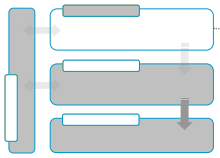
RAMP MANAGEMENT AND CONTROL: OVERVIEW



Getting Started

2.1 Chapter Overview

This chapter provides an overview of ramp management and control issues and activities that are examined within the remaining chapters of this handbook.

The topic of ramp management and control is introduced and the key points that practitioners need to understand and consider in successfully developing, selecting, implementing, and maintaining ramp management and control techniques and strategies are discussed. This chapter provides an overview of ramp management and control and a high-level understanding of the entire handbook. Thus, this chapter can be used by practitioners to navigate to the sections within it to obtain additional information.

A ramp management and control element of an agency's traffic management program offers several techniques and strategies to manage traffic on freeway ramps. The intended use and application of these techniques and strategies vary depending on the goals and objectives of an agency's traffic management program as well as the conditions in the field. Ramp management techniques and strategies can improve safety and mobility while reducing the environmental effects associated with traffic congestion and delay.

Chapter Organization

The key issues of this chapter deal with developing a high-level understanding of ramp management and how ramp management may fit with other traffic management efforts. This chapter also covers how to take advantage of opportunities throughout the life cycle of the freeway facility and explore ways to improve freeway and ramp performance and safety. The chapter follows the logical progression of implementing a ramp management and control program and introduces ramp management and control concepts in the same order that they are presented in the remaining chapters of this handbook.

Initiating ramp management and control techniques and strategies requires close analysis of agency program goals and objectives to determine if and how a ramp management strategy may fit into an agency's traffic management program (Chapters 3 and 4). The relationship of ramp management to other elements of the traffic management program must be closely analyzed to determine if a given ramp management strategy will support other traffic management elements. Only after the analysis of an agency's traffic management program shows that ramp management fits and is supportive of agency goals and objectives should agencies begin to make decisions about how to develop, select and implement ramp management techniques and strategies (Chapters 5, 6, and 7). After implementing a ramp management strategy or set of strategies, agencies must take steps to successfully operate and maintain (Chapter 8) and measure the performance (Chapter 9) of the selected strategy(ies). Once the strategies are selected, the physical elements of the strategy are normally deployed through capital or operational improvement projects. Planning for and designing those elements are discussed in Chapter 10.

Chapter 2 Objectives:

Objective 1:	Develop a high-level understanding of what ramp management is and how it can benefit agencies.
Objective 2:	Understand how ramp management fits within a larger traffic management program and how to prepare for successful ramp management operations.
Objective 3:	Become familiar with the each step of the ramp management life cycle, from developing strategies to operations and maintenance.
Objective 4:	Identify typical transportation improvements and how ramp management strategies can be considered within these improvements.

2.2 Introduction to Ramp Management and Control

As previously discussed in Chapter 1, attempts to manage ramp-based traffic were first conducted over a half-century ago in metropolitan areas such as Chicago, Los Angeles, and Detroit. These attempts, although slightly different than those deployed today, were successful and bred additional attempts to manage traffic entering freeways from ramps. Over the last four decades, strategies such as ramp metering and ramp closure have flourished as effective traffic management strategies and have continued to evolve to meet the additional demands of the public and the constraints inherent to public agency budgets.

If performed effectively, ramp management and control strategies can significantly improve the operation of not only ramps but also the facilities they connect (i.e., freeways and arterials). This conclusion is based in part on the fact that ramps are the only facilities that motorists may use to legally make connections between these facilities and, as such, represent the only locations where traffic entering and exiting these facilities can be controlled. As conditions on ramps, freeways, and arterials continue to worsen due to an increasing gap between roadway capacity and traffic demand, ramp management strategies can be employed as a cost-effective approach to manage traffic that use these facilities on a daily basis.

2.2.1 What is Ramp Management?

As stated in Chapter 1, ramp management can be defined as "the application of control devices such as traffic signals, signing, and gates to regulate the number of vehicles entering or leaving the freeway, in order to achieve operational objectives".[1] Those objectives usually are stated similarly to the following:

- Balance freeway demand and capacity.
- Maintain optimum freeway operation by reducing incidents that produce traffic delays.
- Improve safety.

Ramp management is one of several freeway management elements. Ramp management should seek to satisfy freeway management goals and objectives in a similar way that freeway management works to satisfy surface transportation goals and objectives.

2.2.2 Ramp Management and Control Benefits

Before and after evaluations of ramp management strategies offer strong evidence that ramps, freeways, and even adjacent arterials operate better once these strategies are implemented. Typical benefits of ramp management strategies are briefly outlined in the following sections.

Safety

According to evaluations from across the country, ramp metering reduces collisions on freeways and ramps from 15 to 50 percent.[1,2] Ramp metering reduces stop-and-go driving behavior, resulting in fewer rear-end collisions. It also breaks up platoons entering the freeway, resulting in fewer side-swipe and merge-related collisions.

Mobility and Productivity

Ramp management strategies often increase travel speeds while reducing travel time and delay. Freeways that have metered entrance ramps usually carry more traffic than they did before metering began, while attaining the improvements mentioned previously. A ramp metering study in Minneapolis showed a 25-percent increase in peak period traffic volumes while increasing average speeds by 5 km/h (3 mi/h).[1,2]

Environmental Effects

The improved speeds, reduced stop-and-go traffic, and reduced delays that result from ramp management strategies also result in reduced emissions and fuel consumption.

Traveler Perception and Satisfaction

Ramp management and improved operations on freeways demonstrate to the public that agencies responsible for transportation facilities are doing something about congestion and safety problems. As a result, travelers and the public in general will be more satisfied with transportation agencies and the job they are doing. Higher public satisfaction makes it easier for agencies to acquire the needed resources to develop, implement, operate and maintain transportation improvements.

2.3 Ramp Management and the Traffic Management Program

At the most basic level, ramp management efforts must support the vision and mission of the agency. Ramp management should be considered as an element of the overall traffic management program versus a program that operates parallel to or separate from it. Ramp management strategies need to be considered as a means of meeting the goals and objectives articulated in the agency strategic planning process.

Ramp management strategies require funding to be implemented, operated and maintained, and therefore must compete for funding with other agency actions. Transportation decision-making follows a tiered government structure starting at the national level, filtering through state and regional levels, and culminating at the agency level. The authority for transportation decision-making spans all these tiers and may also involve several agencies within the same level. Decisions to fund ramp management are primarily at the state, regional, and agency levels, however the overall funding levels and policy direction at the national level affects these decisions.

In order to successfully compete for funding, ramp management strategies not only need to support the goals and objectives of the agency and region, but must also be included in agency and regional long-range transportation plans and shorter-term business plans. The manager responsible for ramp management needs to understand the transportation and business planning processes in his or her agency and region in order to provide input into these processes. In turn, the manager develops specific actions to reflect the decisions made in these processes.

The plans are implemented through annual or multi-year program plans. The program plan lays out the specific projects that will receive funding as incremental steps toward meeting the long-range transportation plan.

It is vital that agency staff understand how the program plans are developed so that they can provide input into their development and advocate for projects of interest, such as ramp management projects. The Traffic Manager or the manager responsible for ramp management activities must understand that there are different funding mechanisms. Knowledge of the funding structure is what allows agency staff to determine how their program can be funded.

Ramp management strategies need to address, and usually conform to, existing regulations and policies. At the same time, regulations and policies should be reviewed to make sure ramp management activities are consistent and to determine if any updates or amendments in regulations and policies are needed. The key is for the manager responsible for ramp management to ensure that there is an appropriate support structure for accepted ramp management activities.

In addition to regulatory and policy support, organizational support is needed in order for ramp management activities to be successful. Agency management should be updated and their support is needed in order for ramp management to be successfully implemented. Once agency management supports the concept, the organizational structure should be assessed to make sure the structure will support ramp management activities. There is no single structure that is better than another and reorganization is rarely required. It is more a matter of determining where in the existing structure ramp management activities best fit.

2.4 Preparing for Successful Operations

There are several institutional and operational considerations that are vital to the success of ramp management. These include:

- Coordination.
- Staffing.
- Resources to support successful operations.

2.4.1 Coordination

Coordination includes internal (intra-agency) and external (inter-agency) activities. Inter-agency coordination covers a broad set of agencies and stakeholders. The key is to break down barriers between agencies and institutionalize working together as a way of doing business among transportation agencies, public safety officials, and other public and private sector interests within a metropolitan region. The agencies and disciplines that are critical to ramp management include:

- Enforcement agencies.
- Local traffic engineering or public works departments.
- Transit agencies.
- Metropolitan Planning Organizations and congestion management agencies.
- Media organizations.

Internally, ramp management needs to be coordinated with the broader traffic management program. As mentioned throughout this handbook, ramp management is one element of the traffic management program and needs to further the goals and objectives of that program. However, internal coordination goes beyond the traffic management program. Personnel responsible for ramp management activities must also coordinate with the following set of internal staff:

- Planning staff, to make sure ramp management needs are incorporated into the agency plans.
- Design staff, to make sure that ramp management needs are incorporated in project designs.
- Maintenance staff responsible for maintaining ramp management equipment.
- Public information staff who are responsible for informing the public of activities related to ramp management.
- Senior management, so they are aware of any issues arising from ramp management activities.

2.4.2 Staffing

Successful ramp management requires skilled, well-trained staff in sufficient numbers to operate and maintain the strategies at effective levels. Staff who operate and maintain ramp management strategies should have knowledge, skills, and abilities (KSAs) similar to staff who operate and maintain other traffic management elements. The needed KSAs will differ based on the functions that staff are intended to perform – planning/design, operations, or maintenance. Chapter 4 provides specific KSAs needed for each of these functions.

Staff assigned to ramp management must be properly trained in the knowledge areas identified above. Training is available from in-house sources, national transportation organizations (e.g., the National Highway Institute), and educational institutions.

The appropriate staffing level will depend on a number of factors including the size of the system, the system complexity, the hours of operation and the specific ramp management strategies chosen. For example, ramp metering will usually require more operations staff in a traffic management center, whereas time-of-day ramp closure will take more field staff.

2.4.3 Resources to Support Successful Operations

Operations staff should be provided with the tools and resources they need to effectively and efficiently carry out their job duties. These tools and resources include:

- Operating procedures.
- Operations, training, and maintenance manuals.
- Operations and maintenance tools.

Operating Procedures

Developing and following standard operating procedures is critical to the success of ramp management activities. Procedures are needed to provide staff with the information needed to do their job – which includes both technical and human resources or personnel procedures. Procedures should be developed for operating, monitoring, and maintaining all ramp management strategies employed. Ramp metering, because metering rates and traffic conditions can change frequently throughout a single peak period, requires the largest set of procedures dealing with operations. Some of the topics to be considered for standard operating procedures include:

- Basic ramp meter operations.
- Ramp meter timing and adjustment.
- When to adjust ramp meter timing based on performance and need.
- How to monitor ramps and their effect on both mainline and arterial traffic flow.
- Performance measures.

For ramp closures, step-by-step procedures are needed to assure that a ramp is closed properly and safety is taken into consideration. These procedures include how to operate any electronic and mechanical equipment that is used for closure, and where and how to place any barriers and signs that are needed for the closure.

Maintenance procedures are needed for maintaining field equipment, such as ramp meters and detectors. Maintenance procedures cover preventive and response maintenance actions and diagnostics.

Operations, Training, and Maintenance Manuals

Training information can either be incorporated into the Standard Operating Procedures (SOP) or reside in a stand-alone document. For ramp management, training manuals should include the information noted above as being part of the SOP as well as detail on the theory behind the strategy, under what conditions the strategy is effective, how to operate the strategy, and how to track performance.

For maintenance personnel, their training manual should include the above information as well as equipment manuals, installation and maintenance instructions, maintenance schedules, and troubleshooting guides.

Operations and Maintenance Tools

Practitioners responsible for ramp management must provide their staff with the tools needed to effectively operate, maintain and troubleshoot ramp management strategies. These tools include software to help staff do their jobs more efficiently or effectively and diagnostic equipment for maintenance personnel so they can more quickly determine the cause of failures to equipment.

2.5 Ramp Management Strategies

As briefly discussed throughout the earlier sections of this handbook, there are four commonly accepted and proven strategies to manage traffic on freeway ramps:

- Ramp closure.
- Ramp metering.
- Special use treatments.
- Ramp terminal treatments.

These strategies are not all mutually exclusive and may be combined to maximize their potential advantages. For example, high-occupancy vehicle (HOV) ramps or bypass lanes, a special use treatment strategy, are often implemented with ramp metering. Ramp terminal treatments are often combined with any one or combination of the other three. However, the unique advantages and disadvantages of each ramp management strategy differ, thereby requiring practitioners to closely analyze each to determine their appropriateness for satisfying existing problems and conditions. The four ramp management strategies that comprise much of the discussion contained in this handbook are introduced and briefly described in the following sections. Chapter 5 of this handbook closely examines each strategy and their related techniques, and provides practitioners with the knowledge needed to narrow the list of appropriate strategies to those that best address existing conditions and problems. The comprehensive analysis of strategies provided in Chapter 5 will also prove useful to practitioners seeking to implement, operate and maintain selected strategies.

2.5.1 Ramp Closure

Ramp closure has the greatest potential impact on existing traffic patterns and is rarely implemented as a long-term strategy. The potential for significant impact is especially true for full or permanent ramp closures, where access to the ramp is no longer provided, requiring traffic to seek alternative routes to access the freeway. In many cases, full ramp closure involves the physical removal of the ramp roadway so as not to give the false impression that the ramp will be re-opened. Other types of ramp closures that affect traffic to a lesser degree include temporary and scheduled closures. These types of closures usually involve deploying automatic gates or manually placing barriers at the ramp entrance to prevent access to the ramp. Due to the relatively high impact on existing traffic patterns, ramp closures are seldom considered for deployment if other viable options are available. Full ramp closure is best applied as a last resort for severe safety problems. Temporary or scheduled closures may be applicable for reducing potential vehicle conflicts that may result from construction, major incidents, emergencies, or special events.

"Ramp metering is the use of a traffic signal(s) deployed on a ramp to control the rate by which vehicles enter a freeway facility."

2.5.2 Ramp Metering

Ramp metering has been deployed and used successfully for roughly a half century in several metropolitan areas. Ramp metering is the use of a traffic signal(s) deployed on a ramp to control the rate at which vehicles enter a freeway facility. By controlling the rate at which vehicles are allowed to enter a freeway, the flow of traffic onto the freeway facility be-

comes more consistent, smoothing the flow of traffic on the mainline and allowing more efficient use of existing freeway capacity. Although controversial at times, if deployed correctly, ramp metering can be an effective tool to address congestion and safety concerns that occur at a specific point or along a stretch of freeway.

Ramp metering offers the potential to reduce congestion and its direct effects through the optimal use of freeway capacity. Metering can significantly improve freeway safety by reducing stop-and-go driving behavior and smoothing the flow of traffic entering freeway facilities. Ramp metering can also improve overall system performance by increasing average freeway throughput and travel speed, thereby decreasing travel delay. Finally, ramp metering can lead to a reduction in fuel consumption and vehicle emissions. Specific benefits documented in past literature are described in Chapter 5.

There are several aspects associated with ramp meter operation that practitioners should be aware of prior to deciding whether to implement ramp metering. These aspects affect how a ramp meter or the system of ramp meters control traffic, based on agency goals and objectives and local conditions. Aspects of ramp metering that need to be considered are listed below. Each aspect is described in greater detail in Chapter 5.

- Metering strategy.
- Geographic extent.
- Metering approaches.
- Metering algorithms.
- Queue management.
- Flow control.
- Signing.

2.5.3 Special Use Treatments

Special use treatments for ramp management give “special” consideration to a vehicle class or classes to improve safety, improve traffic conditions, and/or encourage specific types of driving behavior. Treatments include HOV bypass lanes, exclusive HOV ramps, and ramps dedicated for the sole use of construction, delivery, or emergency vehicles. Special use treatments require that the necessary policies (e.g., HOV, special events) be in place before strategies are implemented and funding requirements can be met.

2.5.4 Ramp Terminal Treatments

Ramp terminal treatments are solutions to specific problems that occur at the ramp/arterial intersection or have the potential to affect operations on the ramp, adjacent arterial, or freeway. Typically, ramp terminal treatments focus on managing queues that form on the ramp that spill back onto an adjacent arterial or the freeway facility. Ramp terminal strategies implemented at entrance ramps will provide better flow of arterial traffic not destined for the freeway and will improve the flow and handling of traffic on the ramp. Ramp terminal treatments implemented at exit ramps may reduce queue spillback from the ramp terminal signal, reducing the potential for collisions on the freeway at the back of the queue.

There are at least four different strategies that can be implemented at ramp terminals that can improve traffic conditions (e.g., traffic flow and safety) on or near ramp facilities:

- Adjustments to signal timing and phasing.
- Ramp widening.
- Additional or changes to turning movements and storage lanes.
- Additional or improvements to signing and pavement markings.

These ramp terminal treatments are described in detail in Chapter 5.

2.6 Developing and Selecting Ramp Management Strategies

Due to the abundance of ramp management strategies, the process of selecting and developing a strategy that best addresses an existing problem or situation can be difficult. It is often helpful to narrow the list of available strategies before selecting the preferred strategy. As part of this process, the impacts of each available strategy should be analyzed more closely to ensure that strategies do not result in new problems or shift existing problems from one location to another. Additionally, the indicators (current conditions or problems that are present that may be corrected through ramp management) for ramp management strategies should be analyzed and the strategies that best satisfy observed indicators should be selected.

The process of selecting ramp management strategies should begin by revisiting transportation management program goals and objectives. Further clarification and understanding of program goals and objectives will help practitioners identify the ramp management strategies that best fit within an agency's transportation management program.

Just because a ramp management strategy is deemed feasible does not necessarily make it the most appropriate strategy based on situations and problems observed in the field. Ramp management strategies may also unintentionally shift problems from one location to another, reducing the overall benefits. Impacts that have the potential to affect the selection of an appropriate ramp management strategy are listed below and discussed in greater detail in Chapter 6:

- Traffic diversion.
- Equity issues.
- Vehicle emissions.
- Arterial impacts.
- Public perception.
- Shifts in land values.
- Ramp geometry and spacing.

Practitioners who consider implementing ramp management strategies should analyze traffic operations on ramps, the freeway mainline and adjacent arterials. There are several indicators that may be used to justify

implementing a strategy. Indicators that may warrant ramp management strategies are listed below:

- Safety.
- Congestion.
- Convenience.
- Access.
- Ramp capacity and queues.
- Adjacent facility operations.

Besides taking into account the impacts of strategies and the indicators that may warrant ramp management strategies, agencies must also consider the fact that, although ramp management strategies may provide additional benefits, existing conditions on the freeway, ramp or arterial may be satisfactory and ramp management may not be necessary. Additionally, agencies considering ramp management strategies may not have the policies in place to support their implementation. However, if it appears that operations on the ramp or nearby freeway or arterial facilities are not satisfactory, and policies are in place, ramp management strategies may be needed and applicable. In this case, the selection of the strategies deemed acceptable needs to be more thoroughly analyzed in order to determine the strategies or set of strategies that are most beneficial for existing conditions. The recommended processes for selecting specific ramp management strategies are provided in Chapter 6.

2.7 Implementation Issues

Ramp management strategy implementation is a delicate process that begins well before strategies are physically deployed, and concludes only when deployed strategies have been successfully tested and initially operated. Before ramp management strategy implementation is seriously considered and systems or equipment are purchased, practitioners must coordinate internally with upper management to determine the feasibility of and support for ramp management strategy implementation. This includes close examination of the minimum requirements to successfully deploy and operate ramp management strategies, such as staffing levels and needs, hardware and software needs, budgetary constraints and resources, and policy directives.

Assuming that the necessary requirements for successful ramp management strategy implementation can be secured and that upper management support has been obtained, practitioners must actively market the benefits of ramp management strategies. As part of this effort, practitioners must solicit and report information to the public and to the various agencies directly and indirectly affected by implementation. In doing so, practitioners must develop methods and tools to successfully collect and distribute information to these groups. Agencies that may be directly affected by the implementation of ramp management strategies include both municipal and county traffic departments, state and local law enforcement, emergency services, and local transit. Coordination with the media as well as neighborhood and community groups is needed to encourage their support so they act as advocates for the implementation of ramp management strategies.

2.8 Operations and Maintenance Issues

Upon implementation, ramp management strategies must be actively operated and maintained to maximize benefits, and to reduce the negative impacts that result from malfunctioning or broken equipment. Failure to operate and maintain systems and equipment in an effective manner will result in inefficiencies that in turn result in decreased performance and safety. Operations and maintenance personnel need to be trained to effectively operate and maintain the ramp management strategies that are implemented. Operators need to be aware of all the internal and external dependencies that may either positively or negatively affect ramp, freeway, and adjacent arterial operations. Operators also need to understand that their actions directly influence the success of ramp management strategies, and as such they must remain cognizant of the policies and procedures that dictate how ramp management strategies are to be operated and maintained.

2.8.1 Operations

Ramp management is one of many elements of a freeway management program. Ramp management operations should not conflict with, but should rather support the overall performance of the transportation management program. All staff responsible for the operation of ramp management strategies should be familiar with established transportation management and ramp management policies and procedures and should be able to reference the operational policies and procedures resources when needed. Operational policies and procedures with respect to the four ramp management strategies outlined in this handbook are provided in Chapter 8.

2.8.2 Maintenance

Regular and timely maintenance of systems helps to extend their useful life spans.

Systems, software, and other devices that support ramp management strategies must be routinely maintained to ensure adequate performance and operational stability. This involves replacing defective parts, cleaning components, updating software, logging repairs, and testing equipment. When systems or devices fail, staff must be available to fix problems in a timely manner to reduce the impact on and exposure to the public. Any delay in fixing problems will result in greater public skepticism of the effectiveness of ramp management strategies. In short, timely maintenance of ramp management strategies ensures the effectiveness of those strategies and furthers the basic goals and objectives of those strategies, such as improving safety and reducing congestion, vehicle emissions, and fuel consumption.

Systems that are maintained according to vendor requirements will last longer than those that are minimally maintained or not maintained at all. Regularly scheduled maintenance activities will allow agencies to use systems up to (or perhaps even beyond) their designed life cycle and obtain maximum benefits from their investments. However, even the best maintained systems will have unexpected component failures. When failures occur, systems need to be repaired as soon as possible. In emergency situations, systems should be repaired immediately so operations can be restored. Therefore, agencies must also define responsive and emergency maintenance procedures, so operations of failed equipment can be restored in a timely manner.

2.9 Performance Monitoring, Evaluation, and Reporting

The goal of performance monitoring is to determine if selected strategies are achieving their intended objectives. Chapter 9 provides a detailed structure for practitioners to carry out the tasks needed to monitor, evaluate, and report performance of ramp operations and ramp management strategies.

More specifically, there are three key components to this process. First, performance monitoring involves collecting performance statistics using manual or automated means. The data collected are used to evaluate or assess the measures of effectiveness (MOEs) of the ramp management strategies. Second, the evaluation presents the data analysis and provides feedback on system performance. Third, reporting is the documentation of the evaluation in a format that is suitable for agency personnel and management, decision makers, or the public.

Determining the type of analysis is the first step of an evaluation. This is dependent upon the objectives of the evaluation and the type of feedback that is desired. Some of the different types of analyses include predeployment studies, system impact studies, benefit/cost analysis, and ongoing system monitoring and analysis. A critical element of the analysis is the definition of an appropriate study area, of which there are three broad categories: localized, corridor, or region-wide. Each has a particular application that can be based on the selected performance measures, proposed analysis tools, and available evaluation resources.

Performance measures are the foundation for identifying the severity and location of problems and for evaluating the selected strategy's effectiveness. Selection of good performance measures includes consideration of goals and objectives, data needs, decision-making processes, and stakeholder involvement. Though there are many categories of performance measures, those that are common deal with safety, mobility, travel time reliability, environmental effects, throughput, and public acceptance.

In addition, for the data collection effort, performance measures must be limited in number, easy to measure, simple, understandable, and geographically appropriate. A variety of data collection methods and tools are discussed in detail in Section 9.3.

After determining the type of analysis, the evaluation has six steps: 1) form the evaluation team, 2) develop the evaluation strategy, 3) develop the evaluation plan, 4) develop detailed test plans, 5) collect and analyze data and 6) document the results. Most evaluation efforts are conducted with a variety of analysis techniques. These can either be analysis tools or models to enhance field measurement or to be used in place of field measurement when data is unavailable. Traffic analysis tools can be grouped according to the following categories: sketch-planning tools; travel demand models; analytical/deterministic tools (*Highway Capacity Manual*-based); traffic signal optimization tools; and macroscopic, mesoscopic, and microscopic simulation models.

Reporting is the link between performance monitoring and strategy refinement. It is also instrumental in showing the benefits of ramp management and building support for ramp management activities. Formats vary based on the needs of the evaluation and the audience.

2.10 Planning and Design Considerations

There are a variety of considerations for the planning and design of the systems and field elements within any capital improvement project that supports a ramp management strategy. Planning and design considerations are discussed in detail in Chapter 10 of this handbook. Every project must be reviewed to ensure that it is consistent with the operational objectives and that all pieces of the project are consistent with one another.

2.10.1 Planning Considerations

To be effective, ramp management strategies often need to take into consideration aspects of ramp management strategy implementation that indirectly affect overall outcomes. For instance, ramp management implementation and operation may be perfect, but if ramp management strategies are not enforced, the overall objectives of strategies may not be achieved. Similarly, if issues affecting equity are ignored, strategies may viewed unfavorably by certain groups of individuals, ultimately limiting the positive impacts that strategies offer. Last but not least, maintenance of strategies must be taken into consideration during the planning process to ensure that strategies can be actively maintained and that malfunctioning equipment does not confuse motorists. Issues related to maintenance, enforcement and equity are discussed further in the following paragraphs.

Enforcement is one key to effective ramp management and control. This is especially true for ramp metering because compliance is critical to its operational success. Therefore, enforcement issues associated with ramp management strategies must be taken into consideration during the planning process so appropriate actions are taken to ensure that ramp management strategies are enforceable. This includes a coordinated effort with law enforcement to ensure that issues such as an appropriate enforcement strategy, safe enforcement areas, adequate staff, and support by the courts are addressed.

Similar to enforcement, equity and environmental justice issues are also a key consideration for ramp management projects. The direct involvement of diverse cultural and economic communities in the development of transportation projects will help to ensure that projects fit harmoniously within their communities without sacrificing safety and mobility.

Performance measurement should be examined in the planning stages of the project. Various types of equipment can be installed to conduct performance monitoring and streamline the data collection process.

Planning is also required for maintenance, especially if new systems are implemented. Therefore, it is important to include the maintenance staff in the planning stages of a project, as they will have recommendations on the types and manufacturers of equipment to procure, equipment location, and other issues that are an integral part of their jobs.

2.10.2 Design Considerations

The *American Association of State Highway and Transportation Officials* (AASHTO) *Design Guidebook* and the *Manual on Uniform Traffic Control Devices* (MUTCD) provide design guidelines for freeway facilities. Some agencies also have their own design guides. Sections 10.6 through 10.9 address the design considerations for ramp closures, special-use ramps, ramp terminal treatments, and ramp metering. The types of equipment, signing, and pavement markings needed are outlined for each.

With many ramp control strategies, ITS elements are typically required. Section 10.8 offers guidance in following a systems engineering approach, whereby the agency can guide their ITS procurement through a step-by-step process from the Concept of Operations and detailed requirements and design to implementation and system acceptance.

2.11 Ramp Management and Other Transportation Improvements

As mentioned earlier in this chapter, ramp management strategies represent one approach to meeting an agency's or region's transportation goals and objectives. However, ramp management strategies should not be viewed in isolation and are often most effective when implemented in conjunction with other transportation improvements. When planning or implementing these other improvements, consideration should be given to ramp management. This section describes some of the possible transportation improvements that are often considered and how they relate to ramp management.

2.11.1 Corridor Planning and Investment

At the heart of any transportation system or program is the efficient operation of the existing or planned facilities. Corridor studies and plans generally look at over-arching needs to improve mobility and increase the people-moving capacity in a transportation corridor. Ramp management activities enhance the efficiency of freeway facilities and could reduce the needs for more costly capital improvements. Ramp management should be considered in corridor investment decisions. The definition of the ramp management component of alternative investment strategies should support the overall character of the investment strategy itself and the transportation goals and objectives of the agencies involved.

Usually, ramp management is not a competing strategy to alternative investments, but is considered as a supporting element of many, if not all, corridor investment strategies. Ramp management strategies can be linked with roadway improvements to improve overall operation for the funding available. Alternative ramp management approaches can be considered, but there is often insufficient detail in the analysis techniques at the corridor level to select from among alternative ramp management strategies. At this level, selection of ramp management approaches to be carried forward is often a matter of policy.

2.11.2 New Highways

The construction of new highways provides additional freeway capacity and travel routes for motorists. It is relatively rare that new highways are constructed in totally new corridors. It is more rare that new highways in urban areas operate in an uncongested state very long after opening. Ramp management, along with the full spectrum of traffic management tools, should be considered in the planning and design of new highways in urban and suburban areas. Geometric decisions, such as ramp spacing and the design of ramp tapers and merge areas, should be made considering ramp management concepts. Accommodations for electrical and communication components of ramp management should be made in the design and construction of new facilities.

2.11.3 Additional Lanes

The addition of more freeway lanes is one of the most basic ways to increase roadway capacity. Ramp management should be analyzed when considering the addition of new lanes, both as a complementary improvement and as an alternative to adding new lanes. As in new construction, consideration should be given to ramp management concepts, including ramp geometrics, ramp spacing, and accommodation of electronic and communication components of ramp management.

2.11.4 Geometric Improvements

There are a variety of other geometric improvements that can be made to a freeway facility. Eliminating geometric deficiencies such as narrow shoulders, narrow lane widths, or substandard acceleration and deceleration lanes are just a few examples of improvements that can complement ramp management strategies. In particular, it is important to consider the merge distance and queuing storage area requirements if ramp metering is a current strategy employed or a likely strategy to be implemented in the future.

2.11.5 Reconstruction and Traffic Management

Ramp metering can sometimes be a “hard sell” to the locals. As an alternative, ramp metering could initially be installed as a temporary solution during a reconstruction project to provide better traffic flow through the work zone. If deemed successful, it can be used afterwards as a permanent installation. Other ramp management strategies, such as ramp closure and special use treatments, can also be effective during construction to improve merge areas in and upstream of work zones.

2.11.6 Incident Detection and Verification

Detecting, verifying, and clearing incidents quickly and effectively reduces resultant congestion and delay and helps to restore roadway capacity in a timely fashion. Ramp management, both metering and closure, can help limit the demand through incident scenes, making it easier for emergency response vehicles to arrive at the incident. Limiting traffic demand through incident scenes also helps to restore free-flow conditions as quickly as possible.

2.11.7 Traveler Information Systems

Traveler information systems assist motorists in making informed decisions about their trips. There are a variety of pre-trip and en-route traveler information sources available – all of which require accurate data to be of value. Ramp management systems also need accurate data to operate properly. Data collected for ramp management purposes can also be used by traveler information systems. For example, most ramp metering algorithms require real-time data on freeway mainline traffic conditions. This information is also of interest to motorists. Further, ramp conditions may be an important element of the traveler information system. Motorists could be alerted to congested areas, queues and incident locations from the data that is collected for the ramp metering system.

2.11.8 Corridor Traffic Management

The greatest concentration of congestion occurs along the principal routes in major metropolitan areas.[3] These routes are often "critical corridors" that link activity centers (e.g., business centers, sports arenas, and shopping areas) with residential areas and carry the highest volumes of people and goods. Ramp management strategies can be coordinated with other corridor traffic management activities to reduce impacts and improve overall mainline traffic flow. For instance, metering may help corridor traffic flow by smoothing the flow of vehicles entering the mainline, but also by encouraging a portion of traffic to use adjacent routes that parallel the mainline. Unused corridor capacity often exists on parallel routes, especially in the non-peak direction on freeways and arterials.

2.11.9 Operational Improvements

Ramp management strategies can improve operations on freeways and arterials and the ramps that connect them. When implementing these strategies, however, special consideration should be taken to ensure that existing signing, pavement markings, and lighting are adequate for the changes in traffic patterns these strategies may cause. For instance, lighting in and around metered ramps should be reviewed to determine if it is sufficient for the queues that may develop. Similarly, geometric improvements to the ramp may need to be implemented if a nearby ramp is closed and the percentage of trucks that use the ramp greatly increases.

2.11.10 High-Occupancy Vehicle Facilities

Providing incentives (e.g., less delay) for high-occupancy vehicles (HOVs) can reduce demand by converting single-occupant vehicle trips to HOV trips. Ramp management strategies can support policies to encourage HOV trips. HOV bypass lanes or HOV-only ramps allow motorists to avoid queues formed at metered locations. HOV ramp management treatments are especially important around park-and-ride facilities to provide unencumbered freeway access for buses, vanpools, or carpools originating at the park-and-ride facility.

2.11.11 Special Event Management

A special event is "a public attended 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." A special event represents a trip generator; thus the impact an event has on transportation system operations as a whole must be examined. This includes operations on freeways, arterials and ramps. Ramp management can improve operations on these facilities when special events occur, helping to minimize the impacts that special event traffic has on neighborhoods and non-special event-related traffic near the special event. Ramp management may be applied to reduce the length of queues on ramps, allowing queues to be fully contained to the ramp instead of flowing back onto the freeway and adjacent arterial. This not only improves safety on these facilities, but also improves the flow of traffic that use them. Ramp management may also be used to minimize the impacts on neighborhoods near the special event by restricting assess to ramps in the areas, requiring special event traffic to use upstream and downstream ramps, where traffic will have less of an impact.

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