MODULE 4. LANE USE CONTROL

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Figure 4-1. Proper Lane Use Control Can Facilitate Safe and Efficient Operations.

4.1 INTRODUCTION

BACKGROUND

Another approach to improving the safety and efficiency of freeway operations is the control of traffic on the freeway mainline. This involves the regulation, warning, and guidance of traffic on the freeway mainline so that some or all of the following objectives are addressed:[(1)]

- To achieve a more uniform and more stable traffic flow as the freeway demand approaches capacity, thereby improving the utilization of the facility and preventing the onset of congestion.
- To reduce the probability of rear-end collisions caused when motorists unexpectedly encounter congested conditions.
- To distribute total delay in a more equitable manner, saving some freeway capacity for downstream segments.
- To increase the efficiency of operation under restricted-capacity conditions caused by incidents or maintenance operations.
- To divert some freeway traffic to alternative routes or to alternative departure times in order to make better use of corridor capacity.

TREATMENTS

Traditionally, freeway lane use control is accomplished through one or more of the following methods:

- Static signing.

- Dynamic message signs.
- Temporary traffic control devices.
- Law enforcement/legal restrictions.
- Economic incentives/disincentives.

These methods are often combined to form an effective subsystem from both a safety and operations perspective. For example, both appropriate static signing and temporary traffic control devices are required in order to temporarily close a freeway travel lane for maintenance or construction activity.(2) In some instances, dynamic message signs may be provided upstream to encourage diversion from the freeway or to further warn of the downstream lane closure. As another example, the restriction of large trucks to certain travel lanes may be accomplished by static signing to notify truck drivers of the restriction, and by police enforcement of those restrictions.

MODULE OBJECTIVES

The objectives of this module are as follows:

- To provide a summary and description of different lane use control philosophies and treatments.
- To provide insight into the issues associated with lane use control subsystems for freeway traffic management.

MODULE SCOPE

This module begins by applying the decision process described in **Module 2** to the lane use control subsystem analysis. The techniques used to control lane use on freeways are then described. Special issues associated with lane use control are addressed following description of the techniques. The module concludes with examples of lane use control subsystems, describing the dynamic information system component of TransGuide in San Antonio, and the use of congestion pricing on the SR 91 Express Lanes in Orange County, California.

4.2 DESIGN PROCESS

PROBLEM IDENTIFICATION

The development of a lane use control subsystem begins by developing a full understanding of the problems or situations that need to be addressed through this subsystem. At the most basic level, the problems treated via lane use control are similar to those specified for other freeway management subsystems. These include excessive peak period vehicle demands that result in congestion, safety problems, excessive vehicle emissions that degrade the air quality of a region, etc. Most generally, the types of problems that need to be treated through lane use control are as follows:

- One or more vehicle lanes must be closed to all traffic for some period of time (due to scheduled work activity or an incident).
- One or more types of vehicles need to be separated from each other in one or more vehicle lanes.
- Speeds and flow rates in a given lane are judged to be too high for safe and efficient operations.

These problems lead directly into the three basic categories or situations that are most commonly treated through some form of lane use control:

- Restricting the use of freeway lanes and shoulders by all vehicles.
- Restricting the use of freeway lanes or shoulders by specific vehicle types.
- Metering how vehicles utilize a freeway lane or shoulder.

The restriction of freeway lane usage by all vehicle types includes such specific actions as temporary lane closures for roadway maintenance and construction activities or incidents when crashes or vehicle stalls block individual travel lanes, and peak-period congestion relief actions where vehicles are allowed to utilize a shoulder as a temporary travel lane during the peak period. Lane use restrictions based on vehicle type covers such topics as high-occupancy vehicle lanes and large truck restrictions. Finally, strategies to meter a freeway lane or a shoulder include freeway-to-freeway connector metering or the reduction of speed limits through dynamic advisory speed signs or speed enforcement.

For freeway lane use control, it is imperative that decision makers have a true understanding of the problem(s) being addressed through lane use control, and also a sense of the degree of urgency or severity of those problems. Not all strategies available for use are equally effective or costly in managing freeway lane usage. For example, both dynamic advisory speed signs and speed enforcement strategies can be viewed as methods of reducing freeway speeds in one or more lanes. However, the effectiveness and costs would be expected to be significantly greater for enforcement than for advisory signing.[3]

IDENTIFICATION OF PARTNERS AND CONSENSUS BUILDING

For all aspects of freeway management, information sharing is essential in today's environment. This is particularly true for lane use control strategies. The political implications of these control strategies can be very important, particularly with respect to lane restrictions which require legislation and enforcement to enact. Also, support by enforcement agencies of the decisions made regarding lane use control is essential if those decisions are to achieve their intended purpose.

Potential Partners

The partners involved in lane use control will vary depending on the particular problems being addressed. The partners that are most commonly associated with these types of activities include the following:

- State and local DOTs.
- State and local law enforcement agencies.
- Elected officials.
- Transit agencies.
- Trucking companies.
- Private contractors.

Concern over the interaction between automobiles and trucks on freeway facilities is often a controversial part of freeway management activities. Fortunately, trucking companies have demonstrated a willingness to work with public transportation and enforcement agencies to develop compromises about when and where trucks will travel during peak periods, major freeway construction activities, or special events.[(4)] Consequently, they can be an integral partner in decisions regarding lane use control as well.

Consensus Building

After identifying the partners affected by lane use control actions, a consensus about the problems and need for solutions must be developed. Early on, it is critical to establish support for the general concepts about lane use control from elected officials and the general public. This is particularly important when not all motorists are affected equally by the actions that may be implemented (via tolls, lane restrictions for certain vehicles, etc.). Support is also needed from upper management at each of the agencies listed above.

ESTABLISH GOALS AND OBJECTIVES FOR LANE USE CONTROL

Proper decision making about the selection, design, and implementation of lane use control strategies requires goals and specific objectives about what is to be accomplished by using these strategies. General goals and objectives that feed directly into this step may have been established early on in the development of a comprehensive freeway management system . If not, it is imperative that the exact objectives to be accomplished via lane use control be specified. As discussed in **Module 2**, goals are broad statements of intended outcomes, whereas objectives specify exactly what is to be accomplished. Examples of objectives which lane use control may be able to address include the following:

- Increasing the available throughput over a given section of freeway.
- Providing at least a travel time incentive to high-occupancy vehicles.
- Extending pavement life (by restricting trucks from particular lanes).
- Reducing truck-automobile accidents over a given freeway segment.
- Reducing peak-period traffic demand on the freeway.

ESTABLISH PERFORMANCE CRITERIA

Performance criteria must be established for each of the objectives identified in the previous step of the process. These criteria are used to determine whether each of the objectives is met or exceeded. For the most part, performance criteria to be used will be fairly obvious if the objective(s) to be accomplished are specified correctly. For example, an objective to reduce high-occupancy vehicle travel time would utilize a travel-time measure as its performance criterion. However, additional performance criteria may be specified as checks of the primary performance criteria, or to measure other constraints that may exist on freeway lane operations. As another example, performance criteria concerning single-occupant vehicle violation rates might also be used to evaluate the need for a barrier-separated HOV lane (see **Module 6**) versus a concurrent flow HOV lane with no barrier separation. The following list presents some typical performance criteria for lane use control subsystems.

- Level of service on a facility (see **Module 2**).
- Compliance (lane violation) rates.
- Change in mode split, average occupancy rates.
- Accident reductions.

- Results of public and/or special interest opinion polls.

DEFINE FUNCTIONAL REQUIREMENTS

The functional requirements of a lane use control component in a freeway management system define specific actions or activities that are to be performed in order to achieve one or more of the objectives for that component. In theory, the functions should be defined independent of the technology used to implement them. However, some lane use control objectives may be so narrowly defined and governed by standards or policies (temporary freeway lane closures for maintenance, for instance) that this step in and of itself defines the technology to be used.[5] For other objectives, though, the technology required may not be so obvious, and so a definition of functional requirements would be warranted . Figure 4-2 presents an example of possible functional requirements of a lane control subsystem to increase peak period freeway capacity.

DEFINE FUNCTIONAL RELATIONSHIPS, DATA REQUIREMENTS, AND INFORMATION FLOWS

The functional relationships, data requirements, and information flows show how the lane use control functions will be integrated with each other and with the other freeway management system components (such as surveillance or motorist information dissemination). When defining the functional relationships, data requirements, and information flows as they impact dynamic message signs and surveillance, the National Transportation Communications Interface Protocol (NTCIP) and the National ITS Architecture should be followed.[6] This approach provides the following advantages:

- Automatically determine when freeway lane volumes reach 90 percent of estimated capacity.
- Check to ensure that no stalled vehicles are located on the shoulder in the affected section of freeway.
- Notify motorists at the beginning of the affected section that freeway shoulder can be used as a travel lane.
- Notify motorists at the end of the affected section that they should return to the normal freeway travel lanes.
- Terminate motorist notification of allowability of freeway shoulder usage at the end of the peak period.

Figure 4-2. Example of Possible Functional Requirements of a Lane Use Control Objective.

- It allows components from different vendors to be used interchangeably, increasing competition and reducing costs.

- It eases future upgrades or expansions of the components. The necessary interfaces to other components of the freeway management system (i.e., surveillance) have already been established.

For other lane use control functions, informal functional relationships, data requirements, and information flows may be acceptable, but should be prepared nonetheless. For example, the functional relationships, data requirments, and information flows for managing a temporary total freeway closure over the weekend might include how real-time data concerning traffic conditions, project status, and/or the effects of weather are transferred between the transportation agencies (such as the traffic, maintenance, and public information divisions), enforcement agencies, the media, and the private contractor.

IDENTIFY AND SCREEN TECHNOLOGY

After the functional relationships have been specified for the functions to be accomplished through freeway lane use control, decision makers must then assess available technologies and strategies to determine which are most appropriate to meet the desired objectives of this subsystem. Depending on the types of functions being accomplished, the assessment should include considerations of both the spatial and temporal characteristics of the freeway system and motoring public. For example, spatial considerations address technology/strategy adequacy from the aspect of roadway design and construction, and may require the decision maker to answer questions such as the following:

- Is the pavement on the shoulder adequate to support vehicle travel?

- How will restricting large trucks to a specific lane or lanes affect vehicle merging or diverging maneuvers at entrance and exit ramp locations?

Temporal considerations are also important for assessing technologies for real-time lane use management. For example, before considering truck lane restrictions on a freeway facility, a decision maker may want to consider whether truck-automobile conflicts and crashes are a problem at all times of the day or only during certain periods. Likewise, decisions regarding when and how many lanes will be closed to accomplish a given work activity are a major part of the work zone planning process.(7) For instance, it may be possible to close more travel lanes at night to do the work, but this requires channelizing devices and other traffic control devices that provide higher levels of retroreflectivity (increasing planning and traffic control costs).(7)

Another factor to consider when identifying and assessing alternatives for lane use control are the political sensitivities and ramifications to those alternatives. Those alternatives which would adversely impact some motorists in order to provide an advantage to other motorists have typically been met with resistance. For instance, those HOV projects which have taken a regular-use travel lane and converted it into an HOV lane (i.e., take-a-lane alternatives) have generally been less successful than those which have constructed a new HOV lane while maintaining the same number of regular-use lanes as before (i.e., add-a-lane alternatives).(4) Alternatives that involve direct cash outlays, such as toll facilities or congestion pricing schemes, have also been met with resistance.[8] These alternatives require more public outreach and political interaction between the partners to ensure that they will be successful if implemented.

PLAN DEVELOPMENT

After the various lane use control alternatives available have been screened and the one(s) most appropriate for use selected, decision makers then prepare detailed plans regarding implementation of the selected alternatives. The actual format and content of the plan varies dramatically by the type of alternative being implemented. The plan for a temporary lane closure for maintenance work may be as simple as a standard traffic control plan (TCP) that has been adopted by the agency for that particular roadway/road work condition. Conversely, the plan to implement a congestion pricing scheme based on real-time traffic conditions and utilizing ITS technologies may need to follow detailed implementation plan requirements as specified by FHWA (see **Module 2**). [9]

Enforcement should be a key element of all lane use control plans that are developed. Plans should address both the management and coordination requirements between the various partners, relative to enforcement. Operational issues such as staff requirements and citation locations also need to be addressed during plan development.

FUNDING SOURCE IDENTIFICATION

Many of the lane use control strategies employed during freeway management activities are supported as part of an operating agency's normal activities, or are addressed during development of other components of the freeway management system (i.e., information dissemination subsystems). Consequently, the primary concern for these strategies is the extent to which introducing the new strategy affects the existing budget for operations and maintenance, and whether this impact can be accommodated through a reallocation of agency funds.

Those strategies which are larger in scope and/or applied across jurisdictional boundaries often require more innovative and complex funding mechanisms. Funding of lane use strategies involving HOV lanes, information dissemination, and/or incident management subsystems are addressed in **Modules 6**, **7**, and **8**, respectively.

Two of the major lane use control options, implementation of tolls and/or congestion pricing strategies, result in revenues that are used to offset the cost of constructing and operating these strategies. Traditionally, toll facilities were converted to "free" roadways once the bonds used to construct the roadway had been paid. Recent changes in legislation, however, now allow agencies to continue toll operations after bond payment, and to use the revenues to fund other traffic management activities.

IMPLEMENTATION

Experiences from past freeway management projects indicate that it is best to implement strategies and techniques incrementally where possible in order to develop operational experience with the strategies, and to demonstrate the advantages of the techniques to elected officials and to the public.[4] This may be true for some of the more "innovative" or controversial lane use control strategies as well. For these situations, consideration should be given to initiating small, demonstration-type projects at a location or over a section of freeway where the benefits are expected to be the greatest. In this way, the partners can illustrate the benefits of the strategy and generate the support necessary to proceed with more extensive implementation if desired.

EVALUATION

The final step in the decision process for lane use control is to establish the mechanism for evaluation of the strategies once they have been implemented. It is important to monitor the impacts and benefits of new strategies and techniques as they are implemented to determine if they meet the intended objectives and functions for which they were designed. Also, it is important that these data be collected so that they can be collated and disseminated in an ongoing manner to elected officials and the general public. In this way, continued funding for these strategies can be obtained more readily, and expansion of activities to further improve facility operations will be more readily accepted.

4.3 TECHNIQUES AND TECHNOLOGIES

Lane use control can be implemented through the following means:

- Static signing.
- Dynamic information systems.
- Channelizing devices.
- Use of narrow lanes and shoulders.
- Mainline metering.
- Toll facilities/congestion pricing.
- Automated highway systems.

A brief description of how each of these technologies applies to the lane use control concept is provided below.

STATIC SIGNING

Signs are used to provide guidance and warnings as needed to ensure the safe and informed operation of individual elements of the traffic stream. Signs can provide lane use control by restricting certain vehicles from using or not using a particular lane. Examples include the following:

- Restricting trucks to the right most lane(s) or to specific times of day that they can use a facility.
- Establishing lane(s) for high-occupancy vehicle use only.

Discussions of these examples follow.

Static signing is also used for warning purposes in advance of construction and maintenance work zones to inform motorists that one or more travel lanes are closed downstream. These generally supplement the channelizing devices placed at the point of closure to require drivers to vacate the lane at that point (channelizing devices are discussed later in this module).

Truck Restrictions

Several States restrict the lanes in which trucks may operate. The objective in restricting trucks to the right lane or lanes is typically to improve highway operations and reduce accidents. Also, to provide for uniform pavement wear, trucks are sometimes restricted from the right lanes. Lane restrictions through construction zones are used to move the trucks away from workers and from narrower lanes. Table 4-1 is a summary of experience regarding lane restrictions in various states and in research studies.[5] Several States adopted lane restrictions because trucks were often observed traveling abreast across several lanes, denying passing opportunities for other vehicles.

A survey of State practice in 1986 by the FHWA identified the most common reasons given for using truck lane restrictions:

- To improve operations (fourteen States).
- To reduce accidents (eight States).
- For pavement structural considerations (seven States).
- Because of restrictions in construction zones (five States).

A total of 26 States used lane restrictions, according to survey information. The survey of FHWA field offices also indicated that, in most cases, restrictions have been applied without detailed evaluation plans, including before-and-after studies. Where accident analyses were undertaken, little change in accident experience was noted under any of the restrictions.[10]

Truck restrictions can be implemented in a number of other ways as well. Table 4-2 summarizes the constraints and impacts of different types of restrictions.

HOV Restrictions

Another form of lane use control is when a lane is restricted for use by high-occupancy vehicles only. Several types of static signs have been used to communicate the restriction. (For discussion on high occupancy vehicle lanes, see **Module 6**).

INFORMATION DISSEMINATION SYSTEMS

Information dissemination systems can be employed to advise motorists of freeway conditions so that appropriate actions can be taken to enhance the efficiency and safety of freeway operations. **Module 7** provides a discussion of information dissemination principles and technologies. For lane use control applications, both lane control signals (LCS) and full-matrix dynamic message signs (DMSs) can be used to convey lane use and lane status information to drivers. LCSs are a fixed-grid DMS (refer to **Module 7**) that use both color and symbols to convey information. The Manual on Uniform Traffic Control Devices (MUTCD) defines LCSs as special overhead signals having symbols that are used to indicate whether the use of a specific lane or lanes of a street or highway is permitted or prohibited, or to indicate the impending prohibition of use.[2] In the United States, LCSs have most commonly been used for reversible-lane control. However, they are also appropriate for use on freeways in the following situations:[2]

- On a freeway, where it is desired to keep traffic out of certain lanes at certain hours to facilitate the merging of traffic from an entrance or exit ramp or other freeway.
- On a freeway, near its terminus, to indicate a lane that ends.
- On a freeway or long bridge, to indicate a lane that may be temporarily blocked by an accident, a breakdown, or some other incident.

In addition, at least one operating agency (Virginia) uses LCS to indicate to motorists that a shoulder can be used as a travel lane

Table 4-1. Lane Restrictions Experiences.[5]

Location/Study	Conditions	Results/Comments
Florida I-95, Broward County	Conducted a 6 month, 7 am to 7 pm study in 1988	Public feels safer with lane restrictions for trucks. Overall accidents up 6.3 percent (7 am to 7 pm period); truck accidents down 3.3 percent.
Georgia	Beginning Sept. 1986, trucks were restricted to the right lane(s) except to pass or to make a left-hand exit.	On I-285, trucks were at fault in 72 percent of lane-changing violations. Before the restriction, trucks were observed occupying all lanes thus prohibiting passing.
New Jersey	Turnpike Authority (NJTA) imposed lane restrictions in the 1960s. Restrictions do not allow trucks in the left lane of turnpike roadways that have three or more lanes by direction.	Sources at the NJTA stated that the compliance rate for truck lane restrictions is very high.
Illinois	Began in 1964.	Public feels safer, and better operations.
Maryland Capital Beltway	Believed to have been implemented as a reaction to a major truck accident.	Public feels safer. Effects on safety not well known.
Virginia Capital Beltway	Four studies, one for 24 months, others for 12 months.	Public and political perception: safer highways. Engineering study recommended removal. Accident rate increased 13.8 percent during 2-yr study. Second study also showed increase.
Michigan	Statewide restrictions require trucks to use the right two lanes on roadways that have three or more lanes.	Establishment was thought to be politically motivated No studies available to evaluate the countermeasure.
Garber Study	Simulation based on data from nine sites.	Decreased headways in right lane Slight increase in right lane accidents.
Hanscom Study	Two 3-lane suburban sites, all <100,000 AADT.	Beneficial traffic operations and reduced congestion.

Table 4-2. Summary of Impacts from Truck Restrictions. [11]

Action	Constraints/Limitations	Impacts
Lane Restrictions	• Lane drops at freeway-freeway interchanges limit application. • Could be difficult to enforce. • Could accelerate pavement deteriorations. • Could reduce visibility of overhead signing (if trucks restricted to outside lanes).	• For freeway segments with lane drops, would concentrate lane changes in short section of freeway. • Would increase merging conflicts.
Time-of-Day Restrictions	• Truck traffic peaks do not coincide with typical commuter peaks. • Could be difficult to enforce. • Could be challenged on legal basis.	• Negligible impact on operating speeds. • Could divert trucks to other less congested time periods, or other, lower quality roadways. • Could negatively impact trucks that must travel during restricted periods.
Speed Restrictions	• Differential speed limits for trucks and non-trucks could be difficult to enforce. • Could require extensive enforcement program. • May require use of innovative detection, apprehension, and citation strategies.	• Reduction in speed (differentials) could have positive safety impacts.
Route Restrictions	• Efficient routing plan could not exclude freeways.	• Negligible impacts on safety and operations. • Could have positive impacts if applied to transportation of hazardous materials.
Driver Training/ Certification	• Requires strict application and enforcement of regulations.	• Short-term impacts minimal. • Long term impacts could be significant.
Increased Enforcement of Existing Regulations	• Would require additional enforcement personnel. • Could require incorporation of enforcement requirements in design/re-design of freeways.	• Increased enforcement could lead to increased compliance with traffic laws. However, there is no conclusive proof that increased compliance reduces accidents.

during peak travel periods.[12] Figure 4-3 shows a typical freeway LCS.

The MUTCD gives information on the design, location and operation of lane-use control signals. The meanings of freeway lane-use control signals are as follows:[2]

- A steady DOWNWARD GREEN ARROW means that a driver is permitted to drive in the lane over which the arrow signal is located.
- A steady YELLOW X means that a driver should prepare to vacate, in a safe manner, the lane over which the signal is located because a lane control change is being made, and to avoid occupying that lane when a steady RED X is displayed.
- A steady RED X means that a driver shall not drive in the lane over which the signal is located, and that this indication shall modify accordingly the meaning of all other traffic controls present.

In contrast to LCSs that display a rather small number of colors and symbols, full-matrix DMSs are capable of providing a large number of descriptive messages to indicate that one or more travel lanes are closed downstream, that a freeway shoulder can be used as a temporary travel lane, that an HOV lane is open to mixed-use traffic (as might occur during a major incident), or that trucks normally restricted to a right lane can use other travel lanes as well (as also might occur during a major incident).

Figure 4-3. Typical Freeway Lane Control Signal.

LCSs are smaller than full-matrix DMSs, and so are considerably cheaper to purchase and maintain. This means that LCSs can be installed more frequently along a freeway than can larger and more expensive DMSs. Also, since LCSs use symbols and colors rather than words to convey information, they can be more readily understood by non-English speaking motorists. However, the amount and type of information that can be displayed via LCSs is much more limited than via a typical DMS.(13)

Regardless of the technology used, information dissemination systems alone cannot force vehicles to vacate a lane or utilize a shoulder as a travel lane. They do provide guidance about lane status, and are intended to promote safer operations by warning motorists upstream of an actual lane blockage.

USE OF NARROW LANES AND SHOULDERS

Research has confirmed that shoulders and narrow lanes can be used effectively to increase capacity in congested metropolitan corridors. Based on a recent NCHRP study, it is recommended that these strategies be reserved for use as techniques to improve traffic flow in congested corridors.(14) Widening a corridor over an extended length through the use of these strategies is not recommended. Rather, applications of these strategies should be viewed as a temporary technique for congestion relief. It is recommended that this technique should typically be limited to sections of 1.61 km (1 mi) or less.

Reduction in the travel-lane width to 3.4 m (11 ft) should be the first modification considered. Next, reduction of the left shoulder should be considered before reducing the right shoulder. Research and observations by enforcement personnel indicate that the right shoulder is the preferred refuge area. Also, emergency response is easier to provide if the right shoulder is maintained. If the right shoulder is used and the left shoulder maintained, emergency equipment entering a congested area must work its way across the queue to the left shoulder as opposed to proceeding on the right shoulder. In some cases, the right shoulder or both shoulders have been used. Table 4-3 summarizes the primary advantages and disadvantages of each approach.

Where there is a high percentage of truck traffic (i.e., 5 to 10 percent) during the peak period, use of shoulders and narrow lanes is not recommended. Also, for projects involving possible application of shoulders and narrow lanes, a step-by-step approach (site specific) must be used to ensure an adequate evaluation.

MAINLINE METERING

Mainline metering controls the mainline traffic entering a freeway control section. While the technique can create congestion on the mainline upstream of the control section, it can help maintain uncongested flow on the mainline downstream through the control section. An application of mainline metering has been documented in Japan, where it has been made effective by regulating the number of toll booths open, thereby controlling the traffic entering the freeway. Another application is the San Francisco-Oakland Bay Bridge mainline metering in Oakland, where controls are used after vehicles pass through the toll plaza at a point prior to entering the ridge.(15) Other applications of mainline metering on controlled-access facilities such as terminals, bridges, and toll roads have been found to be effective, but the concept has yet to be applied to a typical metropolitan freeway system.

Table 4-3. Primary Advantages and Disadvantages of Shoulder Removal. [14]

Design Alternative	Advantages	Disadvantages
Use of Left Shoulder	• Left shoulder not used as much for emergency stop/or emergency enforcement • Least expensive if width is available • Trucks often restricted from left lane	• Usually requires restriping • Sight distance problem with some median treatments
Use of Right Shoulder	• Often the easiest to implement	• Right shoulder is preferred area for emergency stops and enforcement • Sight distance changes at merge and diverge areas of ramps
Use of Both Shoulders	• Not recommended • Use ONLY in extreme cases	• Requires restriping • Safety concerns (no refuge) • Enforcement is difficult • Incident response longer • Maintenance more difficult and expensive

Another potentially effective use of mainline metering that has not yet been applied is in a construction zone where traffic demand greatly exceeds the capacity available, and some reserve capacity for vehicles entering at downstream ramps needs to be provided.[1]

Another application of mainline metering involves using DMSs to display reduced advisory speed limits over sections of freeway. This technique is commonly used on portable DMSs upstream of work zone lane closure activities.[16] However, its application to freeway management in the U.S. has been less favorable. Nonetheless, this approach is used with reasonable success outside of the U.S.[17]

FREEWAY-TO-FREEWAY RAMP METERING

The primary benefit of ramp metering is that it reduces congestion and shockwaves on freeways. Metering eliminates the heavy surges or platoons of entering traffic and allows the freeway to carry substantially higher volumes at higher speeds. It also substantially reduces accidents, especially the rear-end type crashes that result from stop-and-go driving. Reduction in accidents and congestion also results in overall reductions in fuel consumption and air pollutant emissions. Freeway-to-freeway ramp metering uses a meter on a ramp from another freeway to control the entrance of vehicles onto the new freeway. Minnesota Department of Transportation (MnDOT) has been successfully metering freeway-to-freeway ramps for over 20 years and is currently metering 74 ramps. Although there is some concern over metering these high volume ramps, MnDOT believes it is desirable to do so because heavy surges of traffic, if left unmetered, can severely affect the operation of the receiving freeway by causing congestion and accidents.[18]

CHANNELIZING DEVICES FOR WORK ZONES

Traffic management in construction and maintenance work zones is important to the safety of both workers and motorists. Time is required to properly develop and implement the traffic control when lanes must be closed to complete the work. No one sequence of traffic control devices can be designed for all situations. The traffic control plan should be designed to provide the same number of lanes of traffic during construction as before and ideally, be designed for the same free-flow traffic speed that existed before freeway construction began. A work zone cannot always maintain the same number of lanes and, in addition, where motorists drive in a work zone can be influenced by the traffic control devices present.

Static signs are used for directing traffic in advance of and within a work zone. However, variable message signs and arrow panels supplement channelizing devices and provide additional target value and suitable messages that attract motorists' attention as they approach a work zone. Highway Advisory Radio (HAR) can also be used to provide more information, including route detours. Newspaper articles and traffic broadcasts can also be employed to alert motorists to general construction and maintenance work zone locations, but provide limited detailed information about specific lane closures and traffic delays.[1]

Within the work zone itself, traffic must be channeled from the lane(s) being closed to one that is open. A number of different types of channelizing devices can be used, depending on the duration of the closure, traffic speeds, etc. These devices include but are not limited to the following:[2]

- Cones.
- Tubular markers.
- Vertical panels.
- Drums.
- Barricades.

Regardless of the device used, it is critical that proper spacing and length of taper be employed to safely transition motorists from the closed lane(s) to the open lane(s).[2]

Portable barriers may be used to separate traffic from the work area and to protect the construction workers. Special signing and temporary delineation and/or route detours may be needed when these barriers are moved and traffic is shifted. Portable barriers have been used to create HOV lanes in Dallas and Boston. This device could also be used as a lane control technique in a construction area. (See the discussion in **Module 6** for additional information).

TOLL FACILITIES/CONGESTION PRICING

Toll facilities are fully controlled access roadways designed to the same high standards of design as freeways. However, because of both the economic influence they exert on traffic demand for the facility and the traffic metering effect that occurs at the toll collection plazas, toll facilities can also be considered another form of lane use control. Toll facilities form the most direct user charge for providing revenues based on the costs of travel. Often, they can be implemented more quickly, because the capital funding is available up front and because toll roads often do not have to comply with federal regulations. [19] Also, toll facilities provide adequate funding for ongoing operations and maintenance.

In recent years, legislation has been enacted to facilitate the development of toll facilities through innovative financing. For example, the Federal Highway Act of 1987 provided for eight demonstration projects across the nation, allowing a mixture of toll revenues with State and federal funds on new projects.[20] California enacted legislation that allows the development of joint-power authorities to collect developer fees for transportation projects, and awarded four franchises to private entities, allowing private designing, financing, construction, and operation of toll facilities for 35 years.[20]

Two basic types of collection methods are used: mainline barriers at intermittent spacings, and toll collection at interchanges. Where mainline barriers is used, the location of the barrier should be far enough from exit or entrance ramps to avoid weaving problems. Toll plazas should be located on tangent alignment with decision sight distance provided on the approach. Grades approaching the plaza should not exceed 0.5 percent. The design of the plaza itself should be based on the expected number of peak-period arrivals and the rate at which they can be processed. Sufficient toll collection lanes of great enough length should be provided to minimize the length of queuing at the plaza. Where toll collection occurs at exit and/or entrance ramps, care should be taken in interchange ramp design. Plazas should be placed far enough upstream from the ramp diverge to provide for normal deceleration and braking to a queue.[1]

A new technology experiencing increased use is Automatic Vehicle Identification (AVI) technology for automatic toll collection. The technology is being implemented to increase capacity and decrease delays and congestion at toll plazas. Figure 4-4 illustrates the proposed use of the AVI technology on the toll roads. An AVI system speeds the toll collection process by having a device identify each vehicle as it approaches a toll plaza or passes a check point, and charging the proper toll to the user's account, eliminating the need for vehicles to stop.

Congestion pricing is a transportation management technique similar in concept to toll facilities, but which attempts to spread peak traffic demands to less congested segments of the network and to less congested periods of the day. The application of congestion pricing has been very limited within the U.S. Experience in Hong Kong in the mid-1980s proved the program to be a technological success, although not widely accepted by the public.[22]

Recent advances in technology are making congestion pricing a viable option in the U.S. Automatic fare collection systems can be used for this purpose, including optic scanners and radio frequency technology. The system would automatically charge the user by prepayment, direct billing, or credit card. A billing statement would be received by the user each month. Typically, the user would receive advance notification of billing rates, ideally one month prior to charging. Table 4-4 shows a typical user fee schedule.

Key issues relative to congestion pricing in the U.S. are as follows:[23]

- Technology compatibility — between toll collection systems across the country and across travel modes.

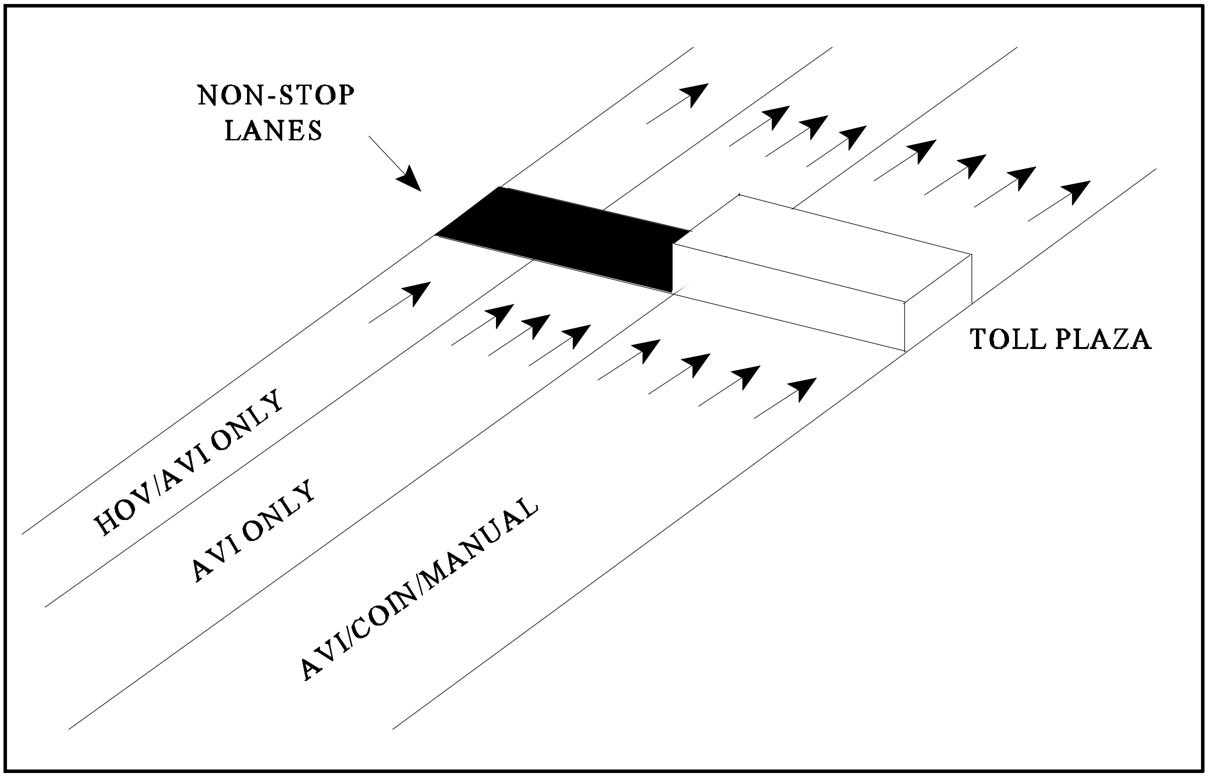

Figure 4-4. Schematic of an AVI Toll Plaza. [21]

- Enforcement — concerns about legislative changes needed to allow vehicle owners to be ticketed, rather than drivers. Also, verification of occupancy requirements (if implemented) needs to be accommodated without unduly affecting the overall operations of the facility.

- Privacy — concerns about the potential tracking of individuals through the AVI technology. One alternative proposed is the use of "Smart" cards which maintain their own internal data about the individual's account.

- Price determination — questions have to be resolved (should charges be based on short-term marginal road user costs of an additional vehicle added to the traffic stream, or on long-term costs of providing an equivalent amount of extra capacity to the facility to accommodate that alternative pricing structures upon traffic demand, air quality, land use, etc. are difficult to estimate at this time.

AUTOMATED HIGHWAY SYSTEMS

Automated Highway Systems (AHS), a component of the Intelligent Transportation Systems (ITS), is seen as the next major performance upgrade of the United States vehicle-highway system. It should be mentioned, however, that AHS is still in its infancy and is many years from being an operational reality. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 established a program to determine the feasibility of an AHS. Research has shown that AHS has the potential to double or triple the nation's roadway capacity and reduce the frequency and severity of incidents while providing more stable traffic flow.[24,25] The increased capacity will result from the closer longitudinal and lateral

Table 4-4. Typical User-Fee Schedule.[22]

Route Segment Number	Peak Period (6:01 am - 9:00 am; 3:01 pm - 7:00 pm)				Off-Peak Period (9:01 am - 3:00 pm; 7:01 pm - 6:00 am)			
	1	2	3	4	1	2	3	4
A	$0.09* 45 mph	$0.09 45 mph	$0.09 45 mph	$0.07 50 mph	$0.05 55 mph	$0.05 55 mph	$0.05 55 mph	$0.04 55 mph
B	$0.04 60 mph	$0.04 60 mph	$0.04 60 mph	$0.04 60 mph	$0.02 60 mph	$0.02 60 mph	$0.02 60 mph	$0.02 60 mph
C	$0.06 25 mph	$0.06 25 mph	$0.05 30 mph	$0.05 30 mph	$0.04 35 mph	$0.04 35 mph	$0.02 40 mph	$0.02 40 mph
D	$0.10 40 mph	$0.10 40 mph	$0.08 45 mph	$0.08 45 mph	$0.08 45 mph	$0.08 45 mph	$0.06 50 mph	$0.06 50 mph
E	$0.10 20 mph	$0.10 20 mph	$0.08 25 mph	$0.08 25 mph	$0.08 25 mph	$0.08 25 mph	$0.06 30 mph	$0.06 30 mph
F	$0.05 30 mph	$0.05 30 mph	$0.08 30 mph	$0.08 30 mph	$0.04 35 mph	$0.04 35 mph	$0.06 35 mph	$0.06 35 mph
G	$0.04 45 mph	$0.04 45 mph	$0.07 40 mph	$0.07 40 mph	$0.03 55 mph	$0.03 55 mph	$0.05 55 mph	$0.05 55 mph

* Dollar amount indicates user-fee rate (dollars per mile) for using a specific route. The mile-per-hour figure indicates anticipated travel speed when using a specific route. For example, travel on Route B/Segment 3 during the peak period would cost $0.04 per mile, with an anticipated average travel speed of 60 mph.

spacing that will be allowed due to the full control of the AHS expressway. The Federal Highway Administration (FHWA) has established an AHS program that will be able to carry out the following:

- Identify and analyze alternative AHS concepts.
- Demonstrate the potential feasibility of AHS in 1997.

Concept

AHS refers to the use of modern electronics, sensors, and communications on highway vehicles to provide "fully automated" vehicle operation. The automated system of roadways will run adjacent to the existing infrastructure providing an option to choose the AHS facility or remain on the conventional freeway. As a vehicle approaches and accesses an AHS lane of an AHS expressway, the vehicle's steering, braking, and acceleration are controlled until the vehicle exits the lane, after which the driver once again assumes control of the vehicle. An AHS expressway will have four major components that are fundamentally different from a conventional expressway. These segments are as follows:[26]

- Vehicle characteristics.
- Roadway infrastructure.
- Command and control.
- Entry and exit infrastructure.

The functional characteristics of each of these segments are discussed in the paragraphs below.

Vehicle Characteristics

The function of the AHS vehicle is to carry the driver, passengers, and goods as they are moved through an AHS system. The vehicle must do the following:

- Provide for controlled vehicle movement.
- Interact with the AHS roadway infrastructure component to obtain traction and support for operation while in the system, and to obtain lane boundary indications.
- Interact with the entry and exit infrastructure component to provide smooth and rapid entry and exit to AHS.
- Provide accurate control responses to directions received from the command and control component regarding vehicle braking, steering, throttle, and lights.
- Detect and maintain the status of critical vehicle functions.
- Support access to and from the command and control component.
- Interact with the driver, on a user-friendly basis.

Roadway Infrastructure

The primary function of the roadway infrastructure is to:

- Provide traction and support for vehicle operation, including vehicles operating properly and those that are malfunctioning.
- Enable safe vehicle operation by ensuring vehicle separation in case of severe system malfunction.
- Provide connectivity for entering and exiting vehicles and connectivity to other AHS systems.
- Provide passive or active indication of lane boundaries.
- Provide sensing of environment or obstacles, or both.
- Support/enable command and control and communication access to AHS vehicles and to roadway conditions.
- Support access to roadway by emergency and maintenance vehicles.

Command and Control

The AHS expressway is controlled primarily by the command and control component. The approach that is taken to accomplish the AHS command and control functions will have a strong influence on how the entire system is to be implemented. The five primary functions of the AHS command and control segment are listed below:

- Traffic flow management.
- Intervehicle coordination.
- Incident management.
- Vehicle control.
- Vehicle management.

Entry and Exit Infrastructure

The entry and exit infrastructure refers to the component of the system that transitions to and from the AHS expressway onto or from the regular freeway lanes. There are several methods for making this transition, but it is hypothesized that these transitions will include separation by vehicle classification and type of in-vehicle AHS technology. The classification separation is made so that lateral space can be optimized.

Goals

In order for an Automated Highway System to be successful, it must provide positive and noticeable benefits. Benefits must be realized in the areas of capacity, safety, energy, level of service, and environmental and community impacts. AHS will provide a more efficient utilization of right-of-way by decreasing lateral and longitudinal spacing of vehicles, thus increasing capacity. Safety improvements will be realized through the implementation of AHS due to the automation of usually manual tasks that create the possibility for driver error. Due to the smooth operation and flow of the vehicles along an AHS expressway, increased energy efficiency will be experienced. By decreasing total trip time, increasing level of comfort, and maintaining flexibility, the level of service of the system can be increased. The AHS system is expected to improve each of these components. Lastly, the AHS will aid realization of environmental goals related to noise and air pollution, community disruption, and user acceptance.[27]

4.4 LESSONS LEARNED

PLANNING

Freeway-to-Freeway Ramp Metering

In considering whether to implement a freeway-to-freeway ramp metering system, several concerns must be examined (e.g., whether or not to provide a dynamic warning device to alert approaching motorists that there is a ramp meter in operation, and possibly a substantial queue downstream). MnDOT, which is currently metering 74 ramps, bases its analysis upon available sight distance, approach speeds, and queue lengths. In general, MnDOT uses ramp meters at most freeway-to-freeway ramps, except loops. If an advance warning device is used, it is a 30 cm (12 in) flashing yellow signal head, accompanied by a standard symbolic "traffic signal ahead" sign, mounted on a 3 m (10 ft) traffic signal pedestal. It is placed in flashing operation when the ramp meter is cycling.[18]

In the operation of the MnDOT freeway-to-freeway ramp meters, metering rates and geometrics are carefully analyzed. Freeway-to-freeway ramps use different timing parameters than other meters. A narrower range of rates is used so that under severe incident conditions ramp flow is reduced by 25 percent, as compared to a 50 percent reduction at other ramps. These parameters help to guard against long queues. When necessary, MnDOT constructs an extended storage lane upstream of the meter to prevent queuing from backing up onto the intersecting freeway. Also, signing is used to encourage motorists to wait in line on shoulders, rather than in the through lanes of intersection freeways.

MnDOT has noted that there are several major concerns at freeway-to-freeway ramps that do not exist at other metered ramps, and they may be the reasons why some traffic management agencies have been reluctant to meter these ramps. The biggest concern is over accidents on freeway-to-freeway ramps, or upstream on the approaching freeway. This concern is related to stopping high speed/high volume ramp traffic, and the resulting queues. Experience over the past 25 years in Minnesota has indicated that there have actually been very few accidents at these ramps and that there is a net reduction in crashes.

Another concern over freeway-to-freeway ramp meters is that they may result in motorists being metered several times while making one trip. For example, a motorist entering the freeway from a metered ramp at an arterial street may also use several other freeways on a trip, thus encountering several ramp meters. There is also concern over negative reaction from the public when freeway-to- freeway ramp meters are deployed. The faster metering rates used at freeway-to- freeway ramps, however, have resulted in substantially fewer complaints about freeway-to-freeway ramp meters as compared to other ramp meters.

Toll Facilities

Toll road facilities are a means of financing roadway improvements. The intent is to finance roadway construction only if there is sufficient demand willing to pay a premium for services rendered by the facility. Furthermore, the user population must be willing to pay for the opportunity to save time in the system because toll road facilities are generally less congested. Currently, the concept of toll roads is being considered as a realistic procedure to finance the construction of needed facilities in a short time period. There are several advantages and disadvantages involved in the implementation of toll roads as opposed to free roads. Table 4-5 lists some of the advantages and disadvantages of financing a road via user tolls.

Congestion Pricing

There are logistical, institutional, and attitudinal barriers that must be addressed when implementing a congestion pricing system. A feasibility study must therefore be undertaken prior to implementation. The following tasks should be conducted:[22]

- Review of appropriate state-of-the-art technology.
- Attitudinal surveys of the system users.
- Organization of participating agencies and private-sector partners.
- Conceptual design for select U.S. cities.
- Preliminary capital and operational and maintenance cost estimates.
- Development of a conceptual implementation plan (i.e., time frame, lead agency, potential funding sources, institutional requirements).

Congestion pricing has seen very limited use in the United States, though already proven successful in efforts to reduce congestion in Singapore and several Norwegian cities. Implementation of roadway pricing has been discouraged in the U.S. due to technical and political problems. The use of AVI technology overcomes some of the technical barriers such as congestion at toll booths. In order to overcome political barriers, demonstration projects can be performed to introduce the concept. Congestion pricing should not be introduced on a facility that traditionally has no charge. Two recommended facilities that should be used to introduce this concept are as follows:[29]

Table 4-5. Advantages and Disadvantages of Toll Road Financing. [28]

Advantages	Disadvantages
• Timely construction, no delays. • Reduced construction costs. • Earlier realization of benefits, such as lower fuel costs, greater safety, comfort and convenience. • Regular inspections and maintenance required by lenders. • Inclusion of operating costs in financing and income plans; costs include police, emergency services, snow and ice control. • Ability to free tax funds for "free" roads.	• Higher maintenance and operations costs, in most cases. • Infrequent access. • Possible adverse effect on other roads in corridor. • Delays at toll booths. • Added costs of borrowing, collecting tolls.

- Existing toll facilities, where off-peak discounts and peak-hour surcharges can be introduced in order to increase ride-sharing incentives and reduce congestion.

- Completely new facilities.

A pricing schedule should be designed so that initial costs are fairly low. These costs should be maintained for a period of 6 to 12 months to "permit behavior patterns to stabilize," after which the cost should increase. This process should continue until the cost is at the desired level. The use of congestion pricing is expected to improve the traffic flow, ridesharing, and emission-reduction experienced on the roadway. These improvements should be quantified in the demonstration project to prove these benefits.

Table 4-6 presents barriers to the implementation of congestion pricing using AVI technology, and recommended strategies. Three arguments that justify the use of congestion pricing are:[30]

- Economic argument—automobile users should pay the full cost of the congestion their use of the road imposes on the public.

- Congestion is reduced.

- Environmental improvement—less congestion means less air pollution due to slow moving traffic flows.

Channelizing Devices for Work Zones

There is a wide variety of channelizing devices currently available for use in highway work zones. The MUTCD presents basic design standards for these devices and general guidelines for their use; however, it is the highway agency's choice where and when to use particular devices or sets of devices. Typically, work zone channelizing devices are chosen on the basis of one of the following practices:

1. Select the device with the lowest initial cost.

2. Select the device that is normally used by the agency.

Table 4-6. Barriers to Congestion Pricing Implementation. [30]

Barrier	Description	Recommended Strategies
Technical		
AVI technology	• Equipment unreliability.	• More research.
Logistical Problems	• Numerous structures at checkpoints needed. • Equipping vehicles with proper equipment. • Geography of the city.	• Provide financial incentive for equipment installation on vehicles. • Many problems solved with time.
Uniformity	• Different AVI technologies used by each agency.	• Develop standards for AVI systems. • Will require legislation but should not be a problem.
Social and Political		
Congestion Pricing as an Additional Tax	• Public perceives it as another form of taxation instead of a price to use the road.	• Stress that this is a user fee to support roads, not a tax. • Stress that revenues from the system will be linked to further expenditures on the system. • Describe lower rates at non-peak periods as a reward for traveling at that time.
Privacy	• Public does not want their vehicular movements monitored.	• Stress that a congestion pricing payment is no different than an itemized telephone bill. • Information not used for enforcement. • Pictures only taken of license plates. • Not looking at individuals, just tags.
Equity	• Forces poorer drivers off the road--politically undesirable.	• Show that it would not be any more equitable or inequitable than present system.
Business Interests	• May create decreased interest in downtown shopping areas.	• Effects not certain--need demonstration project.

3. Select a device already in stock.

4. Select the “very best” device just in case.

Each of these approaches has drawbacks, and collectively they have resulted in inflated job costs, unnecessarily large inventories, lack of uniformity, and in some cases, improper device use. As an alternative to the typical methods used for selecting channelizing devices for work zones, the value engineering approach (see **Module 11**) can be used. The approach involves 7 steps:[31]

- Determine the intended purpose of the devices.

- Identify available alternative devices.
- Select appropriate measures of device performance.
- Determine the performance of the alternative devices on the basis of selected performance measures.
- Estimate the total cost of each acceptable alternative.
- Calculate the relative value of each acceptable alternative, where value equals performance divided by cost.
- Select the alternative with the greatest value.

The following recommendations should be followed when using this approach:[31]

- Base value engineering study on comprehensive and accurate information.
- Use a team approach—team members are well trained and diverse in experience and technical background.
- Consider value engineering approach most appropriate for central office use—through pooling central office staff and data-gathering resources.

DESIGN/CONSTRUCTION

LCS and DMS Placement

A panel of eight TxDOT managers and engineers with expertise in Lane Control Signal (LCS) design and operation in freeway traffic discussed problems and potential solutions regarding LCS. Their recommendations included the following:[13]

LCS Visibility

- Drive throughs should be performed by TxDOT personnel when a red X is displayed due to its low legibility distance.
- If the department chooses to require double-stroked symbols for LCS displays, a maximum pixel spacing and/or effective stroke-width-to-letter-height should also be specified.
- A regular cleaning and bulb replacement schedule should be implemented.
- Back plates or back panels should be considered for placement behind LCS on overhead sign structures.

LCS Spacing and Mounting Locations

- LCS should be placed every 0.8 to 1.6 km (0.5 to 1.0 mi), but special geometric characteristics and driver decision points should also be considered during this placement.
- Mounting LCS on a cross-street bridge structure rather than on an overhead sign structure is desired.
- Positive guidance principles should be employed when determining the placement of the LCS.

DMS Placement

It is recommended that the following points should be considered when placing dynamic message signs for freeway management:[32]

- Signs should be targeted at an audience that is made up of local drivers generally familiar with the surrounding street system. This allows less detail in the messages presented.

- A 3-line sign with 18 characters per line is recommended.
- A letter height of 46 cm (18 in) is recommended to allow sufficient legibility distance.
- The minimum spacing between a DMS and other guide signs not co-located with the DMS should be 305 m (1000 ft).
- The maximum distance from a detour exit that a DMS should be placed is 1220 m (4000 ft).
- DMS located upstream from an interchange should not be used for messages requiring a detour maneuver beyond the interchange.
- Placing DMS on the far side of a sharp horizontal or vertical curve may limit the driver's ability to read the sign.
- An unrestricted visibility distance of 183m (600 ft) should provide the driver plenty of time to read and comprehend the message.

Use of Narrow Lane and Shoulders

Design guidelines for the implementation of projects involving the use of shoulders and narrow lanes were developed in a recent NCHRP research study based on the experience of agencies that participated in the study. Additional details are provided in the NCHRP report. The guidelines developed in the research represent more of a guide for *applying* design standards. They are intended to supplement, rather than supersede, existing standards. Following is a selection from the guidelines: [14]

- Field observations indicate that operational impacts of reduced shoulder or lane widths are most notable in the transition area. It is recommended that the transition area be located on a tangent, preferably in an area where there are no crossing structures, retaining walls, or other roadside appurtenances.
- On facilities with high truck percentages, it is recommended that trucks be restricted from using a right shoulder lane, which typically does not have adequate pavement structure to support heavy trucks.
- Emergency turnouts and crossovers should be provided along altered sections. It is recommended that enforcement and emergency response personnel be involved in selecting locations. These turnouts should be large enough to accommodate a tractor trailer unit and at least one piece of emergency equipment. The location of crossovers should be considered in conjunction with incident management plans.

4.5 EXAMPLES

SAN ANTONIO (TRANSGUIDE)

Description of System

In late 1995, the Texas Department of Transportation began operation of an advanced traffic management system on approximately 41.6 km (26 mi) of freeway in San Antonio, Texas. The system, labeled TransGuide, includes inductive loop detectors and closed-circuit television cameras for traffic surveillance, and a combination of dynamic message signs and lane control signals to convey freeway traffic conditions and lane status information to motorists on or approaching the freeways.

Other components are being introduced as the technology is developed. The system is also being expanded to include additional freeways in the San Antonio area.[34]

Lane control signals are placed approximately 1.6 km (1 mi) apart between major freeway-to-freeway interchanges. Signal spacings are then reduced to about 0.8 km (0.5 mi) spacing near the interchanges. Dynamic message signs are located upstream of major detour points on the freeway, and on the entrance ramps to the freeway. When an incident or work zone activity requires one or more lanes to be closed anywhere within the limits of TransGuide operations, predefined information dissemination plans are called from the computer database and implemented on the lane control signals and dynamic message signs. The actual plan (termed a scenario) selected is based on the expected duration of the incident, the time of day, and the number of lanes blocked.

A scenario consists of changes in up to three sets of lane control signals upstream of the incident. The two sets of signals closest to the incident and over the lane(s) that are blocked display a red X, and the open lanes display a green downward arrow. At the third signal location (the farthest upstream), signals over the lanes that are blocked display a downward diagonal yellow arrow to the left or the right. These diagonal arrows are not currently specified in the MUTCD as acceptable lane control signal symbols.[5] However, they are utilized extensively in Canada and other countries for this purpose. Also, recent research suggests that diagonal arrows may be better understood as a transition symbol than the yellow X that is currently allowed by the MUTCD for this purpose.[33]

Effects of Information

Recent evaluation of the TransGuide system indicates that drivers are obtaining and responding to the overall dynamic information system. For example, the number of drivers reportedly diverting to alternative routes in response to available information (primarily radio traffic reports before TransGuide, reports plus the dynamic message signs and lane control signals after TransGuide implementation) has increased from 33 to 80 percent.[34] However, the effect of the dynamic information system upon driver lane usage upstream of the incident has not been as well defined to date. Limited data suggests that a small portion of motorists do move from the closed lane to the open lane farther upstream of an incident when the lane control signals indicate a downstream blockage.[35] Survey results also suggest that the signals are seen and correctly interpreted by most drivers.

Operators of the TransGuide system have indicated the importance of providing accurate and useable information on the dynamic message signs in conjunction with the lane control signal displays in order to obtain appropriate driver responses. In one instance, operators closed two lanes where glass had been dropped on the road. They indicated “debris in left two lanes” and activated the appropriate lane control signal sequences, but saw drivers continuing to utilize the left lanes for travel (through the area of glass). They then switched the sign to read “glass in left two lanes.” Nearly all drivers vacated those lanes and remained out of those lanes until the lane control signals indicated that all lanes were open.[35]

SR 91, ORANGE COUNTY, CALIFORNIA CONGESTION PRICING

Recent construction of four express lanes (two each way) in the median right-of-way of State Route 91 in Orange County, California, was a $126 million undertaking that was accomplished through an innovative franchising agreement between the public sector and private enterprise (California Private Transportation Company, CPTC). To pay for construction, CPTC will collect tolls from the facility for the next 35 years, after which it will revert to State operation. The project has received extensive publicity as the first implementation of congestion pricing in the U.S. Users of the facility will be charged a toll ranging from $0.25 to $2.50, depending upon the time of the day and traffic demand levels.

A key component of the SR 91 system is the sole use of electronic toll collection equipment. No toll booths are present along the facility. Instead, only overhead radio receivers, which read small transponders that motorists place in their windshields are used to approve approaching vehicles to enter the express lanes and make appropriate toll charges to the motorist's account. Toll violators may be ticketed by the California Highway Patrol or via the mail and receive a $100 to $300 fine.[36] The revenues from toll collections are used to pay for the costs of enforcement. At the same time, the facility is designed to encourage carpooling. Buses, vehicles with three or more occupants, motorcycles, and vehicles designated as emission-free can use the express lanes for free (although they must still have a transponder in their vehicle).

Because of the system's recent initiation, experiences to date are limited. However, it was reported that within just a few weeks of its opening, the toll lanes and nearby Metrolink trains drew so many commuters that congestion levels on the mixed-use lanes on SR 91 dropped to levels not seen in 15 years.[36] After only a few months of operation, over 50,000 transponders are in use in the SR 91 corridor.

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