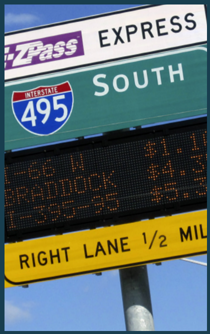
Roles of Transportation Management Centers in

Incident Management on Managed Lanes



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16. Abstract This guidebook examines traffic incident management practices that are implemented by transportation management centers on managed lanes. The document examines the unique operating environment of managed lanes from an incident management perspective. The roles of the transportation management center in the managed lane environment are discussed in terms of incident preparedness and real-time incident management activities and support. A comparison of best practices for eight case studies is presented, and an in-depth analysis of the role of the transportation management center in incident management is presented for three of the managed lane facilities examined in the case studies.		
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EXECUTIVE SUMMARY

Introduction and Background

Managed lanes are becoming an increasingly popular strategy to address traffic congestion, because they efficiently carry large numbers of people within a small amount of roadway space. This guidebook examines traffic incident management (TIM) practices that are implemented by transportation management centers (TMCs) and evaluates their use in the unique operating environment of managed lanes. This guidebook provides a framework for successful development and implementation of a TIM program using a TMC in the managed lane environment. It can be of use to planners developing new managed lane facilities, and transportation professionals who oversee existing managed lane facilities looking to optimize the use of their TMC and make their TIM program as effective as possible.

Managed lanes function as a "freeway within a freeway" and employ proactively implemented operating strategies in response to changing conditions. The goal is to have the managed lanes operate efficiently and reliably, with little or no congestion, to provide a higher level of service to eligible vehicles. Vehicle eligibility can be based on the type of vehicle (bus, truck, transit vehicle), the number of occupants in the vehicle, or the willingness to pay a toll. The most common types of managed lanes include High Occupancy Vehicle (HOV) lanes, Express Toll lanes (ETLs), and High Occupancy/Toll (HOT) lanes. The latter two categories utilize congestion pricing with variable toll rates that rise and fall based on traffic demand to "price out" low value trips and maintain the higher level of service in the managed lane.

Efficient TIM is critical for the success of a managed lane facility. Incidents that occur in managed lanes will affect greater numbers of people, as vehicle occupancy rates are typically higher in managed lanes than other lanes. The users affected by an incident in a managed lane are typically those road users with the highest priority within the transportation network, such as HOVs or transit vehicles. The reliability of the managed lane depends on quick clearance of incidents. Otherwise, operators cannot provide reliable service to users, which may limit the effectiveness of the facility.

Unique Aspects of TIM in Managed Lanes

The TMC will typically have unique capabilities and functionalities for the managed lane system since the managed lanes must respond to changing traffic conditions. Therefore the TMC's ability to detect an incident is enhanced, and the amount of operational control that a TMC has over a managed lane is also enhanced through the use of Intelligent Transportation Systems (ITS). Financial considerations are important during TIM in priced managed lanes, as there will be revenue loss if tolls are suspended or the facility is closed.

The method of separation between a managed lane and the parallel general purpose lanes can present challenges during TIM for responder access and diversions. Several facilities use permanent physical barriers which create an access limitation. Others use flexible posts or movable barriers that can be crossed during an incident. Many managed lanes rely solely on driver compliance with painted lines and buffer zones and have no physical separation.

TMC Role in the Managed Lane Environment—TMC Preparedness

The TMC role in TIM in managed lanes is generally similar to its role on other highway facilities; however the TMC must be aware of the additional challenges when an incident occurs within a managed lane environment. A TMC will typically have access to robust technology and communications capabilities. These capabilities can detect incidents, enhance necessary interagency coordination, and collect and disseminate data to stakeholders. Data sharing agreements and communications protocols have been established to facilitate this sharing of information along the managed lanes corridor. Interagency coordination protocols and agreements are in place between all TIM stakeholders. These agreements will involve other transportation agencies operating along the managed lane corridor in addition to response agencies, and should clearly define each agency's responsibilities. As part of the agreement, a designated point of contact at each agency for planning-related matters should be identified, and a communication protocol with multiple points of contact at each agency established for real-time operational matters. The goals of such agreements are effective coordination among all agencies, proper dissemination of information, TIM, and transportation system management during an incident.

A TMC or managed lane operator will typically have enforcement agreements with local law enforcement agencies. These enforcement agreements will be focused on enforcing compliance with access rules and enhancing operation of the managed lanes under normal circumstances. These law enforcement agencies may also be responsible for roadway service patrols, and will also typically be the first responders at the scene of an incident. Therefore, enforcement agreements should not only account for normal circumstances but should also account for the agency's role during an incident. Procedures for TIM in the operating environment of the TMC, and defining the appropriate level of enforcement should be part of the agreement. A TMC will have many other resources available to support TIM in the managed lanes. In priced managed lanes, toll revenue may be used to support the operation of the TMC and its activities. A portion of these funds and resources could be allocated to further the goals of the managed lane and provide a higher level of service to high priority vehicles in the transportation network.

A TMC should be involved in the early stages of planning for a managed lane facility, as this will ensure that TIM needs are taken into account during the design of a managed lane concept. The TMC will have knowledgeable staff that can provide valuable input into the design process, including the design and maintenance needs for ITS components, managed lane control software needs, the overall systems engineering process, and the physical designs of the managed lane, such as the location of access points and the type of separation treatments used. The TMC can also provide valuable input into the operational planning for the managed lane, including integration of the managed lanes with established ITS strategic plans and ITS regional architectures. The TMC plays a key role in development of operation plans, maintenance plans, and the TIM programs and performance measures that will be used on a managed lane facility.

TMC Role in the Managed Lane Environment—Real Time TIM Response Activities and Support

While multiple transportation agencies may be responsible for operation of the corridor on which the managed lane operates, the TMC must treat the network as a single transportation system when coordinating during an incident. Interagency agreements and joint communications protocols ensure that the various agencies work efficiently to clear the incident and carefully monitor the effects. This includes the effect of any incidents in the general purpose lanes that may affect the operation of the managed lanes or require use of the managed lanes for the response. The ability of the TMC to coordinate among multiple agencies is key during incident detection and verification, as the TMC may detect an incident outside of its primary jurisdiction or may receive reports of an incident from another TMC, especially if multiple TMCs operate along one corridor.

The response to an incident in a managed lane may be complicated by the physical access to the lanes. It may be worthwhile to have dedicated response vehicles, such as tow-trucks, pre-positioned at key locations along the managed lanes if recovery vehicles may not be able to easily access the lanes. Safety patrol vehicles on a patrol route provide a valuable source of incident detection and verification information. These vehicles can be dispatched by a TMC to the scene of an incident to assist with establishing a TIM zone, and can provide the TMC with accurate real time information which can be relayed to other agency partners. Quick and efficient response is important for minimizing facility downtime, maintaining access for priority vehicles, and reducing revenue losses on priced managed lanes.

A TMC may have the ability to support TIM by temporarily reducing demand on the managed lanes through the use of vehicle access management strategies. This could involve a vehicle eligibility change, which can be implemented by raising the vehicle occupancy threshold or eliminating access to the managed lane by vehicles paying a toll, in effect temporarily operating a HOT facility as an HOV facility. Priced managed lanes that have flexibility in setting prices can adjust toll rates to discourage vehicles from entering the lanes. In other cases, access to the managed lanes can be closed by activating Dynamic Message Sign (DMS) units, gates, or lane control signals. On managed lanes without access control features, the TMC can direct responders on the ground to block access to the lanes.

The TMC will also support TIM in the managed lane by providing scene management support to responders, which is especially important when the managed lane has limited room to establish a typical TIM zone. ITS devices are used to notify travelers of the incident and actively monitor the scene. Coordination with partner agencies, maintenance of close communications with those agencies, and dispatching of additional resources needed to support an effective incident scene will take place in the TMC. Another function of the TMC is to provide traffic control support, which will supplement any vehicle access management strategies implemented. This includes typical traffic control functions of a TMC, coordination between agencies in the managed lane environment, monitoring and tweaking of the plan as needed, and coordinating the opening of movable barriers where required for the response. If diversions are needed, such as opening the managed lane to all traffic, the TMC will coordinate the implementation of the management strategy.

The final stage of the TIM process is the clearance and recovery phase. The TMC will provide significant support during the recovery and clearance process with the goal of restoring normal operation as quickly as possible to reduce the impacts to managed lane users. The support provided will include coordination of necessary clearance and infrastructure repair resources. With the TMC's coordination and resource planning abilities, the incident can be cleared as quickly as possible.

The TMC may have the ability to provide system and corridor management, as an incident may affect other parts of the transportation network well beyond the scene. TMCs may have the ability to implement some or all of these strategies. They include use of lane control signals, ramp metering, adjusting traffic signal timing, posting travel times, implementation of diversions including modal transfers, providing traveler information, and expanding motorist assistance patrols. These actions can be implemented through the coordination of multiple TMCs and agencies to have a true corridor effect of the TIM strategies implemented.

Case Studies

Eight managed lane facilities in the United States were used as case studies for this guidebook:

1. Long Island Expressway (I-495) HOV Lanes (Long Island, NY).
2. I-35W Priced Dynamic Shoulder Lane (PDSL) System (Twin Cities, MN).
3. I-10 Katy Freeway Managed Lanes (Houston, TX).
4. I-95 Express Lanes (Miami, FL).
5. I-93 Contraflow HOV Lane (Boston, MA).
6. I-15 Express Lanes (San Diego, CA).
7. I-85 Express Lanes (Atlanta, GA).
8. I-495 Express Lanes (Fairfax County, VA).

The case study review revealed significant variation in the operation and physical design of these managed lane facilities, as well as the TMC role in TIM. A table containing a detailed comparison between the eight facilities can be found in Chapter 5 of this guidebook. Key findings are summarized as follows:

- All managed lane facilities use the TMC to provide basic TIM functions found on typical non managed lane facilities.
- All facilities have assigned police patrols for the managed lanes, with dedicated patrols solely responsible for the managed lanes in some cases and shared with the general purpose lanes in others. Special equipment may be needed to interact with toll equipment on priced managed lanes.
- When the managed lanes are operated by a different agency from the general purpose lanes, there are likely to be multiple TMCs with jurisdiction over a corridor. One TMC may have primary responsibility for general purpose lanes, and the other for managed lanes. In several cases, multiple agencies were co-located in one TMC.
- Three managed lane facilities adjust eligibility restrictions: I-85 in Atlanta, I-35W in the Twin Cities, and I-15 in San Diego. The restriction is implemented in HOT lanes by removing

eligibility for toll-paying vehicles to enter and retaining the existing HOV restriction, rather than altering the HOV restriction threshold.

- All agencies without a physical barrier between the managed and general purpose lanes, in addition to California (using designated access points) specifically cited the ability to open managed lanes or shoulders to general traffic.

Additional findings about the case studies are discussed in detail in Chapter 5. Furthermore, three of the eight managed lane facilities investigated for this guidebook are presented in greater depth as case studies in Chapter 5 of this guidebook; Minneapolis's I-35W Priced Dynamic Shoulder Lane (PDSL), Houston's Katy Freeway Managed Lanes, and Northern Virginia's I-495 Express Lanes.

Conclusions

In order for managed lanes to function properly, the facility must operate reliably with minimal downtime. The TMC supports this by properly preparing for TIM activities that will occur on the managed lanes, and then by supporting the real-time TIM activities during an incident.

CHAPTER 1—INTRODUCTION AND BACKGROUND

Managed lanes are becoming an increasingly popular strategy for addressing the problem of traffic congestion in major metropolitan areas, as these are lanes designed to optimize the movement of large numbers of people within a small amount of roadway space. In order to accomplish this goal, managed lanes must respond to both recurring changes in traffic patterns and non-recurring incidents.

The purpose of this guidebook is to document traffic incident management (TIM) practices that can be implemented from a transportation management center (TMC) within the managed lane operating environment. It provides a framework for successful development and implementation of a TIM program for planners designing new managed lane facilities, as well as for transportation professionals with existing facilities looking to optimize the use of their TMC as part of their TIM program.

Figure 1. Photo. Uncongested managed lanes adjacent to congested general purpose lanes.

For the purpose of discussion in this guidebook, the term TMC is used in a broad sense. Its connotation is not limited to "direct" operational activities such as traffic monitoring and management or incident detection and response. Neither is it limited to consideration of personnel involved in these "direct" operational activities such as TMC operators or shift supervisors. Rather, the term TMC in this guidebook is a broader term which relates to the fact that TMCs are often an element of a larger program that performs or supports other activities, including strategic and operational planning, system design, and coordination of operational stakeholders.

The content of this guidebook is divided into six chapters as follows:

- **Chapter 1—Introduction and Background**
  Overview of the guidebook, description of the managed lane operating environment, and the importance of TIM in managed lanes.

- **Chapter 2—Unique Aspects of TIM in Managed Lanes**
  Description of how TIM in managed lanes is different from typical freeway TIM and special TIM-related considerations.

- **Chapter 3—TMC Role in the Managed Lane Environment – Preparedness**
  Description of best practices for day-to-day operation of the TMC to prepare for incidents in managed lanes, classified by TIM element.

- **Chapter 4—TMC Role in the Managed Lane Environment – Real Time TIM Response Activities and Support**
  Description of the TMC's best practices for detection, response, and clearance of incidents in managed lanes.

- **Chapter 5—Case Studies**
  A look at how the best practices are applied on managed lane facilities in the United States. Practices on eight managed lane facilities are compared, and three case studies from Minnesota, Texas, and Virginia are analyzed in greater depth.

- **Chapter 6—Conclusions**
  A summary of the most important findings presented in this guidebook.

1.1 DEFINITION OF MANAGED LANES

There are several different definitions of managed lanes used by different sectors of the transportation community. While managed lanes can cover a broad range of facilities, the definition of managed lanes used in this guidebook is narrower.

Figure 2. Photo. Managed lanes function as a "freeway within a freeway".

The Federal Highway Administration's (FHWA's) definition of managed lanes is: "Highway facilities or a set of lanes where operational strategies are proactively implemented and managed in response to changing conditions." This definition is very broad and encompasses a wide variety of facility types, ranging from dynamically priced express toll lanes to simple curbside urban transit lanes.

This guidebook focuses on freeway managed lanes with actively managed operations, eligibility restrictions, and access restrictions that co-exist adjacent to non-managed general purpose lanes. From an operational perspective, these lanes operate as a "freeway within a freeway" with the managed lanes functioning separately from the general purpose lanes.

Some facilities are considered managed lanes based on the FHWA definition, but are not a freeway within a freeway. Such facilities include stand-alone dynamically priced toll roads where all lanes are tolled, exclusive busways, and managed lanes on non-freeways. These facilities are not covered in this guidebook as TIM practices for these roadways are very similar to TIM on a normal freeway or urban arterial roadway.

1.2 ACCESS TO MANAGED LANES

The success of a managed lane facility depends upon the ability to maximize the use of available capacity while regulating vehicular demand to prevent the lane from becoming saturated. There are various methods that can be implemented to regulate demand by controlling access to managed lanes. These methods can be used to manage traffic during an incident. Descriptions of the most common access control methods as they operate under normal circumstances are discussed below.

High Occupancy Vehicle (HOV) Lanes

A managed lane facility with a vehicle eligibility restriction that reserves the managed lane(s) for the exclusive use of vehicles with a driver and one or more passengers, including carpools, vanpools, and transit vehicles. HOV lanes may operate at all times, or only during peak hours with the lane open to general traffic during other time periods. Some vehicles are exempt from HOV access restrictions depending on the jurisdiction's laws, such as electric vehicles, hybrid vehicles, transit buses and taxis with no passengers, and emergency vehicles.

Figure 3. Illustration. MUTCD sign showing HOV lanes have a minimum vehicle occupancy requirement.

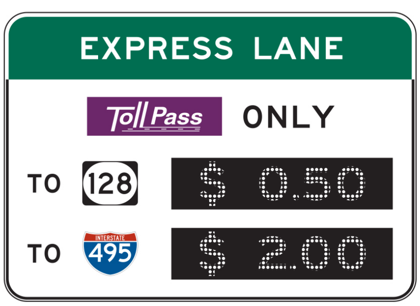

Figure 4. Illustration. MUTCD sign showing ETLs with congestion pricing have variable tolls.

Express Toll Lanes (ETLs)

Managed lanes that charge a toll for access to the lane. Many ETLs utilize congestion pricing, where tolls increase as traffic volumes, traffic densities, or congestion increase. The theory is that a higher price will reduce demand and thus reduce congestion by "pricing out" vehicles whose drivers do not wish to pay the higher fee for access. ETLs may have rates that adjust on a set schedule, or the rates may adjust dynamically depending on the traffic conditions in the lanes. ETLs use electronic toll collection in order to collect tolls with minimal disruption to traffic flow, and thus many require enrollment in an electronic toll collection program in order to use the lanes.

High Occupancy/Toll (HOT) Lanes

HOT lanes are a hybrid between HOV lanes and ETLs. An occupancy requirement is set, and vehicles meeting the occupancy requirement can travel in the managed lane for free, while vehicles not meeting the occupancy requirement must pay a toll to travel in the lane. The toll structure typically utilizes congestion pricing to manage congestion in the lanes. Some HOT lanes require all vehicles to enroll in an electronic toll collection program and to carry a transponder, while other HOT lanes allow free use by HOVs with no transponder or toll account.

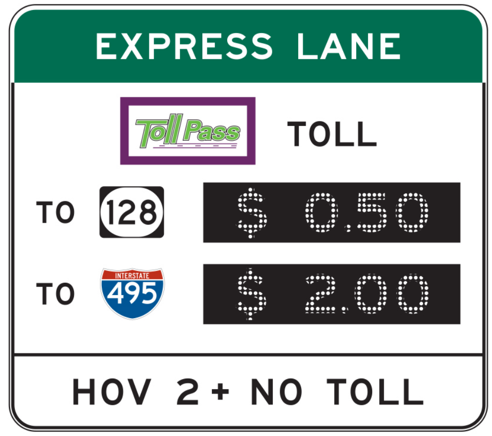

Figure 5. Illustration. MUTCD sign showing HOT lanes are ETLs where HOVs do not pay for access.

Bus Lanes

Bus lanes have a vehicle eligibility restriction permitting use only by buses. The restriction may allow any bus to use the facility, or it may restrict use to transit buses only. Bus lanes prioritize mass transit vehicle movement and are less prone to congestion than other types of lanes which allow cars to enter. In some cases, authorized transit buses are permitted to utilize the roadway shoulder to bypass traffic congestion. This is a type of bus lane that has fewer capital costs to implement, but requires additional training for bus drivers to use the shoulder while maintaining a safe operating environment for the buses, general traffic, and disabled vehicles parked on the shoulder.

The access control methods discussed above represent most common strategies for controlling access to a managed lane. The details of how the strategies are implemented can vary widely among different facilities. The type of access control and the level of flexibility in adjusting the access requirements can potentially play a big role in TIM in the managed lanes.

1.3 PHYSICAL DESIGN OF MANAGED LANES

Managed lanes are located next to general purpose lanes and there are varying degrees of physical separation between the two. The level of separation plays an important role in how authorities respond to incidents. The following is a brief overview of typical physical designs of managed lane facilities.

Shoulder

The right or left shoulder of the roadway is used as a full-time or part-time managed lane, and use of the shoulder is typically regulated by electronic signs. When the managed lane is in operation, there is reduced or no shoulder space on the side of the roadway with the managed lane. When the managed lane is not in operation, the shoulder can be used for emergency stopping or incident clearance. In some cases, shoulder use is restricted to authorized transit buses. There are fewer electronic signs, as there is a driver training component for all drivers utilizing the lanes.

Figure 6. Photo. Part-time shoulder lane.

Painted Buffer

The managed lane is separated from the general purpose lanes with a double white line or a wider painted "buffer area" that is illegal to cross. The painted buffer can be as narrow as 4 feet or wide enough for a disabled vehicle to fit between the lanes. Entering and exiting the managed lane is accomplished using gaps in the painted buffer where vehicles are allowed to change lanes. Alternatively, painted "slip lanes" that function as an acceleration/deceleration lane between the managed and general purpose lanes can be used. Painted buffers allow easy access to the managed lane during incidents, but rely heavily on voluntary compliance with buffer crossing prohibitions during normal operations.

Figure 7. Photo. Managed lane separated from general purpose lanes with painted buffer.

Continuous Access Lane

The managed lane operates as a typical freeway lane with some form of usage restriction. Drivers may enter and exit the lane at any location. This physical design allows easy access for incident response. For part-time managed lane facilities, the lane can either be closed or operated as an additional general purpose lane outside the typical operating hours.

Figure 8. Photo. The left lane is a continuous access HOV lane.

Painted Buffer with Electronic "Invisible" Barrier

This design is the same as the painted buffer, with the addition of an electronic system to deter drivers from illegally crossing the buffer. This system uses a series of cameras, license plate readers, and/or toll transponder readers to detect

Figure 9. Photo. Invisible electronic barrier using toll tag readers and cameras.

when a car enters or exits the managed lane between legal entry/exit points. A warning or violation notice is sent to drivers who do not follow the posted rules. This system provides a deterrent to illegal crossing of the buffer, and it can be easily deactivated if crossing the buffer is needed for incident response.

Figure 10. Photo. Plastic post barrier.

Plastic Post Barrier

This design utilizes flexible plastic posts, sometimes referred to as "candlesticks", placed inside a painted buffer area to separate the managed lanes and general purpose lanes. The posts can be located adjacent to the travel lanes, or there can be a paved shoulder between the posts and the travel lane. Plastic posts will not stop an errant vehicle from crashing through the barrier, but most drivers will typically avoid deliberately crossing the barrier. The posts can be removed if necessary to provide responder access to the managed lanes. The use of plastic posts may be impractical in northern climates due to the increased maintenance costs associated with damage caused by snow removal activities. However some agencies with priced managed lanes and lower rates of driver compliance with signs and markings may justify the increased maintenance costs if the plastic posts are used for revenue protection purposes.

Permanent Physical Barrier

A permanent physical barrier, such as a Jersey barrier, physically separates the managed and general purpose lanes. There is typically a full shoulder between the travel lane and the barrier. The managed lanes operate as a completely separate roadway from the general purpose lanes. This design prevents errant vehicles from crossing the barrier, but also restricts emergency access to defined access points along the facility.

Figure 11. Photo. Permanent physical barrier creates two separate roadways.

Figure 12. Photo. Zipper barrier and mobile machine.

Zipper Barrier

A zipper barrier is a physical barrier that can be moved by a special mobile machine. Zipper barriers are often used to create "contraflow lanes", where a lane in the off-peak direction of travel is used for travel in the peak direction. The zipper barrier has the advantage of physical separation between lanes, as it will stop most errant vehicles. The zipper barrier also has the advantage of flexibility in operations, since it can be moved to open or close lanes as needed. Typically the barrier is moved according to a set schedule usually around commuter peak periods; however it is also possible to move the barrier in the case of an incident.

Reversible Roadway

These managed lanes are entire roadways that reverse direction, and are typically built to handle large directional peaks in traffic volumes. Reversible roadways are usually located between the two sets of general purpose lanes, but can also be elevated or located off to one side. The entry and exit points to a reversible roadway are carefully controlled with dynamic message signs (DMSs), signals, and gates to prevent wrong way entry into the lanes during normal operations. During incidents these features can be used to control access to the lanes or allow emergency access.

1.4 IMPORTANCE OF TIM IN MANAGED LANES

TIM is the process of coordinating the resources of a number of different partner agencies and private sector companies to detect, respond to, and clear traffic incidents as quickly as possible in order to reduce the impacts of incidents on safety and congestion, while protecting the safety of on-scene responders and the traveling public. Efficient TIM is important because when an incident occurs, congestion quickly builds up and the likelihood of a secondary incident increases.

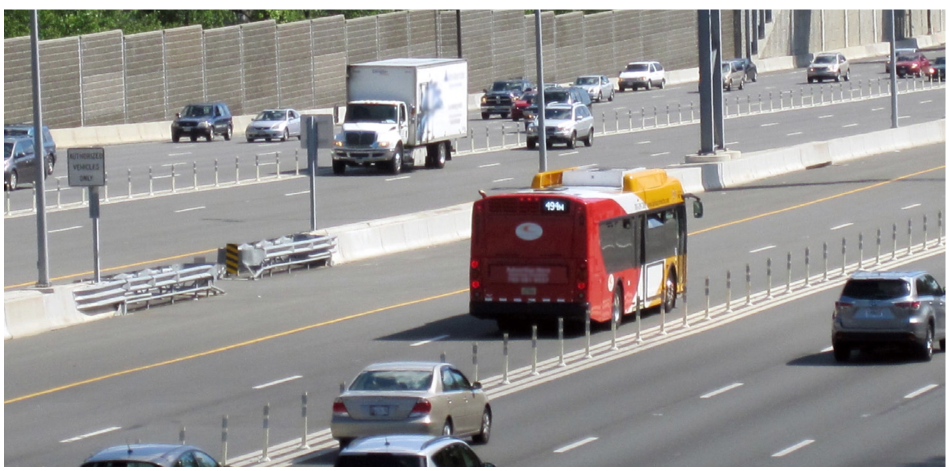

Figure 13. Photo. An incident in a managed lane can inconvenience many people, such as transit riders, since vehicle occupancies are high.

The sooner an incident is detected, the sooner safety personnel can respond to it and clear it from the roads allowing traffic lanes to re-open and traffic to return to normal conditions. TIM assists with the process of creating a safe work area with proper signs and equipment for emergency crews responding to an incident.

The effects of an incident and the importance of TIM are compounded in the managed lane environment for the following reasons:

- Priority access to managed lanes is given to vehicles with high occupancies or to drivers with a high value placed on time, as evidenced by willingness to pay a toll for access. An incident occurring in a managed lane will therefore adversely impact vehicles that require the highest priority within the transportation network.
- Managed lanes are designed to move large numbers of people using limited roadway space. Since the average vehicle occupancy in managed lanes is high, an incident in a managed lane can impact a small number of vehicles yet impact a large number of people.
- Managed lanes provide eligible vehicles a more reliable trip and a higher level of service compared to the general purpose lanes. The success of managed lanes depends on the reliability of the facility. Swift clearance of incidents will instill confidence in managed lane users that the managed lane facility is reliable and that incidents will be cleared as soon as possible. Lack of confidence in the reliability of a facility could cause users to abandon the managed lanes, which in turn could increase congestion and decrease ridesharing.

A robust and effective TIM program will ensure that managed lane facilities operate as reliably as possible and that downtime is minimized. This in turn will provide an acceptable level of service to the greatest number of people and the vehicles with the highest priority within the transportation network, such as HOVs or transit vehicles.

1.5 TMC OPERATIONS

The TMC is the most important TIM resource. The TMC is a centralized hub that provides real-time monitoring of the highway, incident detection and verification, coordination and support for incidents, and distribution of traveler information. The TMC helps to reduce congestion, increase safety, and increase the efficiency of the transportation network. These goals are typically achieved using the TMC's communications capabilities and its access to ITS assets on the roadway network.

Typical TMC TIM functions and capabilities include:

- Detection and verification of incidents.
- Notification and/or coordination with responders.
- Implementation of traffic management strategies to mitigate or manage traffic flow in the area, such as revised traffic signal or ramp meter timing.
- Implementation of a traffic diversion (if appropriate).
- Distribution of traveler information related to incident status and conditions to the public and media.
- Monitoring traffic conditions at and around an incident scene and adjust TMC response and support actions as needed.
- Coordination with other TMCs and response agencies on incident status and conditions.

- Supporting any needs for additional response, such as those needed for spill cleanup or serious injuries.
- Supporting on-scene response with motorist assist patrols, traffic response teams, or emergency traffic control by motorist patrols.
- Logging incident related information, such as detection, response and clearance times.
- Standing down or revising traffic management strategies, support personnel, and traveler information systems as the incident clears.
- Participation in post incident reviews at a later date.

Figure 14. Photo. Inside of the New Jersey Statewide Transportation Management Center.

CHAPTER 2—UNIQUE ASPECTS OF TIM IN MANAGED LANES

Many of these topics are familiar to transportation and emergency response professionals. This guidebook links these topics together. This chapter will examine how TIM using a TMC in managed lanes is different than typical freeway TIM, which is a critical component to understanding the best practices that will be presented later in the guidebook.

2.1 NEED FOR INTERAGENCY COORDINATION

On most transportation corridors under the jurisdiction of a TMC, there is one transportation agency responsible for operation and maintenance of the entire corridor. However some managed lane facilities are operated by a different agency than the adjacent general purpose lanes. This will require coordination between the two agencies for normal operations and during incidents.

Figure 15. Photo. Express Lanes in Orange County, CA are operated by a different agency than the adjacent general purpose lanes.

The agency that ultimately operates a managed lane facility depends on many factors, including when the facility was constructed, if the facility was purpose-built or converted from another use, funding constraints, and the operating authority of the various transportation agencies in a metropolitan area. Typically, one of three types of agencies operate managed lanes:

- The same public sector transportation agency as the general purpose lanes: Typically a state DOT that operates freeways and other transportation facilities. The managed lanes will be well integrated into the transportation network and communication will exist between incident responders and only one transportation agency.
- A different public sector transportation agency than the general purpose lanes: Typically a toll road authority or operator, a transit agency, or a metropolitan planning organization. The operators of the general purpose and managed lanes may share a TMC or other transportation assets, and will generally have common goals of providing a seamless transportation network and providing premium service to carpools, rideshare vehicles or, drivers willing

to pay a congestion pricing toll. There is a need for interagency coordination between the two operators for TIM, maintenance, and operations, and this coordination will generally be more formal than when the same transportation agency operates both the general purpose and managed lanes.

- A private sector operator for the managed lanes alongside general purpose lanes operated by the public sector: Often a concession or other special operating agreement is made between a transportation agency and a private firm for designing, building, operating, and maintaining a managed lane facility. The private sector operator of the managed lanes may have different objectives than public sector transportation agencies, and each operator may have their own TMC, operating procedures, and ITS assets. Communication between the private sector operator of the managed lanes and the public sector transportation agency will typically be more formal and subject to specific protocols outlined in contract documents.

Having more than one transportation agency or operator responsible for roadways co-existing in a single right-of-way is unique to the managed lane environment. In some cases, the two operators' jurisdictions are separated by only a few feet of pavement with a very simple barrier between the two, if any. The result of this physical configuration is a high likelihood of interaction between the general purpose lanes and the managed lanes during normal operations, maintenance, and incidents. Maintenance activities must be closely coordinated to ensure adequate operation of the transportation corridor and that two agencies are not competing for the same roadway space for their respective activities. An incident on one facility may be detected by the other facility's operator. Additionally, an incident on one facility can quickly affect operation of the other facility. The barrier between the two facilities may be breached during the incident, and the barrier may need to be crossed by responders and diverted traffic.

All of the above scenarios will result in the need for close coordination between the operator of the general purpose lanes and the operator of the managed lanes if the two facilities are not operated by one agency.

2.2 ENHANCED TRAFFIC MANAGEMENT SYSTEM CAPABILITIES

Managed lanes usually have more ITS assets and TMC functionality than a typical freeway. Managed lanes are designed to allow proactive implementation of management strategies

Figure 16. Photo. Managed lanes typically have extensive deployments of ITS equipment, such as these CCTV cameras.

in response to changing traffic conditions. In order for this to occur, ITS assets must be able to detect when traffic conditions change to require a response from the operating agency. This will generally require a more robust deployment of ITS assets that can detect incidents than are found on a typical freeway. In some cases, the entire managed lane facility is within the range of a Closed Circuit Television (CCTV) camera. An agency in charge of operating a managed lane facility is generally willing to provide enhanced ITS and TMC functionality in order to ensure the success of the facility.

Examples of enhanced ITS assets and TMC functionality that can be found on many managed lane facilities include:

- Complete coverage of the managed lane system with CCTV cameras.
- Closely spaced detection equipment to gather volume, speed, and occupancy data.
- DMSs at regular intervals along the facility and at entry points.
- Dedicated enforcement and motorist assist patrols.

The enhanced capabilities of the TMC allow for better detection, verification, response, and clearance of incidents that occur along the corridor. This will result in incidents being cleared faster and subsequently less downtime for the managed lanes.

2.3 ENHANCED OPERATIONAL CONTROL

Some managed lane facilities have traffic control tools that can be activated from the TMC to support TIM. Managed lane facilities are more likely to have these capabilities than other freeway facilities.

Figure 17. Photo. Some managed lanes can be remotely closed from the TMC, such as this reversible facility.

Some examples of control strategies that can be implemented from the TMC include:

Variable speed signing

Some managed lane facilities have changeable speed signs along the facility. These signs can be adjusted from the TMC to reduce the speed limit approaching an incident zone. Depending on the laws of the area where the managed lane is located, this variable speed may be advisory in nature or it may be an enforceable speed limit. In states where both an enforceable speed limit and an advisory speed are both permitted, the choice of which type should depend on the ability to effectively enforce the limit. An advisory speed may be more suitable for areas where police enforcement is not practical. The use of variable speed signing can encourage drivers to slow down when approaching a TIM zone, and thereby reduce the likelihood of injuries to responders, secondary crashes, and reduce the severity of any crashes that do occur in the incident management zone. An enforceable variable speed limit must be supported by state law, and driver compliance may vary depending on the level of enforcement normally associated with the managed lane facility. When an enforceable speed limit or advisory speed is used in combination with DMS messages warning drivers of an incident ahead, the reduced speed may be more effective as drivers will understand the need to slow down.

Figure 18. Illustration. MUTCD sign showing variable speed limits.

Lane control signals

These are the green arrow and red "X" signals that appear over lanes. Some managed lane facilities have lane control signals that can be used to remotely close and re-open lanes from the TMC. These signals can be used in the course of normal operations to open or close lanes, control entry to access points, and assist with switching direction of reversible facilities. Regardless of whether or not signals are used in the course of normal operations, available signals can be a handy traffic control

Effectiveness of Lane Control Signals

Experience in some areas shows that the effectiveness of lane control signals is limited due to aggressive driver behavior and distracted drivers. While lane control signals can be used as a tool to manage traffic at an incident scene, the most effective way to establish an incident scene is with service patrol trucks and emergency vehicles. The greatest compliance with posted lane control signals occurs in free-flow, high-speed conditions.

In order to achieve increased rates of driver compliance with lane control signals, they must be deployed quickly and accurately, which requires a high level of attention from the TMC operator in addition to quick and accurate detection and verification of the incident's location.

tool during incidents. This will improve incident zone safety by directing vehicles out of the blocked lane prior to the incident, and can reduce backups by allowing traffic to merge when gaps are available rather than being forced to merge at the incident. Lane control signals will also allow lane closures to be implemented much faster than if the signals were not available.

Zipper Barrier

Managed lane facilities that have a zipper barrier can have the barrier moved to open or close lanes, allow for diversions, or allow emergency responders to reach an incident. The zipper barrier must generally be moved by a ground vehicle, and TMC staff can direct ground crews to move the barrier if needed.

Facility closure

Many managed lane facilities have some form of DMS units, signals, or gates at the entrances to managed lane facilities that could be used to completely close the managed lane facility to traffic from the TMC. This is a tool that can be implemented if a serious incident blocks all lanes, an incident is expected to be long in duration, or the impact to traffic will be high. Implementing a full closure of the managed lanes may be necessary to prevent severe traffic backups behind the incident or prevent vehicles from becoming "trapped" behind the incident. The closure can be implemented using signs dedicated to providing the open/closed status or by utilizing other signs normally used for other purposes, including the signs listing the toll rate for priced managed lanes. In such cases, the signs could be changed to display "closed" rather than a price. Although a facility closure may not prevent all vehicles from becoming trapped behind an incident, if some vehicles can be directed away from the incident scene, the response to the incident will be improved.

Diversions

A diversion can be implemented in one of two directions: general traffic can be diverted into the managed lanes, or managed lane traffic can be diverted into the general purpose lanes. A diversion is similar to a facility closure, though it is usually implemented by diverting vehicles already in the facility off of it at an intermediate location rather than simply preventing vehicles from entering at defined entry points. If traffic is diverted off at a defined exit point, DMSs can be used to the extent possible to guide vehicles onto the exit ramp. If a diversion is implemented at an intermediate point, responder assistance on the ground may be necessary to direct vehicles into the diversion and to remove any physical barriers that may exist. This effort can be supported by the TMC by activation of the DMSs to warn drivers of the diversion, closure of any entry points downstream from the diversion, and suspending automatic enforcement of regulations that are not applicable during a diversion, such as "invisible barriers".

Adjusting toll rates

Priced managed lanes with dynamically adjustable toll rates can increase the price for use of the managed lanes in order to discourage all but the highest value trips from utilizing the facility. The ability to adjust toll rates may be limited by the managed lane facility's operating procedures. For example, some facilities have an upper limit on the tolls, and others adjust toll rates on a set schedule, and the ability to deviate from that may not be permitted. Other toll facilities adjust toll rates depending on traffic conditions to maintain certain minimum operating conditions, such as a 45 MPH travel speed. In some priced managed lanes, the algorithms which determine the toll price under normal circumstances can be overridden by TMC staff in the case of an incident to reduce the number of vehicles entering the managed lanes. This TIM tool may be useful where a full closure or diversion is not necessary, but a reduction in traffic volumes in the managed lanes is necessary to preserve the operating conditions in the lanes for high priority traffic such as transit vehicles. Careful consideration needs to be given to how drivers react to the toll rates displayed on the signs before relying on this as a TIM strategy. For example, on some facilities, increasing the toll rate may lead to an increase in vehicles entering the managed lanes, since drivers will mistakenly believe that a high price means traffic conditions are poor in the general purpose lanes.

Adjusting vehicle eligibility requirements

This tool is similar to the adjustment of toll rates in that the goal is to reduce the demand on the facility. An existing vehicle occupancy requirement can be increased, an eligibility requirement could be implemented where none normally exists, or a HOT facility could suspend access for those paying tolls and restrict entry to HOVs only. This TIM strategy will typically be implemented by adjusting electronic signs at the entry points to the lanes, and could be constrained by state or local laws. For example, the operating agency may not have the authority to change the occupancy requirement from two person carpools to three person carpools, but may have the authority to deny access to single occupant toll-paying vehicles if the two person HOV definition is not changed, thus granting priority to HOVs. An alternative could be to restrict access to buses or other transit vehicles only, and disallow general traffic. The implementation of a vehicle eligibility requirement change will reduce demand on the HOV facility while preserving access for the highest priority vehicles carrying the most people.

Figure 19. Photo. Managed lanes can suspend all eligibility requirements and allow all traffic.

Suspension of eligibility requirements

This TIM strategy will open the managed lanes to all traffic and is typically implemented in response to an incident in the general purpose lanes where the managed lanes are needed for diversion. Implementing a suspension of all eligibility requirements is generally not seen as a desirable TIM strategy, as priority access for eligible vehicles in the managed lanes is not maintained. However in some circumstances, there may be no suitable alternative to safely and effectively handle traffic from the general purpose lanes other than opening the managed lanes to all traffic. This TIM strategy can be implemented from the TMC by displaying detour information on electronic signs approaching the lanes, and suspending enforcement of tolls and occupancy requirements.

2.4 PHYSICAL ACCESS CONSTRAINTS

Managed lanes are more likely to operate in a physically constrained environment than a typical freeway segment. The physical layout of the managed lane facility will impact the TMC's ability to perform TIM tasks during an incident, including allowing responder access to the managed lanes and the ability to implement a diversion. Section 1.3 of this guidebook discussed various physical layouts for managed lanes. The type of barrier and the lateral clearance between the travel lanes and barrier are factors in the amount of access constraint there is during an incident.

There are three levels of physical barriers which can separate a managed lane facility from the general purpose lanes: permanent physical barriers, movable physical barriers, or no physical barrier. Where a permanent physical barrier is used, access to and from the managed lanes can only be accomplished at designated locations, as crossing through the barrier will not be possible. Managed lanes may have fewer access points than the general purpose lanes due to their design. Many managed lane facilities with permanent physical barriers will have full or partial shoulders on at least one side, per typical design standards. This shoulder will allow for easier access to the incident scene and for vehicles to pass around an incident.

Movable physical barriers can take several forms, including zipper barriers, plastic "candlestick" posts, or removable sections of permanent physical barriers. With this design, the most desirable access to the managed lanes is through the normal entry and exit locations; however if access from these locations is not possible, the physical barriers can be breached or moved to allow access. A plastic post barrier can easily be breached by a large vehicle by driving over the posts. Alternatively, the plastic posts can be removed from their base or other barrier types can be moved to allow access. This activity must be accomplished by ground crews at the direction of the TMC. Since the removal of the barrier requires effort and a removed barrier must be replaced, this method of accessing a managed lane is not the preferred option for accessing an incident or allowing diversion. Managed lane facilities with removable barriers may not include shoulder space or a buffer area on either side of the lanes, as these managed lane facilities are often squeezed into available space within the right-of-way. This may limit the options for responders to access an incident scene more so than a typical freeway.

Figure 20. Photo. Plastic "candlestick" posts can be moved to provide emergency access to the managed lanes.

If there is no physical barrier, accessing the managed lanes for TIM purposes is unrestricted, as vehicles can simply drive across the painted buffer. Physical access to managed lanes in these circumstances is no different than accessing an incident on a typical freeway. If there is electronic enforcement of the painted buffer, this enforcement can be suspended by the TMC during (or retroactively after) an incident.

2.5 FINANCIAL CONSIDERATIONS

Priced managed lane facilities involve the collection of tolls to manage demand on the facility. When an incident occurs on a priced managed lane, financial considerations will come into play. To a managed lane operator, maintaining the revenue stream from toll collections is an important objective.

When an incident occurs, a TMC may need to reduce vehicle demand on the managed lanes by eliminating the option to pay a toll for access and allowing access to HOVs only, or by raising the toll rate and having fewer vehicles paying for access. Raising the toll rate with fewer vehicles may have an adverse impact on revenue collections. In some cases, toll collection is completely suspended during an incident, such as when the managed lanes are used for general purpose lane traffic diversion.

Managed lane operators may be reluctant to take any TIM step that will reduce revenue collections. Careful consideration should be given to the available options in these circumstances, and the loss in revenue weighed against the level of service provided to drivers along the corridor. In some circumstances, it will make sense to maintain collection of tolls if capacity allows toll-paying vehicles to travel in the managed lanes without a severe degradation in service. However the managed lane operators will generally give priority to HOVs and transit vehicles in order to preserve the reliability of those modes of transportation. If there is not sufficient capacity to allow drivers to pay a toll for access to the managed lane facility, it may be logical to disallow those vehicles, even though it will cause a revenue loss, in order to preserve the level of service and reliability of the overall facility.

When the managed lane operator and the general purpose lane operator are the same, the one agency will have the ability to decide on its own when to take steps that will reduce revenue. When the managed lane operator is a different public sector agency or private sector operator, specific guidelines governing the suspension of toll collection may be necessary in order to ensure that the need for revenue collection is properly balanced with the mobility needs of drivers along the corridor.

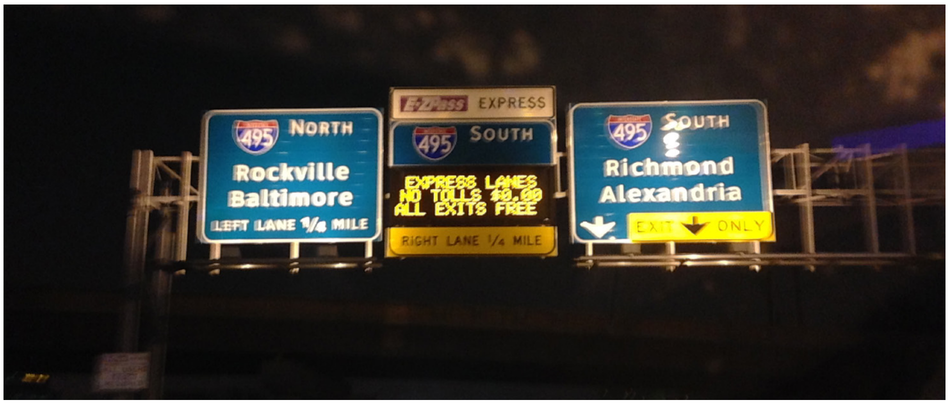

Figure 21. Photo. Suspension of tolls in managed lanes is rare due to concerns of revenue loss, but can be implemented during large incidents, such as this region-wide snow emergency.

CHAPTER 3—TMC ROLE IN THE MANAGED LANE ENVIRONMENT—PREPAREDNESS

TMCs are designed to perform a variety of robust traffic and incident management activities. The extension of the TMC systems and activities to support TIM in the managed lane environment is a natural action which leverages these resources in a highly effective manner.

In some ways, the TMC role in TIM in managed lanes is the same as its TIM role on other highway facilities. Standard TMC systems and practices deployed for general transportation and incident management also apply to TIM in managed lanes. The benefit of this similarity in functions is that these TMC resources can be used for TIM in managed lanes with significantly reduced costs and effort.

However, as described elsewhere in the guidebook, the managed lane environment also presents a number of unique issues that require a TMC to address additional considerations. These include the potential need for a higher level of ITS device deployment, an increased need for enforcement, a greater number and type of partners to coordinate with, as well as different operational scenarios to plan and train for.

These systems and activities, whether standard for general traffic management or unique to managed lanes, involve technology, actions, or coordination that need to be planned, developed, and implemented in advance to enable the TMC to perform the required TIM activities when needed. Since these actions are done prior to and/or in preparation for TIM, they establish the TMC's preparedness to perform during an incident.

Figure 22. Photo. Dispatchers working inside a TMC must make special preparations to handle incidents within managed lanes.

This chapter focuses on the major elements that contribute to TMC preparedness to perform TIM tasks for managed lanes. The discussion of the various elements includes examples of state-of-the-practice and/or best practices that have been identified from a literature search and investigation of various managed lane facilities.

3.1 TECHNOLOGY AND COMMUNICATIONS

There is a nexus of technology and communication within a TMC, and the TMC has access to a wide variety of technologies that can support TIM on managed lanes. These include typical ITS devices such as CCTV cameras, Dynamic Message Signs (DMS), and the 511 traveler information hotline, as well as more sophisticated systems such as Computer-Aided Dispatch (CAD) and emergency communications. These technologies are often available to be leveraged for use by multiple response agencies in the managed lane environment at little or no additional cost.

Figure 23. Photo. A TMC will have many technology and communications resources, such as the ability to display travel times captured from roadway detectors on a DMS.

TMCs typically have established systems and/or protocols for effective communications with responders during incidents. This may involve simple methods such as contact information lists for other agencies, or more complex methods such as dedicated systems that allow for inter-operable communications between agencies. In addition, TMCs often have established protocols

Communication Network Reliability

A TMC must have a reliable and dependable communication system in order to reliably carry out its functions. The communication systems employed by the TMC should include redundancy, self-correction and routing of communication paths, and dedicated repair crews to minimize downtime. In addition, the electricity costs for the communications equipment must be factored into the operating agency's budget.

related to incident communications, dealing with both communications among responders and agency offices in addition to desired approaches for involving the media that support TIM.

The ITS utilized at TMCs incorporate both current and evolving communication technologies with the purpose of minimizing delays and improving traffic conditions for motorists. Typically, private sector contractors are responsible for installing and managing the operation of ITS components into the roadway and at the TMC. Example ITS systems include:

- Lane control signs.
- Ramp meters.
- CCTV cameras.
- DMS.
- Road Weather Information Systems (RWIS).
- Reversible Lane Systems.
- Detectors.
- Sensors.

During TIM, TMCs typically utilize technology and communications for the following actions:

- Displaying travel times and conditions using DMS (or broadcasting via 511 and media).
- Reducing or eliminating tolls when there is an incident.
- Converting managed lanes into a regular travel lane.
- Adjusting posted speed limits.

Most TMCs use commonly available technologies and strategies to monitor and operate managed lanes. However, there is a movement toward the use of more sophisticated technology and management techniques under a program called Active Traffic Management (ATM). ATM uses integrated speed harmonization, queue warning, ramp metering, lane control, and signal timing to manage traffic flow in the managed and general purpose lanes, as well as along parallel diversion routes, as an integrated corridor.

A substantial amount of data dissemination is involved with TMCs, both in terms of inputting and outputting to the ITS devices. TMCs have the communications infrastructure and computer systems to gather and analyze this data to adjust management strategies and produce performance data. Performance data is particularly critical to managed lanes because of their heightened need to keep operations at a high level of efficiency. Data are considered a very valuable resource, so robust data sharing agreements should be established among all stakeholders. As part of these agreements, technology and communication protocols should be included that facilitate information sharing. Specific examples include:

I-15 Express Lanes (San Diego, CA)

The California Highway Patrol provides enforcement services and is co-located with CalTrans at the TMC, which allows for direct coordination and communication during incidents.

I-495 Express Lanes (Fairfax County, VA)

Formal protocols and operating procedures are in place to facilitate communication between the private operators of the managed lanes and the Virginia Department of Transportation.

New Jersey Turnpike (Statewide, NJ)

At the Statewide Transportation Management Center in New Jersey, the New Jersey Turnpike Authority, New Jersey State Police, and the New Jersey DOT are co-located in the same TMC facility, which promotes much needed coordination and communication between the agencies during incidents.

3.2 INTERAGENCY RELATIONS AND COORDINATION

TIM is a coordinated process that involves a number of public and private sector partners. Effective TIM requires comprehensive planning that involves all potentially affected stakeholders, including federal, state, and local agencies, as well as private sector, volunteer, and contract agencies. Since TIM involves such a variety of stakeholders, there is a need for strong interagency communications, especially in cases where managed lanes and general purpose lanes have different operators. From the perspective of motorists, there is only one transportation system, so the interagency interaction that takes place within the TMC facilitates the cohesiveness of the transportation network during an incident by bringing stakeholders together.

Interagency agreements established by the TMC will facilitate this coordination, and creating operational protocols ensures that the coordination to resolve an incident occurs in a predictable and orderly fashion. As part of the interagency agreements, a designated point of contact at each agency for planning-related matters should be identified, and a communication protocol with multiple points of contact at each agency should be established for real-time operational matters. TIM committees are often formed to establish these operational protocols, perform training exercises, and establish good interagency contact that can be maintained. For example, in New York and New Jersey, TIM steering committees have been created that consist of stakeholders from various member agencies who represent incident responders and private entities that have a vested interest in TIM. The purpose of these committees is to oversee the advancement of their respective TIM programs and to allow the agency representatives to become well acquainted with each other’s personnel and policies.

Since incident response involves a variety of organizations, each one should know their specific roles and responsibilities at an incident scene, especially in a managed lane environment. The following roles and responsibilities are common to all stakeholders during an incident:

- Ensure incidents are cleared safely, quickly, and efficiently minimizing traffic backups.
- Communicate with other responders.
- Create a safe working environment for responders.
- Follow established protocols.
- Follow agreed upon multidisciplinary procedures.

- Build partnerships to support multidisciplinary, on-scene response.

Table 1 provides a list of TIM partners and some sample incident roles and responsibilities.

Table 1. TIM partners, agency roles and responsibilities.

Stakeholders	Responsibilities
Law Enforcement State Police, Highway Patrol, County Police, Sheriffs, Municipal Police	Assist in incident detection/verification Secure the incident scene Perform first responder duties Assist responders in accessing the incident scene Establish emergency access routes Supervise scene clearance Direct traffic Control arrival and departure of incident responders
Fire and Rescue County and municipal fire departments, including volunteer services	Protect the incident scene Rescue/extricate victims Suppress/extinguish fires
Emergency Medical Services (EMS) Triage, treatment, and transport of crash victims	Provide medical treatment to those injured at the incident scene Transport victims for additional medical treatment Coordinate evacuation with fire, police, and ambulance or airlift
Towing and Recovery Private companies responsible for the safe and efficient removal of wrecked or disabled vehicles, and debris from the incident scene	Recover vehicles and cargo Remove disabled or wrecked vehicles and debris from the incident scene Assist with vehicle stabilization and extrication, when requested Remove debris from the roadway
Transportation Agencies Develop, implement, and operate TMCs as well as manage Safety Service Patrols	Assist in incident detection and verification Monitor traffic operations Provide Safety Service Patrols Provide traveler information to the public and media Implement traffic control strategies and provide supporting resources Coordinate with law enforcement the establishment of alternate routes and assist in their operation Coordinate use of transportation agency resources (people, equipment, and materials) for clearance and recovery of incidents

When it comes to TIM in a managed lane environment, a single agency such as a state DOT may be responsible. In other cases, individual functions may be performed by separate agencies, private companies, or partnerships among them.

TMCs are valuable assets and serve as the point of contact for coordination and communication with responders and provide a means for dissemination of information to the public and media on current traffic conditions and any restrictions there may be. TMCs perform four general functions: coordination, information dissemination, incident management, and roadway management.

Coordination with Internal and External Partners

Coordinate activities with internal groups and external operational partners. This coordination includes the managed lane operator and the operating agency for the general purpose lanes.

Information Dissemination

- Collect and provide information regarding the status of traffic and roadway conditions as well as TIM activities.

Incident Management

Use ITS and additional resources to effectively manage the incident and other affected roadways as a cohesive transportation system.

- Dispatch appropriate response agencies.
- Assist response agencies in relaying communications to other agencies.
- Provide responders with information on other ongoing incidents.
- Provide data on agency responses.

Roadway Management

Use resources to effectively manage the affected managed lane corridor, the adjacent general purpose lanes, and parallel arterials during incidents.

Privately Operated Managed Lanes

When the agency operating managed lanes is a private firm, some unique factors must be considered. A private firm has a strong financial incentive to resolve incidents as quickly as possible in order to minimize facility downtime. Therefore a private operator may be willing to utilize a significant amount of resources in order to maintain reliability, minimize revenue loss, and focus on providing high quality transportation. However a private managed lane operator may not have the same long-established relationships with incident responders as public sector agencies.

A private sector managed lane operator will generally negotiate the terms of interagency coordination and shared responsibilities during an incident with adjoining public sector transportation agencies and incident responders in advance. In this way, each party will have expectations set and mutual understanding of responsibilities and obligations. This negotiation process will typically occur prior to the opening of the managed lanes, and may involve closed door sessions to protect the proprietary information of the private operator.

Protecting proprietary information is an interest of private sector agencies. Some information may only be released by the private sector on a need-to-know basis, whereas similar information would be available through an information request to a public sector agency. The negotiation process should ensure that public response agencies have access to information needed to quickly and effectively perform TIM functions, and that all agencies will protect the confidentiality of the information.

3.3 MANAGED LANE ENFORCEMENT PATROLS

Enforcement patrols are essential to the operation of managed lanes because they enforce occupancy requirements and toll collections for priced managed lanes as well as provide response to incidents occurring along the managed lane facility. These activities are generally performed by law enforcement personnel such as the state highway patrol, local law enforcement agencies, and/or police associated with a toll or turnpike authority. The final decision on the agency responsible for enforcement varies from region to region and may be determined by state law and/or institutional agreements. Law enforcement should be engaged in the early stages of the planning process for managed lanes. This will ensure that their needs and limitations can be accounted for early in the process, including the development of plans for real-time incident response.

Key enforcement objectives on priced managed lanes should be designed to ensure that motorists comply with occupancy, toll payment, and access/egress policies. This is the primary reason why entities involved in the operation of managed lanes should coordinate with local agencies to agree on effective enforcement strategies. During incidents, the enforcement personnel are typically the first responders to the incident scene. Having adequate enforcement and driver compliance with laws will help prevent incidents from occurring in the first place, and having dedicated enforcement resources will ensure that first responders are nearby when an incident occurs.

Due to the differences in the physical designs of managed lanes, the necessary level of enforcement may vary. But without having proper enforcement strategies in place, the integrity of managed lanes, and especially priced facilities, will be compromised significantly during an incident. Managed lanes often have increased or dedicated police enforcement details and service patrols to support reliable operations. In some cases, dispatching of these resources occurs within one TMC. TMCs typically have contracts, Memorandums of Understanding (MOUs), or agreements related to the enforcement of managed lanes. The primary purpose of these agreements is for day-to-day enforcement of the managed lanes; however these agreements often involve dedicated enforcement patrols that would act as first responders to incidents along the managed lanes. Procedures that detail the frequency of designated enforcement patrols are included in these agreements and are based on discussions with local enforcement personnel who are familiar with the managed lane and understand the needs particularly during an incident. Some examples include:

I-495 HOV Lanes (Long Island, NY)

The INFORM TMC has a specific agreement with the county police departments that defines and funds their managed lane enforcement responsibilities.

I-35W (Twin Cities Metropolitan Area, MN)

MNDOT contracts with the State Patrol to provide extra enforcement on the system during the HOT lane hours of operation.

Katy Freeway (Houston, TX)

The Harris County Toll Road Authority (HCTRA) funds dedicated enforcement patrols for the managed lanes using toll revenues.

SR 91 Express Lanes (Orange County, CA)

The California Highway Patrol is given the authority to divert general purpose traffic into the express lanes in the case of a severe incident. There are three enforcement zones along the express lanes that can be used during an incident.

Enforcement patrol staff can be a good resource for defining TIM requirements and providing ongoing coordination and support. In general, operators of managed lanes use toll revenues and enforcement fines to cover the costs of enforcement which may also support costs associated with TIM.

Source: New Jersey DOT

Figure 24. Photo. Safety service patrol vehicle.

3.4 TMC RESOURCES

TMCs have a variety of resources available to support their transportation management roles. In many cases they can support TIM in managed lanes using existing resources. In other cases, where the managed lane is tolled, some toll revenues may be available to support the TMC. Operators of managed lanes generally use toll costs and enforcement fines to cover the costs of enforcement. TMCs that monitor these priced managed lanes have an opportunity to have the TMC funded by these toll revenues and support enhanced incident management TMC operations.

TMCs often support their own agency's efforts in recovery of funds that are used to replace infrastructure damaged in an incident. It may be possible to use these funding resources and procedures to support the same activity for managed lanes operated by other agencies. Examples include:

I-95 Express Lanes (Miami, FL)

Florida DOT funds the operation of the Express Lanes, the SunGuide TMC, and Road Ranger Service patrols through a combination of federal and state allocations supplemented by revenue generated by tolls.

I-495 HOV Lanes (Long Island, NY)

The NYS DOT provides directly or indirectly (contract) for the resources needed to operate and manage the HOV lanes, including INFORM TMC (the state TMC for Long Island) operations, ITS systems, HELP service patrols, enforcement, and HOV lane construction and maintenance. The majority of these services are funded by federal funds.

I-93 Contraflow HOV Lane (Boston, MA)

The Massachusetts DOT Highway Division provides the resources needed to operate and manage the contraflow lane including Highway Operations Center (HOC) operations, ITS systems, enforcement, and HOV lane construction and maintenance. The majority of these items are funded by federal funds.

3.5 TMC INVOLVEMENT IN MANAGED LANE DESIGN

TMCs have the daily experience to understand the special operational needs of TIM in managed lanes. This knowledge can be brought to the table early in the process when managed lanes are being designed to ensure that the system will support the safest and most effective TIM during daily operations, as well as when the managed lane or managed lane systems need maintenance. TMC involvement is even more critically important in circumstances where the future operator of the managed lane may not have broad experience with TIM operations.

There are a number of key TIM operational considerations that the TMC can advise on during the design process.

ITS Field System Design and Integration

The TMC should advise the designer of the managed lane on how to design the traffic management system to support TIM. Issues involved may include the technology used and the placement of devices such as detectors, CCTV, DMS, and lane control signals, as well as the compatibility and integration of such with any existing ATM systems. Provisions for shared control of devices should be addressed at this time.

ITS Field System Maintenance

During the design phase it is important to address the issue of future device maintenance in the context of relative factors such as placement of devices to allow maintenance without impacting the travel lanes and choice of system components and designs that increase reliability and minimize or simplify future field maintenance tasks.

Managed Lane Control Software

Control software would typically address core functions critical to managed lanes operations such as pricing algorithms, control of access devices, and toll tag reading. The TMC should address items critical to operations during incidents such as DMS and CCTV camera control as well as incident detection algorithms and logging capabilities. The system should facilitate communications with responders as well as distribution of traveler information at both the local and corridor level.

Figure 25. Photo. Enforcement area provides enforcement and service patrol vehicles a safe refuge from traffic.

Access and Separation Treatments

Managed lane access and separation treatments, or the physical design of the facility, have a significant impact on TIM. The decision on which of these type treatments will be implemented is often driven by factors such as right-of-way and transportation system connections. However, the TMC should weigh in on the pros and cons of these options and, once an option is decided, provide input on how to design the approach to best facilitate TIM. For example, if a barrier separated system is selected, the TMC should advise that wide shoulders or enforcement areas need to be available for incident management scenes at specified intervals. In addition, access and egress points in the barrier should be provided to facilitate incident response as well as traffic diversions.

Systems Engineering Process

TMC personnel can often bring extensive knowledge of ITS Systems Engineering (SE) to the managed lane design process. In particular, including SE process elements such as the Concept of Operations, Systems Requirements, System Design, ITS Standards, Configuration Management and System Testing in the managed lane design will be an opportunity for the TMC to firmly set the stage for effective and compatible TIM systems and operations once the managed lane is implemented. The value that the SE process brings to effective TIM operations is discussed further in Section 3.6 TMC Involvement in Operational Planning.

> The SAFETEA-LU Transportation Act of 2005 required that MPOs incorporate "operational and management strategies to improve the performance of existing transportation facilities" in their metropolitan transportation plans.

The following are examples of systems that incorporated effective TIM-related operational considerations in the design of managed lanes:

I-495 HOV Lanes (Long Island, NY)

The HOV lane is separated from the general purpose lane by a 4-foot painted buffer. The initial segments were designed with wide 10 to 14 foot shoulders on the left to accommodate enforcement and breakdowns. Segments constructed later had limited right-of-way so they were designed such that pavement markings create occasional pullout areas on the left side for these purposes. In addition, the center concrete median barrier was designed with occasional "slip ramp" type openings to provide enforcement with safe parking and access points.

Katy Freeway (Houston, TX)

This facility was designed with plastic "candlestick" post barriers separating the general purpose and managed lanes. The posts can be easily removed, or even driven over, when needed to facilitate access to incident locations as well as diversions to and from the managed lanes. In addition, the system design included 12 foot shoulders on each side of the posts to facilitate enforcement and incident management activities.

I-35W (Twin Cities Metropolitan Area, MN)

This managed lane was designed with an ATM system covering the entire system. The ATM includes intelligent lane control signs at half-mile spacing that provide the means to open and close lanes or implement reduced speed advisories to support incident management activities.

Procurement Options

Managed lane projects such as express lanes may have increased financing and operational participation by the private sector. This may trigger consideration of alternate project procurement processes such as Design-Build-Operate-Maintain and Design-Build-Finance- Operate-Maintain.

3.6 TMC INVOLVEMENT IN OPERATIONAL PLANNING

TMC personnel are often the agency's lead for planning related to TIM programs. As such they are a key resource with respect to the manner in which TIM will be planned for and applied to managed lanes. TMCs should perform or support the incorporation of the managed lane TIM into their operational planning documents, processes, and activities and ensure that deployment is consistent with those plans.

There are a number of ITS and operational planning processes that are typically developed to direct and coordinate ITS deployment in an area. These planning processes and the key relationships for managed lane TIM include:

ITS Strategic Plans

Vision, goals and objectives for the managed lane TIM activities as well as deployment strategies, benefits and costs, funding plans and high level performance measures should be consistent with the local strategic plan.

ITS Regional Architectures (RA)

Managed lane TIM deployment should be consistent with the local RA. The RA should describe what TIM systems and services will be deployed and the information that is exchanged between them. The RA should also identify data and communications standards that apply.

Project Systems Engineer Processes

Systems that support managed lane TIM such as incident detection algorithms should be developed using the SE process described in Section 3.5.

Operations and Maintenance Plans

Operations and Maintenance Plans should be developed for, or include, the appropriate managed lane TIM systems and activities including what systems are being deployed, the system functions, how they will be operated and maintained and who will do it.

TIM Programs

Managed lane TIM personnel and activities should be incorporated into the local TIM programs. The program should include involvement of local incident management stakeholders and be a resource for establishing and coordinating a variety of TIM activities including:

- Consistent and effective TIM response policies and practices.
- TIM goals, objectives and performance measures.
- Multidisciplinary TIM training.
- Deployment of effective and compatible technologies and communications.
- Special event planning and post incident debriefings.

Performance Measures Plans and Systems

The success of managed lanes, especially priced managed lanes, is highly dependent on monitoring and managing operations to maintain a high level of performance and reliability. Accordingly, establishing a plan for the collection of data and the production of comprehensive performance measures is critical. TMCs and their systems are routinely set up to collect traffic data and produce performance measures. These systems can easily be applied to managed lanes and can be revised to support the unique needs of managed lanes such as the development and implementation of algorithms that set pricing during normal and incident conditions.

The following are examples of ways in which systems incorporated TIM into the planning for managed lanes:

I-15 Express Lanes (San Diego, CA)

This facility fully incorporated TIM issues into their ITS/Operational planning processes. The following are examples of the documents created:

- Concept of Operations for the I-15 Managed Lanes Toll System.
- I-15 Managed Lanes Operations and Traffic Incident Management Plans.
- I-15 Managed Lanes Value Pricing Project Planning Study - Traffic Operations Plan.
- Systems Requirements for the I-15 Managed Lanes Toll System.

I-495 HOV Lanes (Long Island, NY)

A task force was established early in the HOV lane design phase to engage various stakeholders, including law enforcement, local and state government, transit agencies, the business community, and AAA. TIM in the HOV lanes was one of the topics addressed by the task force.

I-495 Express Lanes (Fairfax County, VA)

The private operator of the managed lanes and VDOT were actively involved with planning for TIM and ITS system integration to ensure that effective sharing of ITS resources could occur between the two entities with different TMCs.

I-35W (Twin Cities Metropolitan Area, MN)

MNDOT designed their managed lane system to include Active Traffic Management (ATM). In addition to lane control signals, extra cameras were added as a result of a request from TMC operators to cover “blind spots”. The ATM software was developed in-house as open source software, and had features added to make lane control signal deployment for incidents easier and more consistent. TMC staff also requested the addition of emergency pull-off areas in sections of the highway where the shoulder was removed.

3.7 TMC PREPAREDNESS CHECKLISTS

These checklists can be used by TMC planning staff and operators to identify preparedness actions that can be taken to support TIM in managed lanes. They will help in the understanding of which unique aspects of TMC preparedness are applicable to their managed lane facility. It can also be used by operators of managed lanes to identify gaps in their preparedness that could lead to improvements in operation if addressed.

TMC Planning Preparedness Checklist

Technology and Communications

- Use and share technology and communications systems
- Establish protocols related to incident communications
- Develop data sharing agreements among agencies

Interagency Relations and Coordination

- Create interagency agreements established by the TMC

Managed Lane Enforcement Patrols

- Ensure enforcement levels and funding for such are adequate
- Define roles, responsibilities and protocols

TMC Resources

- Share TMC resources
- Confirm that sharing agreements are in place
- Examine and obtain funding for managed lanes

TIM Operational Considerations are Incorporated into the Design of Managed Lanes

- ITS Field System Design and Integration
- ITS Field System Maintenance
- Managed Lane Control Software
- Managed Lane Access and Separation Treatments
- Design elements of Project Systems Engineering Documents and Processes

TIM Operational Considerations are incorporated in Operational Planning Processes and Documents related to Managed Lanes

- ITS Strategic Plans
- ITS Regional Architectures
- Planning elements of Project Systems Engineering Documents and Processes
- System Operations and Maintenance Plans
- Local TIM programs
- Data Collection, Fusion, Analysis and System Performance Measures

Figure 26. Checklist. TMC Planning Preparedness Checklist.

TMC Preparedness—Operator's Checklist

Technology and Communications

- Know how to use various technology and communications systems in the TMC
- Know what ITS resources are located on the managed lane system, where the devices are, and the design limitations of the devices
- Understand policies and protocols for use of different communications tools and ITS devices

Managed Lane Enforcement Patrols

- Know which agency has primary enforcement jurisdiction
- Remember that enforcement patrols are a critical source of TIM information and are typically the first responders on the scene
- Understand the general level of motorist compliance with the managed lane operating rules – this may play a role in TIM strategies chosen during an incident

Interagency Relations and Coordination

- Contact information for all TIM responder agencies
- Contact information for other transportation agencies/providers along managed lane corridor
- Know TIM responsibilities/jurisdiction of each partner agency
- Participate in interagency training exercises that are offered

TMC Resources

- Understand protocols for the use of shared TMC resources

Design of Managed Lanes

- Know location of access and egress points along managed lanes
- Have protocols, maps, and response plans for each segment handy

Figure 27. Checklist. TMC Preparedness—Operator's Checklist.

CHAPTER 4—TMC ROLE IN THE MANAGED LANE ENVIRONMENT—REAL TIME TIM RESPONSE ACTIVITIES AND SUPPORT

Traffic Incident Management (TIM) is one of the primary functions of a TMC. TMCs are equipped with a wide variety of systems that support the real time monitoring of the highway, detect incidents, coordinate/support response, and distribute traveler information.

TMCs are usually operational at all times, or at least during hours that cover the most congested time periods. TMCs have operations personnel resources and the expertise to perform TIM functions.

The most effective use of the TMC's resources is critical to ensure prompt detection, response, and clearance of an incident in the managed lanes. The focus of this chapter will be on TMC practices learned through the literature investigation that will minimize detection and response time, provide adequate travel information to users of the managed lanes, and effectively control vehicular access to the incident scene to allow for quick clearance of the incident and return to normal operations.

Figure 28. Photo. Traffic incident and response.

4.1 SHARED OPERATIONS RESPONSIBILITIES

TIM is formally defined by FHWA as, "the process of coordinating the resources of a number of different partner agencies and private sector companies to detect, respond to, and clear traffic incidents as quickly as possible to reduce the impacts of incidents on safety and congestion, while protecting the safety of on-scene responders and the traveling public." In a managed lane environment where the managed lane is operated by a different entity than the general purpose lanes, this coordination is particularly important, especially in situations where there are multiple TMCs responsible for operation of the corridor. Strong partnerships and previously agreed upon operating procedures should be developed among transportation and response agencies to ensure smooth operation of the managed lane facility. Priced managed lanes in particular require significant real-time traffic management, including monitoring traffic and responding to incidents.

Figure 29. Photo. The I-495 Express Lanes in Fairfax County, VA are privately operated while the general purpose lanes are operated by the state DOT, yet they must function as a unified transportation system.

TMCs often treat the transportation network as a single system and have extensive experience in coordinating operations with multiple operating partners. During different types of incidents, the specific details of sharing responsibilities will be critical to ensure that the incident is detected, verified, responded to, and resolved efficiently. TIM on a managed lane and especially a priced managed lane is important to maintain the reliable and quick trip that motorists expect from the facility. A variety of entities may be involved in this function including state DOTs, state highway patrol, local emergency response units, and private towing and recovery contractors. The degree of coordination challenges increase if the agencies are not co-located in a single TMC, or if one of the operators is a private sector entity. In these cases to coordinate TIM efforts between key stakeholders responsible for the corridor, formal interagency agreements and joint operations protocols should be implemented. These protocols should aim for quick response and incident clearance, and outline the individual responsibilities of each entity.

The following situations would require additional coordination among the different entities involved in operating a managed lane facility:

- Increased traffic volumes in the adjacent general purpose lanes and/or in the managed lanes.
- Nonrecurring incidents on the general purpose lanes, which will influence speeds and create increased demand for the managed lanes.

- Nonrecurring incidents, such as minor/major incidents on the managed lanes, which can slow or shut down managed lane operations.
- Incidents of any kind on nearby roadways that may shift demand to the managed lanes or adjacent general purpose lanes.

In the event of an incident on the general purpose lanes, responders might need to use the managed lanes to respond to the incident. If an incident occurs on the managed lane or the general purpose lane, traffic might need to be diverted to the adjacent lanes. If different agencies operate the general purpose and managed lanes, revenue considerations may complicate agency speed or desire to implement diversions, but sometimes it is absolutely necessary. For example the I-15 HOT Lanes in San Diego, CA have procedures in place where tolls can be remotely eliminated if an incident occurs within the express lanes. If an incident occurs on the general purpose lanes, CalTrans has the ability to open the express lanes to all traffic. Similarly, tolls are not collected when the express lanes are used by general traffic.

Where there are multiple TMCs responsible for operation of a corridor, personnel at both TMCs must work together to ensure that the corridor functions seamlessly as a single transportation system. If one TMC is responsible for the managed lanes and another TMC covers the general purpose lanes, each TMC should have procedures in place to establish quick communication with the other TMC in the event of an incident, as it is possible that an incident can be detected by the “wrong” TMC. The correct TMC can then take the lead on the incident response.

In some cases, the managed lane operator may not have a fully equipped TMC, and may instead rely upon a regional TMC for assistance with TIM. In such cases, it is critical to have agreements in place covering various incident types and severities such that the TMC is ready to support the managed lane operator when an incident occurs. The TMC may not have direct operational control over the managed lanes, but it can still provide assistance with dissemination of traveler information, dispatching responder resources, and assisting with scene management.

Specific examples of shared operations responsibility include:

I-10 Katy Freeway (Houston, TX)

Texas DOT operates the general purpose lanes and the Harris County Toll Road Authority (HCTRA) operates the managed lanes. HCTRA has its own TMC, and also has staff at Texas DOT’s TMC.

I-495 Express Lanes (Fairfax County, VA)

Virginia DOT performs the traffic operations for the general purpose lanes and Capital Beltway Express, which is a private entity, operates the managed lanes. The two TMCs are connected via a dedicated communication link for sharing information.

I-85 Express Lanes (Atlanta, GA)

Georgia DOT operates the general purpose lanes and the State Road and Tollway Authority operates the managed lanes.

I-15 Express Lanes (San Diego, CA)

The tolling system is operated by SANDAG, the local MPO, and is supported by the CalTrans TMC. SANDAG relies upon the CalTrans TMC for operational support and TIM. CalTrans has the ability to override normal operation of the tolling system in the event of an incident.

Ideally, interagency agreements regarding TIM policies that include information sharing and incident response procedures should be in place and familiar to all entities involved in the operation of the managed lanes, such that all stakeholders are on the same page regarding which agency is responsible for what when an incident occurs.

4.2 TIM PROCESS

The stages of the typical TIM process involve the following as depicted in Figure 28:

- Detection.
- Verification.
- Response.
- Scene Management.
- Motorist Information.
- Clearance.
- Recovery.

The TIM process for incidents in managed lanes is the same as for incidents occurring in general purpose lanes and other areas. The process has been implemented and tweaked over many years; however each managed lane system has its own unique considerations due to each unique operating environment and these must be addressed in any customized TIM plan.

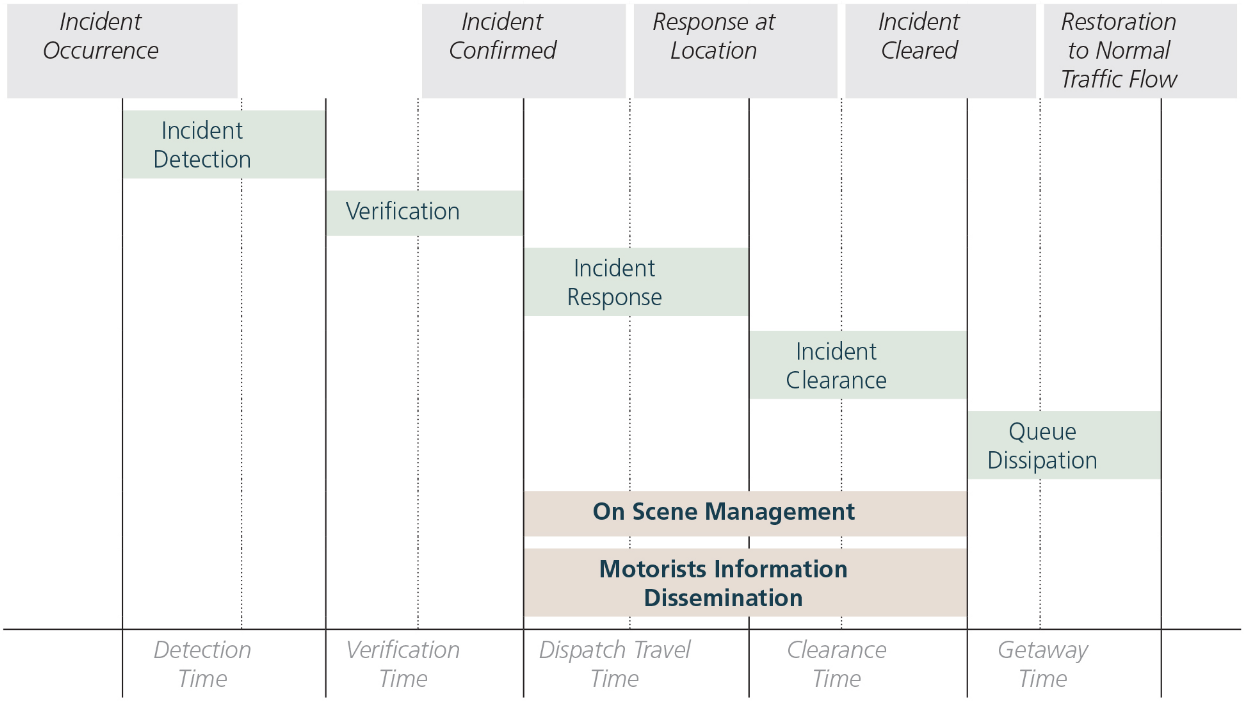

Figure 30. Chart. Stages of the TIM process.

4.3 INCIDENT DETECTION AND VERIFICATION

Detection and verification are the initial stages of TIM where vital information is gathered on an incident. Detection involves determining that an incident has occurred and notifying the agency or agencies that are responsible for maintaining the roadway. Detection methods can be grouped

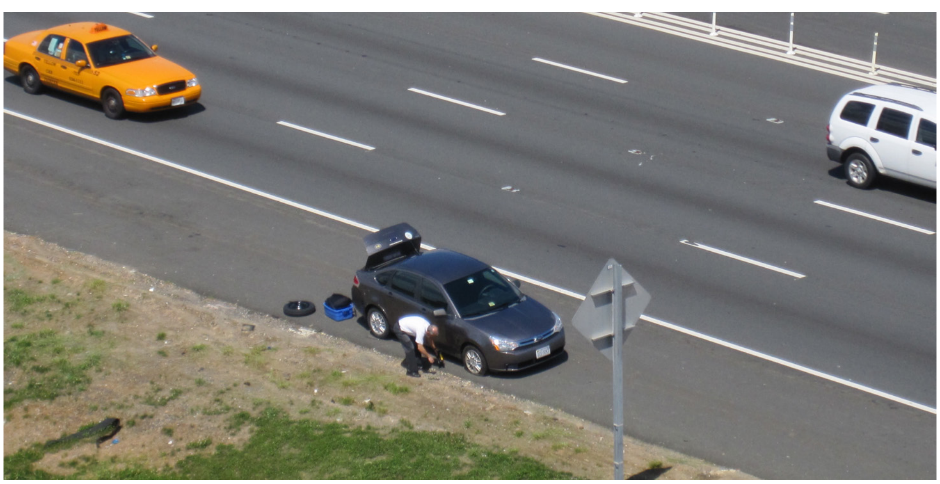

Figure 31. Photo. Verification of the exact location of the incident is important when there is physical separation between lanes.

into the following three general categories: Public Input, ITS Components, and Responder Reports. Examples for each method include:

Public Input

- Cell phone calls from motorists.
- Motorist aid telephones and call boxes.

ITS Components

- CCTV cameras viewed by TMC operators.
- Electronic detection (video processing, radar, induction loops) with traffic incident detection algorithms.

Responder Reports

- Input from other transportation agencies/TMCs along the corridor.
- Law enforcement patrols.
- Monitoring responders' dispatch audio.
- CAD feeds from responders.
- Service patrols.
- Aerial surveillance.
- Calls from DOT or public service crews.
- Traffic reporting services.

In urban areas where managed lanes are present, there are higher traffic volumes and robust cell phone coverage, which will lead to quicker detection of incidents. Ability to detect an incident faster helps to begin the TIM process to clear the incident as soon as possible.

After detection, verification is the key next step during TIM. Verification involves confirming that an incident has actually occurred, including determining the type of incident, determining its exact location, and gathering as much pertinent information needed to dispatch the proper response personnel and resources. Proper verification of an incident in a managed lane environment is very important, especially where there is physical separation between the managed lanes and general purpose lanes. An improper verification could lead to incident response being dispatched to the wrong side of the physical separation, which will lead to longer clearance times since resources must be repositioned. Verification can be performed onsite by emergency personnel or offsite by TMC personnel and generally include the following methods:

- CCTV images.
- Law enforcement at the scene.
- Communication from aerial surveillance sources.
- Combining information from multiple telephone calls.

Since managed lanes may involve multiple agencies it is especially important that TMCs have the capability to gather information from different sources. The collective information received from these sources should be used by the TMC to ascertain the type and severity of an incident, identify which agency has primary jurisdiction, and relay this information to the appropriate responding agencies.

Effective incident detection and verification is especially important for managed lanes because:

- Users of managed lanes, especially those paying a toll, expect a high level of service.
- Responders to the incident may need special information to properly access the incident scene and alert them of any dangerous conditions which may exist such as fire or hazardous materials).

4.4 INCIDENT RESPONSE

Incident response is typically considered the most important component of the TIM process. Incident response involves dispatching the appropriate personnel/equipment and activating the appropriate communication links and motorist information to media that a traffic incident has occurred. In order to facilitate a timely and effective response it is important that TMCs coordinate with enforcement personnel and other incident responders on the dispatch of response to collect all necessary information. The following are a few sample questions that TMC staff should ask when corresponding with emergency personnel or other persons reporting an incident:

- What is the exact location of the incident (roadway, direction, reference marker)?
- Is the incident in the managed lanes or general purpose lanes?
- Has the barrier between the general purpose and managed lanes been breached?
- What type of incident?
- What is the number and types of vehicles involved (trucks, cars, buses)?
- What is condition of vehicles involved (upright or overturned)?
- What is the severity of the incident? Are there any injuries?
- Are there any lanes blocked (by vehicles or debris), and if so which lanes?

Disseminating the incident details collected is a significant role for the TMC because dispatching incorrect equipment and resources can have adverse effects on managing an incident, which can result in increased clearance times, or secondary incidents, or possibly even further injuries and fatalities. TMCs often have access to dedicated safety service patrols that are able to respond quickly and provide assistance at an incident scene.

Some agencies utilize “simultaneous dispatch”, whereby law enforcement and service patrol vehicles are dispatched while the verification step is occurring. After the information is verified, any updated information can be communicated to the responders via radio, CAD, or response agency dispatchers.

Source: New York State DOT

Figure 32. Photo. These New York State DOT HELP trucks have onboard cameras linked to the TMC to provide realtime incident information.

Figure 33. Photo. Pre-positioned service vehicles or service vehicles on a roving patrol can monitor the managed lanes and provide quick response if an incident occurs.

The managed lane environment may present additional challenges to traditional incident response functions coordinated by a TMC, as there may be limited physical access to the managed lanes for responders, and the lanes may have reduced or restricted space for TIM zones, which can complicate TIM response and the ability to establish a safe TIM zone. To overcome this challenge it may be beneficial to have prepositioned response and recovery vehicles at key locations along the managed lane, especially where recovery vehicles may have limited ability to enter a managed lane facility. As mentioned previously, TMCs coordinate with dedicated safety service patrols so it would be ideal to have these patrols monitor the managed lanes to quickly aid in a response when an incident occurs. For example, in the Hudson Valley region of New York there are dedicated Highway Emergency Local Patrol (HELP) vehicles that patrol designated routes and are equipped with a live video stream to the TMC. The dashboard cameras are used to automatically relay real time incident information to TMC personnel which allows them to visually see incident details that aid in expediting a response.

> The US Fire Administration's Traffic Incident Management Systems Report (FA-330, March, 2012) includes an extensive discussion of traffic incident management responder safety, scene management and traffic control.

Another method used to coordinate response efforts is the development of TIM teams along the managed lanes dedicated to responding to incidents. The mission of TIM teams is an inter-agency coordination among all emergency responders to understand the need for quickly and safely responding and clearing incidents from the highway. TIM needs vary from state to state, so TIM teams have the ability to adjust to the needs of their jurisdiction. Urban areas that generally have a large amount of congestion and incidents may require a response from multiple agencies, whereas non-urban areas may require a response from only one or two agencies. Additionally a managed lane environment might fall under the jurisdiction of multiple agencies, so it is important to develop these TIM teams in advance to communicate regularly and coordinate response efforts.

Providing a timely and effective response reduces incident durations and ultimately the amount of time the roadway operates at a reduced capacity. This is especially important for priced managed lane systems where reduced capacity could affect the amount of revenue collected.

4.5 SCENE MANAGEMENT AND TRAFFIC CONTROL

TMCs can be used effectively to support incident site management and traffic control in managed lanes, in many cases using unique assets that may be available in those lanes. TMCs support quick, safe and efficient response to the incident by coordinating with on scene response personnel to set up a safe traffic control strategy and safe incident scene. TMCs can use a variety of transportation management strategies to control the traffic that will use the facility to meet the objective of safe incident clearance. This reduces congestion, helps to create a safer incident management zone, and hastens incident clearance.

Figure 34. Photo. Incident scene management using DMS messages.

The following describes these strategies and actions in more detail.

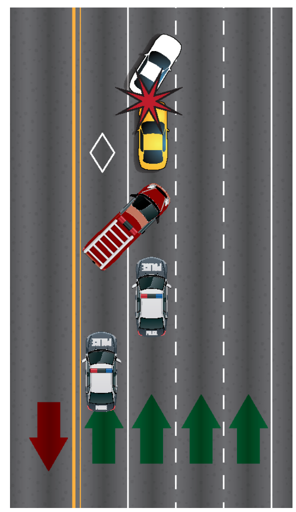

Figure 35. Illustration. Incident zone traffic control to create a safe work area.

Scene Management

Scene management involves the establishment of a safe and effective area where responders can deal with the incident response and clearance. Ideally, if vehicles are drivable and there are no injuries, the vehicles can be moved to a shoulder, pull off area, or off the roadway. If the vehicles cannot be moved, then traffic can be routed around in the vicinity of the scene or, if necessary, diverted from the area. Managed lanes can introduce complexities with scene management when the shoulder area is limited and cannot accommodate the incident scene set up without impacting traffic flow, or where barriers may make it difficult or impossible to allow vehicles to exit or to divert traffic in the immediate vicinity of the scene. Scene management also involves elements such as proper parking of response vehicles and the use of high visibility apparel. Accordingly, it is primarily the function of the onsite responders. However, the TMC can support effective scene management in the followings ways:

- Notify travelers of the incident site and warn of conditions via traveler information systems such as DMS.
- Monitor the scene for conditions and assist as requested in the selection of an effective site.
- Maintain close communications with the responders regarding traffic conditions at and near the scene; discuss scene management changes needed, if any, as the incident evolves.
- Support the establishment of a safe and effective scene by dispatching motorist assist patrols or traffic response teams that can help plan, establish and protect the scene.

- Coordinate response from the appropriate entity where it is necessary to open access to the scene for responders' access and egress.

Traffic Control

Implementing effective traffic control at and around the incident management scene can help increase the safety of the responders as well as reduce the potential for secondary vehicle incidents. It may involve either providing for the safe passage of vehicles around the scene or diverting traffic away from the scene entirely.

The TMC can support effective traffic control for the incident in the following ways:

- Coordinate with responders to develop or explain the traffic control plan.
- Support the implementation of the traffic control plan by dispatching motorist assist patrols or traffic response teams that can deploy flaggers, cones, warning signs, portable DMS and other devices as needed at or near the scene.
- Coordinate response from the appropriate entity where it is necessary to open access to the facility for traffic diversion by actions such as the removal of cones or opening access/egress points in barriers.
- Where managed lanes have movable barriers, adjust the lane configuration to support the need for revised traffic flow.
- Where available, open special use lanes such as HOV or shoulder lanes to accommodate traffic flow around the incident scene.

Additional actions such as controlling vehicle access to the facility to reduce traffic volumes via revised managed lane pricing or eligibility or through access control at the access and egress to the managed lanes are discussed in the subsection on Vehicle Access Management. The ability for a TMC to implement pricing or eligibility changes may be limited by state and local laws.

The following are examples of effective TIM-related scene management and traffic control strategies for managed lanes:

I-15 Express Lanes (San Diego, CA)

Freeway service patrols support incident response and scene management on this facility. For major incidents, a traffic management team may be dispatched in a truck with a mounted DMS attached to the vehicle. That team will assist the incident response in a variety of ways such as providing back of queue warning and traveler information. The system uses a movable barrier to adjust the number of managed lanes in each direction. The movable barrier can be "broken" if needed to provide access at intermediate points in the system for traffic diversions. CalTrans operates the system and is empowered to adjust the lane configuration or suspend tolls if needed in response to a major incident.

I-85 Express Lanes (Atlanta, GA)

Traffic diversion policies have been created that allow responders to divert traffic as needed between the express and general purpose lanes in the event of a major incident. This action is facilitated by the fact that the barrier separation is a painted buffer. The State Road and Tollway Authority operates the system and will waive any toll violations created by crossing this "invisible barrier" during these major incidents.

I-93 Contraflow HOV Lane (Boston, MA)

Two radio dispatched tow trucks are pre-positioned along the facility whenever the contraflow lane is open. These trucks can be quickly dispatched to the incident scene to support safe scene set up as well as incident clearance.

Figure 36. Photo. Some managed lanes can adjust vehicle occupancy thresholds or suspend access by tolled vehicles.

Vehicle Access Management

One of the unique aspects of some types of managed lanes is that the TMC may have the ability to alter vehicle access to the managed lanes in order to reduce congestion, create a safer incident management zone, and hasten incident clearance. This can be done by changing vehicle eligibility (raise occupancy requirements or eliminate access for toll paying vehicles into HOT lanes), pricing (raise the vehicle use price), or through access control (utilizing gates or signals). Many of these access changes can be made directly from the TMC. In some cases the TMC may have to use its communication infrastructure to coordinate with ground personnel to implement the changes and monitor the effects. This section discusses these unique access management techniques and how they can enhance TIM in managed lanes.

It should be noted that the vehicle access management techniques described below are usually accomplished through information and control systems. These systems are implemented by the TMC responsible for operations of the managed lane. In cases where separate TMCs control the managed lanes and general purpose lanes, coordination between the two TMCs is required. In cases where a separate toll agency is involved, coordination with that agency may be required if revenues will be affected. In these cases it is important to work out system functional and control issues and create operational agreements and protocols during the system design phase.

Figure 37. Photo. Priced managed lanes can increase the toll price to reduce demand.

Vehicle Eligibility

The most common eligibility requirement associated with managed lanes is vehicle occupancy. Typically, HOT lanes allow free use of the managed lane based on a minimum number of vehicle occupants – usually two or three. In the event of an incident requiring reducing the traffic volumes in the managed lanes, it might be possible to temporarily raise an HOV 2 requirement to HOV 3 if local laws and policies allow this strategy. The TMC could implement this change using tools such as DMS and managed lane access signs at the points of entry. However, HOV occupancy enforcement requires manual techniques and it may be difficult to get full compliance. An alternative vehicle eligibility change could be to suspend access by single-occupant vehicles in a HOT lane and only allow HOVs. This can be implemented without adjusting the occupancy threshold, which may not be allowed based on the state's laws. The managed lane could also be closed completely if necessary. Techniques for such situations are described in the below section Access Control.

Pricing

Many managed lanes have a pricing element to them, such as HOT lanes and ETLs. Pricing allows vehicles not meeting eligibility requirements (such as HOV 2) to use the lane by paying a toll. The toll is usually variable, based upon factors such as time of day or congestion levels. Vehicles using the lane via pricing eligibility usually need to have a toll tag. Pricing technology allows the operating agency to meter traffic to optimize travel on the managed lane and also allows for a TMC to meter traffic flow in response to an incident. The price can be raised to very high levels to greatly reduce the toll-paying traffic. Priced managed lanes are equipped with systems for altering the toll charge, via DMS or signs at the managed lane access point of entry. There may also be

Figure 38. Photo. Some managed lanes have signs and gates that can be used to quickly close the lanes during an incident.

separate lanes for toll paying vehicles and those can be closed as described in the below section Access Control.

Access Control

There are a variety of ways in which physical access to managed lanes may be controlled. In all cases, TMCs would play a primary role either in direct operations or coordination of operations. Access control techniques that are largely technology-based include:

- Overhead DMS and lane/speed control signs at frequent intervals on the facility.
- Separate ramps or direct connections that have gates and/or closure signing systems.
- Separate access points in the highway with positive entrance control lanes and gantries.

In some cases, the design of the managed lane does not facilitate the use of technology-based access control systems. In these situations it is necessary to implement techniques that are more manual oriented such as:

- Reversible Lanes: the gates and signing may need to be moved and the lane configuration may need to be reconfigured.
- Traditional HOV Lanes with Continuous Access: access control would need to be accomplished by techniques such as DMS and/or manual closure techniques such as placement of police cars, cones or barriers at access points.

In any case, whether access control is technology-based or manual-based, it can be seen that the TMC will play a large role in adjusting access control to facilitate TIM in managed lanes.

The following are examples of effective TIM-related access management systems for managed lanes:

I-15 Express Lanes (San Diego, CA)

This is a HOT lane type system with reversible lanes which is implemented and operated using a moveable barrier. Moveable barriers can create additional complexities in restricting access due to issues associated with reversing traffic and wrong way movements. CalTrans is empowered to open/close or reconfigure the managed lanes or eliminate tolls as deemed needed to support TIM. The I-15 system was built with a variety of technology and manual based systems at entry points to help address these issues including:

- DMS.

Figure 39. Photo. Effective clearance may be challenging in managed lanes with no shoulders and physical barriers, such as this zipper lane in New York City.

- Gates.
- Pop up lane delineators.
- In-pavement lane guidance lights.
- Maintenance vehicles that drive the express lane after a lane reversal has occurred to ensure the lane is clear and safe.

I-35W (Twin Cities Metropolitan Area, MN)

The Priced Dynamic Shoulder Lane system has overhead DMS and lane control/variable speed limit gantries at ½ mile spacing that allow easy closure of the managed lane and/or open the bus shoulder lane for general use. The TMC has the authority to close the managed lane or direct traffic to/from the managed lane and eliminate tolls as they deem necessary to support TIM.

4.6 CLEARANCE AND RECOVERY

Clearance and recovery comprise the final stages of the typical TIM process. Clearance involves removing wreckage, debris, or any other elements of a traffic incident that disrupt the normal flow of traffic. The impacts of an incident can extend beyond the managed lanes to the general purpose lanes and other parallel roadways in the regional transportation network. Therefore, improving clearance procedures could have positive effects including: minimizing motorist delay, enhancing the safety of responders and travelers, and minimizing the loss of revenue.

Recovery involves evaluating what the long-term impacts of an incident may be and identifying what recovery actions might be needed to mitigate those impacts. The ultimate goal of recovery is to restore the roadway capacity to its previous condition before the incident occurred, and to have the managed lane fully operating, collecting tolls if applicable, and providing premium service to eligible users. Recovery actions include:

- Clearing debris.
- Assessing damage.
- Repairing damaged infrastructure.
- Restoring traffic flow.
- Restoring the roadway to its previous condition.

TMCs provide unparalleled support to the quick clearance and recovery of traffic incidents by coordinating with responders to support any needs for additional resources such as tow trucks, medical support, environmental response, or other assistance.

In a managed lane environment several factors may provide challenges to quick incident clearance, such as accessibility of the incident scene and coordination among various responding agencies. To facilitate the clearance of an incident, managed lane operators may use managed lanes to divert traffic, and lane control signs to indicate which lanes are open and closed. After clearing the incident, normal operation of the managed lane facility resumes and signage returns to normal.

Effective clearance and recovery protocols are critically important to the success of priced managed lanes because the longer an incident is on the roadway the less revenue is collected. If priced managed lanes are not providing an enhanced traveling experience, then motorists will not see its advantage and not be motivated to use them.

Source: Adam Froehlig

Figure 40. Photo. Use of lane control signals to close lanes on the I-35W PDSL in Minneapolis.

4.7 SYSTEM AND CORRIDOR MANAGEMENT

Previous sections in this chapter discussed TMC activities related to the typical TIM process. Those sections were primarily directed at actions that will occur at or near the scene or on the affected facility. Although system and corridor management is not part of the typical TIM process, it is a real-time response activity that can be implemented depending upon the functionality of the TMC.

A significant incident on a major limited access facility containing a managed lane will quickly affect and be affected by traffic conditions. TMCs have a variety of transportation management strategies and tools that can be used at a system and corridor level to reduce the traffic that will use a managed lane facility during an incident and encourage travel around the incident.

The current USDOT Integrated Corridor Management (ICM) Program is directed at integrating travel in corridors and provides a forward looking example of the wide variety of transportation management options that can be implemented for this purpose. While most TMC sites in the United States do not have all the capabilities to fully implement TIM from an ICM perspective at this time, most sites have many of the tools.

The strategies include:

Lane Control Signals

Use devices such as lane control signals and signs to implement or warn of lane closures, or reduced speed limits, or to close lanes well in advance of the scene.

Ramp Metering

Modify ramp metering signal timing to reduce traffic volumes entering the facility.

Source: Adam Froehlig

Figure 41. Photo. Signs displaying travel times via private vehicle and public transit can encourage modal shift during incidents.

Traveler Information

TMCs can use systems such as 511, DMS and Highway Advisory Radio (HAR) across the corridor to alert travelers of the incident and the best way to avoid the related congestion.

Arterial Traffic Signal Timing Adjustment

TMCs can adjust signal timing on adjacent frontage roads, arterials and local streets to accommodate increased traffic on these facilities as traffic diverts.

Park and Ride Status and Modal Transfer

In some areas, TMCs have access to the unused capacity of nearby Park and Ride lots and can post DMS messages advising travelers they can change travel modes if parking is available.

Traffic Diversion

Where formal traffic diversions are implemented, TMCs can use DMS and other travel information devices to advise of the diversion and trail blaze motorists through the diversion route.

Travel Times

Where detection information is available, TMCs can use DMS and other travel information devices to advise travelers of comparative travel time route alternatives. This allows travelers to make their own assessment of any need to change route, mode or time of travel.

Expanded Motorist Assist Patrols

As congestion extends further from the affected managed lane facility, TMCs can adjust the times and roadways of coverage of their motorist assist patrols to focus them on the area most affected and help keep those facilities moving at optimum efficiency.

In the context of the corridor-level strategies, a single TMC will rarely have the capability to implement all the strategies across an entire corridor. The TMC will need to coordinate with numerous adjacent TMCs and agencies to accomplish a true corridor effect, which is consistent with the concept of ICM.

The following are examples of effective TIM-related corridor management strategies for managed lanes:

I-35W (Twin Cities Metropolitan Area, MN)

This managed lane system includes a variety of systems that are used to manage traffic at the system and corridor level. An Active Traffic Management (ATM) system covers the entire system and includes Intelligent Lane Control Signs at half-mile spacing that provide the means to open and close lanes or implement reduced speed advisories to support incident management activities. They also can adjust ramp meter timing consistent with congestion levels. Traffic data from the facility is fused at the TMC such that traveler information can be provided across the corridor through DMS or 511.

I-495 HOV Lanes (Long Island, NY)

The INFORM TMC (state TMC for Long Island) monitors and manages the entire corridor using a variety of devices including DMS, ramp meters, and HAR. The full detection coverage that is installed in the corridor allows them to advise travelers of travel times immediately ahead as well as on alternate routes. The TMC controls the traffic signals on the I-495 frontage roads and can adjust signal timing in the event of a major incident.

4.8 TIM RESPONSE AND SUPPORT CHECKLIST

This checklist can be used by TMCs and/or operators of managed lanes to identify the real-time response activities and support actions that TMCs can take to support TIM in managed lanes. It will help in the understanding of which unique aspects of TIM response and support are applicable, or are potentially applicable, to their managed lane facility. This checklist could be used by operators of managed lanes to identify gaps in their TIM response or support functionalities that could lead to improvements in operation if addressed.

TMC Real Time Response Activities and Support Checklist

Shared Operations Responsibilities

Determine entities involved

Contact information and point-of-contacts of each entity

Incident Detection and Verification

Detect and confirm incident

Gather incident details from public input, ITS components, and responder reports

Incident Response

Dispatch the appropriate personnel/equipment

Activate the appropriate communication links

Disseminate information

Management of Vehicle Access During Incidents in Managed Lanes

Manage vehicle eligibility

Manage pricing

Manage access control

Clearance and Recovery

Coordinate with responders to support any needs for additional resources

Scene Management and Control During Incidents in Managed Lanes

Scene Management Activities

Provide traveler information

Determine site selection and monitoring

Communication with responders and follow the evolution of response plan and actions

Dispatch support such as motorist assist patrols for scene management and clearance

Coordinate, if necessary, with agencies responsible for opening access to support responder ingress and egress

Traffic Control Activities

Coordinate with responders to develop traffic control plan

Support traffic control plan implementation via dispatch of support resources such as traffic response teams

Coordinate, if necessary, with agencies responsible to open access to the managed lane for traffic diversion

If present, adjust or coordinate the adjustment of movable barriers to support needed traffic flow

Where available, open the use of special use lanes such as HOV or shoulder lanes to improve traffic flow around the scene.

Implement System and Corridor Management Strategies and Systems

Lane control signals

Ramp metering

Traveler information

Arterial signal timing

Park and Ride status

Traffic diversion

Display travel time information on DMS

Expand/relocate motorist assist patrol services

Figure 42. Checklist. TMC Real Time Response Activities and Support Checklist.

CHAPTER 5—CASE STUDIES

This chapter evaluates how the best practices related to TMC-based TIM are applied to several existing managed lane facilities in the United States.

The case studies presented in this guidebook provide a level of insight into the combinations of best practices that can be implemented, why some best practices were implemented versus others, and the considerations that go into choosing best practices for implementation.

As part of the research for this guidebook, the operations of eight managed lane facilities in the United States were reviewed. After the information was collected, three of the eight managed lane facilities were chosen for a more in-depth presentation in the guidebook. The eight facilities investigated by the project team included:

1. Long Island Expressway (I-495) HOV Lanes (Long Island, NY).
2. I-35W Priced Dynamic Shoulder Lane (PDSL) System (Twin Cities, MN).
3. I-10 Katy Freeway Managed Lanes (Houston, TX).
4. I-95 Express Lanes (Miami, FL).
5. I-93 Contraflow HOV Lane (Boston, MA).
6. I-15 Express Lanes (San Diego, CA).
7. I-85 Express Lanes (Atlanta, GA).
8. I-495 Express Lanes (Fairfax County, VA).

Table 2 presents an overview of the eight managed lane facilities and the TIM best practices employed by each.

Table 2. TIM Best Practices Comparison for Eight Managed Lane Facilities.

	Long Island Expressway HOV Lanes	I-35W Priced Dynamic Shoulder Lane	Houston Katy Freeway Managed Lanes	Miami I-95 Express Lanes	Boston I-93 Contraflow HOV Lane	San Diego I-15 Express Lanes	Atlanta I-85 Express Lanes	Northern Virginia I-495 Express Lanes
Technology and Communications								
Established protocols related to incident communications	✓	✓	✓	✓	✓	✓	✓	✓
Data sharing agreements among agencies - detector data, video feeds, usage statistics	✓		✓	✓		✓	✓	✓
Interagency Relations and Coordination								
Interagency agreements established with response agencies	✓	✓	✓	✓	✓	✓	✓	✓
Interagency agreements established with other transportation agencies			✓	✓		✓	✓	✓
Managed Lane Enforcement Patrols								
Manual enforcement / moving violations	✓	✓	✓	✓	✓	✓	✓	✓
Automated enforcement			✓	✓			✓	✓
Dedicated police patrols	✓	✓	✓	✓	✓	✓	✓	✓
Dedicated service patrols			✓	✓	✓	✓		✓
TMC Resources								
Recovery of some TMC operating costs from toll revenue			✓	✓			✓	✓
Toll revenue fully supports TMC operating costs			✓					✓
TIM Operational Considerations are incorporated into in the Design of Managed Lanes								
Managed lane control software		✓	✓	✓		✓	✓	✓
Managed lane access and separation treatments	✓	✓	✓	✓		✓		✓
Planning Processes and Documents related to Managed Lanes								
TMC operational considerations incorporated into planning processes	✓	✓	✓	✓	✓	✓	✓	✓
Shared Operations Responsibilities								
Managed lanes / general purpose lanes operated by different transportation agency or entity			✓				✓	✓
Multiple TMCs with TIM jurisdiction on corridor			✓	✓			✓	✓
Incident Detection and Verification								
Detect and verify incident from TMC	✓	✓	✓	✓	✓	✓	✓	✓
Incident Response								
Coordination of incident response from TMC	✓	✓	✓	✓	✓	✓	✓	✓
Pre-positioned response and recovery vehicles					✓	✓		
Dedicated safety service patrols for managed lanes			✓	✓	✓	✓		✓

Table 2. (Cont.) TIM Best Practices Comparison for Eight Managed Lane Facilities.

	Long Island Expressway HOV Lanes	I-35W Priced Dynamic Shoulder Lane	Houston Katy Freeway Managed Lanes	Miami I-95 Express Lanes	Boston I-93 Contraflow HOV Lane	San Diego I-15 Express Lanes	Atlanta I-85 Express Lanes	Northern Virginia I-495 Express Lanes
Management of Vehicle Access During Incidents in Managed Lanes								
Adjusting vehicle eligibility during incident		✓				✓	✓	
Adjusting pricing during incident		✓		✓		✓	✓	✓
Closing managed lanes remotely from TMC		✓				✓		
Remotely closing access points from TMC		✓	✓	✓	✓	✓	✓	✓
Scene Management and Traffic Control Activities								
Select location, establish, maintain effective incident scene	✓	✓	✓	✓	✓	✓	✓	✓
Coordinate interagency response to open access points to scene			✓		✓	✓		✓
Adjust or coordinate the adjustment of movable barriers to support needed traffic flow					✓	✓		
Open the use of special use lanes such as HOV or shoulder lanes to improve traffic flow around the scene	✓	✓				✓	✓	
System and Corridor Management Strategies and Systems								
Lane control signals		✓				✓		
Ramp metering	✓	✓		✓		✓	✓	
Traveler information (DMS / HAR / 511)	✓	✓	✓	✓	✓	✓	✓	✓
Arterial signal timing	✓		✓					
Post diversion information on DMS	✓	✓	✓	✓	✓	✓	✓	✓
Post travel times	✓	✓	✓	✓		✓	✓	
Expand/relocate motorist assist patrol services	✓	✓	✓	✓	✓	✓	✓	✓
Clearance and Recovery								
Coordinate with responders to support any needs for additional resources	✓	✓	✓	✓	✓	✓	✓	✓

Many of the best practices are currently implemented on managed lane facilities in the United States. Some of the findings from the investigation are as follows:

- All managed lane facilities have communication protocols established for incident communications and interagency agreements with responder agencies.
- Interagency agreements between transportation agencies were needed only when managed lanes were operated by a different entity than the general purpose lanes.
    - The most detailed and formal interagency agreement was between the I-495 Express Lane operator and VDOT, as the managed lanes are privately operated.

- All facilities have some form of dedicated police patrols for the managed lanes and use those resources for manual enforcement and moving violation enforcement.
    - In some cases, the dedicated patrols are solely responsible for the managed lanes, while in other cases, police resources are shared with the general purpose lanes.
    - On priced managed lane facilities, dedicated police resources may require special equipment that utilizes toll tag readers and/or license plate scanners linked to the toll system.
- Service patrols covered all managed lane facilities, however only a select few had dedicated service patrols for the managed lanes. Facilities with dedicated service patrols were either privately operated, had pre-positioned vehicles such as tow trucks ready to respond to incidents due to tight lane geometry, or were operated by a toll agency with a dedicated fleet of service patrol vehicles used for other facilities in addition to the managed lanes.
- Most entities that collect tolls used toll revenue to support TIM, but only two entities fully fund their TMC from toll revenue. These entities maintain their own TMC exclusively for the managed lane system (I-495 Express) or for the managed lane system and other toll roads (Houston). Most other agencies use toll revenue to support TMC operations, but the TMC has shared responsibility with other facilities besides tolled roads and managed lanes.
- Some form of managed lane control software was in use on priced managed lane facilities. All facilities use some form of software for TIM purposes.
- Managed lane facilities that involved physical construction took operational considerations into account during the design phase.
    - Facilities that were conversions from HOV lanes (I-85), or fit into an existing right-of-way (I-93 Contraflow HOV Lane) have several design considerations for TIM, but since these facilities were designed to minimize capital costs, the TIM related design features are not the ideal features that would be incorporated into a managed lane facility built from scratch.
    - In all cases, the TMC was involved in operational planning for the facilities.
- When the managed lanes are operated by a different agency as the general purpose lanes, there are likely to be multiple TMCs with jurisdiction over a corridor. One TMC may have primary responsibility for general purpose lanes, and the other for managed lanes.
    - In some cases, multiple agencies are co-located within one TMC, and an agency's staff may be present at multiple TMCs. This is the case in Houston, where the managed lane operator has staff in its own TMC and in TxDOT's TranStar TMC.
- Managed lanes on longer corridors may have multiple TMCs involved depending on the coverage area of the TMC. The I-95 Express Lanes are covered by separate TMCs in Miami-Dade and Broward Counties, respectively.

- Only two managed lane facilities rely on pre-positioned response and recovery vehicles. These facilities (I-15 and I-93) utilize physical barriers that cannot easily be breached or crossed by response vehicles, so vehicles are located inside the lanes.
    - Other agencies use dedicated service patrol vehicles for the managed lanes that have a designated “beat”, or patrol route within the managed lane network. This method is helpful where there is no shoulder available to pre-position vehicles. These vehicles on a patrol route are valuable sources of information for incident detection and verification. Response vehicles can cross or breach barriers if necessary to reach an incident.

- Three managed lane facilities adjust eligibility restrictions: I-85 in Atlanta, I-35W in Twin Cities, and I-15 in San Diego. The restriction is implemented in HOT lanes by removing eligibility for toll-paying vehicles to enter and retaining the existing HOV restriction, rather than altering the HOV restriction threshold.
- All but one agency with priced managed lanes can adjust pricing in response to an incident. The exception is Houston’s managed lane facility, which adjusts the variable tolls based on a set time schedule.
- Lanes can be closed remotely from the TMC on most managed lane facilities by adjusting electronic signs at entrances to the lanes, though compliance is not ensured without police or incident responder assistance. San Diego and Minnesota have designated resources for closing lanes: lane control signals or pop-up devices activated from the TMC.
- All agencies without any form of physical barrier between the managed and general purpose lanes, in addition to California (using designated access points) specifically cited the ability to open managed lanes or shoulders to general traffic if needed during an incident.
- Ramp metering is present on most, but not all managed lane corridors.
- Two managed lane facilities (Long Island and Houston) specified the ability to regulate arterial signal timing on some parallel diversion routes during an incident.
- All but two agencies have some corridor travel time information posted on DMSs.
- All TMCs can give traveler information, diversion information, and have the ability to dispatch additional support for the incident scene and the corridor.

The above summary provides an overview of the practices used on a sampling of managed lane facilities throughout the United States. Three of these examples are highlighted in more detail in the following sections: Minnesota’s I-35W HOT/PDSL, Houston’s Katy Freeway Managed Lanes, and Virginia’s I-495 Express Lanes. Each case will be described in detail, and will focus on a certain aspect of TIM from the TMC in a managed lane environment.

5.1 CASE STUDY 1: MINNESOTA’S I-35W HOT/PRICED DYNAMIC SHOULDER LANE AND ATM SYSTEM

Minnesota’s Department of Transportation (MNDOT) operates a part-time HOT lane facility on I-35W south of downtown Minneapolis. In the northbound direction, the HOT lane is extended into downtown Minneapolis as a “Priced Dynamic Shoulder Lane” (PDSL). This managed lane facility is operated by the state DOT, so there are no interagency coordination needs between transportation agencies. The portion of the corridor where the PDSL is located does not have adequate shoulders, as the left shoulder is used by the PDSL and there is no right shoulder. As a result, MNDOT has deployed state of the art ITS resources on this managed lane facility and in the TMC with use of an Active Traffic Management (ATM) system. The ATM system gives MNDOT enhanced TIM capabilities for adjusting lane use, speed limits, and access to/from the managed lanes from the TMC. These capabilities are generally not found on most other managed lane facilities.

Overview

Access Restriction

HOT (peak), open to general traffic (HOT Lane, off-peak), operates as a shoulder (PDSL, off-peak)

Physical Separation

Painted line/painted buffer

Location

The I-35W Managed Lane System is approximately 18 miles long and runs in both directions between Burnsville to the south and the City of Minneapolis to the north. The southern section of the system includes 15 miles of HOT lanes with one lane in each direction. On the northbound side, the managed lane system is extended an additional 3 miles into downtown Minneapolis through a Priced Dynamic Shoulder Lane (PDSL).

Design Type

HOT Lanes: the HOT lanes are 12-feet wide and have a reaction area on the left varying from 2 to 10-feet separating the lane from the barrier as well as a 2-foot buffer on the right established by a painted double white line where there is no access and a single skip line at access points (see Figure 40).

PDSL

The PDSL section uses the existing shoulder and is generally 12-feet wide with a 2-foot buffer on the left separating it from the barrier. The PDSL is separated on the right from the general purpose lanes by a single yellow pained line. Access to and from the lanes is continuous.

General Purpose Lanes

The right shoulder of the general purpose lanes is generally 12-feet wide but is limited in the PDSL area to about two feet. In areas where the right shoulder is limited there are emergency pull offs about every one half mile.

Figure 43. Illustration. I-35W PDSL HOT lane.

Vehicle Eligibility

Free access to the managed lanes (HOT and PDSL) is limited to vehicles with 2 or more passengers (HOV 2+), transit and motorcycles. Single occupant vehicles with toll transponders may use the lane for a charge. The cost is variable depending upon congestion levels in the general purpose lanes.

Operations

The Minnesota Department of Transportation (MNDOT) is the owner/operator agency of the system including the tolling element of the system. The HOT lanes typically operate from 6 AM to 10 AM and 3 PM to 7 PM Monday – Friday. The HOT lanes are open to general traffic at all other hours. The PDSL operates from 6 AM to 7 PM Monday – Friday. The PDSL lane is used as a shoulder at all other times. MNDOT can adjust the specific times of operation at its discretion. During periods of heavy traffic, the PDSL is sometimes left open beyond the 7 PM closure time. The PDSL can also operate on weekends depending upon traffic demand. At the request of MNDOT's snow and ice coordinator, the PDSL will be left open during overnight hours to allow vehicle traffic to disperse anti-icing chemicals.

Additional Special Characteristics Affecting TIM

Bus Shoulder Use

Aside from the PDSL area where there is no right shoulder, buses are permitted to use the right shoulder as a travel lane when speeds fall below 35 MPH on the other lanes. When using the shoulder, buses are limited to traveling no more than approximately 15 MPH faster than vehicles in the adjacent travel lane.

Winter Weather and Snow Removal

The Twin Cities area typically receives large amounts of snow accumulation during the winter season. The winter weather is a significant generator of incidents. The increase in lane miles, reduction in shoulder space, and addition of pull offs on the roadway segments with managed lanes all add to the snow removal requirements. Shoulders are no longer available for temporary snow storage in many locations, the added lanes will require an additional plow, and the pull offs require special equipment that can fit and maneuver into and out of the pull offs. Thus, there are significant additional costs for snow removal, as there are many segments where the snow must be blown into dump trucks and transported off the highway.

TIM State of the Practice Related to the Managed Lanes

Operation and Management

MNDOT owns and operates the managed lane system including the tolling element of the system. The system is monitored and managed from the MNDOT TMC in Minneapolis as part of their overall traffic management responsibilities for all state highways in the area. MNDOT contracts out the fiscal/administrative aspects of the toll system. MNDOT has overall responsibility for both toll and traffic operations and can override pricing and/or open managed lanes to general traffic if conditions dictate.

Traffic/Incident Management (Surveillance/Control - Detection/Verification)

The managed lanes are fully equipped with detectors and cameras for traffic monitoring purposes. In addition there are ramp meters controlling access to the overall freeway based on congestion levels. The entire system is also covered by an Active Traffic Management (ATM) system. The ATM includes Intelligent Lane Control Signs (ILCS), which are overhead signs located at about one-half mile spacing which provide speed harmonization, lane control, and electronic tolling information. The ATM provides a number of incident management capabilities including opening/closing lanes and slowing/smoothing traffic speeds.

Traveler Information

A variety of tools are used to notify the public of conditions that may affect the HOT lane, such as incidents, construction, or diversions. These include the DMS and ILCS as well as a 511 system. In addition, MNDOT has a partnership with a local radio station that broadcasts traffic information every 10 minutes, or more often as needed in the event of a large scale incident.

Enforcement

Enforcement on the system is provided by the Minnesota State Patrol. The State Patrol provides resources for routine enforcement and MNDOT contracts with the State Patrol to provide extra enforcement on the system during the HOT lane hours of operation. There is a dedicated pool of officers who undergo special training in the specifics of traffic enforcement and incident management for the managed lane system. Patrol vehicles are equipped with mobile reader devices that allow them to ascertain whether a vehicle has a toll tag.

Response/Scene Management

The State Patrol is responsible for response to incidents on the system. Other emergency response such as fire and EMS are provided by the appropriate local agencies. MNDOT also has motorist assist patrols (FIRST) that patrol the system to provide routine assistance and can respond to incidents and assist with scene management or push vehicles off the travel way. Towing is provided by local area towing companies as requested by the State Patrol under a tow zone system that considers factors such as equipment, hours of operation, response time, and reliability.

Minnesota has Quick Clearance laws in place to support rapid clearance. MNDOT and the State Patrol have a formal Open Roads Policy. In the event of an abandoned vehicle, the FIRST patrols have authority to initiate the tow. The fact that buses may use the right shoulder to expedite their travel increases the importance of quick clearance of incidents affecting the shoulder.

Diversions

Because the HOT and PDSL have shoulders and access to the general purpose lanes diversion is not a special issue from an incident management perspective. In general, standard procedures are followed when an incident occurs in the managed lanes. As indicated previously, MNDOT can direct general purpose traffic into the managed lanes or waive tolls if necessary, but this is rarely done.

Figure 44. Photo. ATM system on I-35W in Minneapolis.

Institutional Coordination

TIM

MNDOT has a robust TIM program in cooperation with the State Patrol as well as local responders as appropriate. Elements of the program include routine coordination meetings, joint training, post incident reviews, and planning for special events.

Agreements

As indicated previously, there are two significant agreements affecting incident management of the system:

- An Open Roads agreement between MNDOT and the State Patrol.
- A funding agreement with the State Patrol for additional enforcement patrols on the managed lanes.

Resources/Funding

Resources for operating the managed lanes are generally the responsibility of MNDOT and include both traditional funds as well as toll revenues.

Design/Construction/Maintenance Coordination

There is close cooperation among the MNDOT Design, Construction, and Maintenance Offices with regard to the operational considerations of the managed lanes.

Other Issues

MNDOT has a number of research projects underway to improve system operations/management including:

- Researching how to modify the advisory speed limit during inclement weather.
- Researching the extent to which motorists see and react to the message signs.

Summary of TMC Role in Managed Lane TIM

The MNDOT TMC is responsible for managing and monitoring the PDSL HOT lane. The TMC covers the entire system including the general purpose lanes with cameras, ramp meters, and detectors in order to effectively detect incidents. Since the PDSL system and adjacent general purpose lanes are equipped with an ATM system, the TMC has enhanced incident management capabilities such as the ability to remotely open/close lanes and slowing/smoothing traffic speeds with variable speed limits. The ATM also includes ILCS overhead signs, which are used along with DMS, 511 system, and a partnership with a local radio station in order to disseminate incident information to the public.

The TMC dispatches a dedicated pool of officers with special incident management training that can effectively utilize the enhanced TIM tools that are available on this corridor. In addition, MNDOT TMC operates FIRST motorist assist patrols that routinely patrols the PDSL HOT lane to respond to incidents and assist with scene management. Since the shoulders are used by PDSL and buses, quick detection and clearance of incidents is the goal of the MNDOT TMC in operating this corridor. The TMC has the authority to direct general traffic into managed lanes and waive tolls, and it can also direct managed lane traffic into the general purpose lanes, if necessary. Communication of this change can occur using existing ATM and ILCS infrastructure controlled by the TMC.

Findings

MNDOT's extensive use of ATM is unique among the managed lane facilities examined in this project. In the future, it is likely that more facilities using ATM will be constructed to improve TIM and managed lane operations. ATM may be a mitigation strategy for managed lane facilities constructed in a constrained environment where the geometrics are not ideal from a TIM perspective, such as reduced or narrow shoulders. This will help maximize the use of available roadway space while minimizing the disruption from an incident.

5.2 CASE STUDY 2: HOUSTON'S KATY FREEWAY MANAGED LANES AND INTERAGENCY COORDINATION

The Katy Freeway Managed Lanes are located on I-10 west of Houston, Texas. The facility is operated as a HOT lane facility during peak hours and as an Express Toll Lane facility during other times where all vehicles pay for access. The entire Katy Freeway corridor underwent significant reconstruction when the managed lanes were built, and is now one of the widest freeway corridors in the country. As a result of this reconstruction, the purpose-built Katy Freeway Managed Lanes have nearly ideal geometrics, with full shoulders on both sides adjacent to a flexible post barrier separating them from the general purpose lanes.

Of interest to planners about the Katy Freeway Managed Lanes is the shared operating responsibility for the corridor. The managed lanes are operated by the Harris County Toll Road Authority (HCTRA), while the general purpose lanes and frontage roads are operated by the Texas DOT (TxDOT). HCTRA operates tolled facilities in and around Houston, while TxDOT is the primary operator of freeways within the region. Each agency operates its own TMC. HCTRA's TMC covers all of its tolled facilities in the region. TxDOT is the lead agency at the TranStar TMC, which co-locates many of the transportation providers in the Houston area under one roof. Included as part of the TranStar TMC are: TxDOT, Harris County, HCTRA, the City of Houston, and the Houston area's transit agency, Metro. In addition to transportation officials, public safety officials are located at the TranStar TMC, which has an emergency management function in addition to a transportation management function. As a result of HCTRA's participation in TranStar, the agency has staff at two different TMC's in the Houston area. Their TranStar presence will enhance their ability to coordinate with other transportation agencies during a major incident, while minor incidents only affecting the managed lanes can be handled from their own TMC. This arrangement actually requires some intra-agency coordination between its TMC staff located in the two different TMCs.

Overview

Access Restriction

HOT (peak hours), Tolled (non-peak hours)

Physical Separation

Plastic "candlestick" post barrier with full shoulders on both sides

Location

The I-10 Express Lanes extend 12 miles in both directions in the center of Interstate 10 in Houston, Texas.

Design Type

There are two 12-foot wide lanes in each direction, separated directionally by a concrete barrier. The express lanes are separated from the general purpose lanes by a plastic post barrier with 12-foot wide shoulders on both sides of the post barrier (see Figure 42). Direct access to/from the express lanes is provided at each end as well as through slip ramp type openings in the channelization at 3 intermediate points. In addition, there is direct access provided from a Park and Ride lot as well as a transit center. There are three toll gantries located within the system between access/egress points that serve as designator lanes to sort HOV users from toll tag users.

Figure 45. Photo. I-10 Katy Freeway managed lanes with plastic post barrier and full shoulders on either side.

Vehicle Eligibility

Free access to the express lanes is limited to peak hours for vehicles with 2 or more passengers (HOV 2+), motorcycles and exempt vehicles such as metro buses and police. Single occupant vehicles with tags are allowed anytime at a toll price that changes based on time of day. Eligible vehicles must also pay the posted toll price during non-peak hours.

Operations

The Harris County Toll Road Authority (HCTRA) is responsible for the operation of the express lanes including all traffic operations and toll operations. TxDOT is responsible for the operation of the general purpose lanes. The system operates 24/7. Designated peak hours are 5 AM to 11 AM and 2 PM to 8 PM, Monday through Friday.

Additional Special Characteristics Affecting TIM

Toll Gantries

Traffic must sort into one of two lanes at the toll gantries – one lane for HOV-eligible traffic and one for single occupant vehicles with toll transponders. The gantry locations provide an area where enforcement vehicles can park to observe entering vehicles.

Plastic Post "Candlestick" Barrier

The posts can be removed to facilitate diversion to/from the express lanes. They are also flexible enough that vehicles from the general purpose lanes can physically drive over them if necessary to divert traffic in the event of an incident.

Enforcement/Incident Scene Management

Two adjacent 12-foot shoulders, one on each side of the plastic post barrier, provide ample space for enforcement and incident management activities.

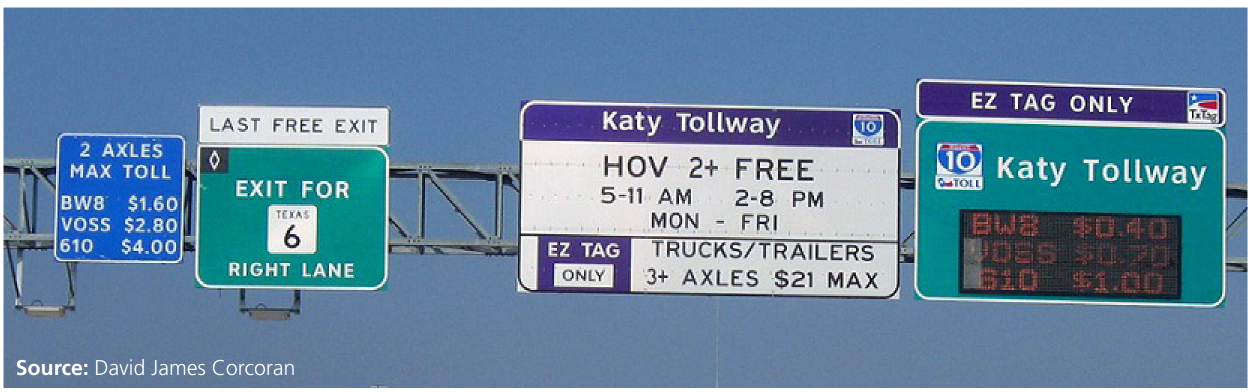

Figure 46. Photo. The Katy managed lanes (or Katy Tollway) operate as HOT during peak hours and ETL at other times, and have a maximum possible toll.

Concurrent Operators

The fact that two separate agencies operate lanes within the system provides special challenges related to traffic management and enforcement coordination, as both agencies need to be involved during any incident where diversion is involved.

TIM State of the Practice Related to the Managed Lanes

Operation and Management

The Harris County Toll Road Authority (HCTRA) is responsible for the operation of the express lanes including all traffic operations and toll operations. TxDOT is responsible for the operation of the general purpose lanes. The Harris County Police provide for enforcement on the express lanes. HCTRA monitors and manages the express lanes from their own 24/7 TMC/Incident

Management Center which includes a robust dispatch system. TxDOT monitors and manages the general purpose lanes from the Houston TranStar TMC.

Traffic/Incident Management (Surveillance/Control - Detection/Verification)

The entire system is equipped with a traffic monitoring and management system including cameras and DMS as well as message signs at the designator lane toll gantries. There are two sets of cameras on the system, one for the express lanes/HCTRA and one for the general purpose lanes/TxDOT. Cameras, detector information and DMS messages and control are coordinated to provide seamless operation.

Traveler Information

A variety of tools are used to notify the public of conditions that affect the express lanes, such as incidents, construction, or diversions. These include the DMS as well as a 511 system. As indicated previously, HCTRA shares detector and speed information with the Houston TranStar TMC, and TranStar merges the information and acts as the single source for regional traveler information.

Enforcement

The Harris County Police provide enforcement on the express lanes. There are 13 patrols dedicated to enforcement on the express lanes. The enforcement costs are treated as part of the overall system operations costs and hence come from the toll revenues. In general, the City of Houston Police Department provides for enforcement on the general purpose lanes. The police have mobile data terminals in their vehicles that allow them to enforce violations related to toll tag accounts. The toll gantries provide police with safe locations for parking to perform enforcement activities.

Response/Scene Management

The Harris County Police provide incident response on the express lanes. In general, the City of Houston Police Department provides incident response on the general purpose lanes. The City of Houston provides fire and EMS response on both systems. The HCTRA is able to dispatch any of these resources from their TMC. The HCTRA has four dedicated motorist assist patrols that monitor the express lanes – two for each direction. These patrols support incident response and scene management. Their resources and capabilities include response vehicles with message boards, towing, and hazardous material spill kits. The Harris County Police are aware of the impact that incidents in the general purpose lane can have on the express lanes. They are often the first enforcement vehicles on the scene for general purpose lane incidents and will get involved to initiate and/or supplement response there. Texas has "Steer It/Clear It" and "Move Over" laws to support quick and safe incident management. The HCTRA and Harris County Police have formal quick removal policies and can respond within 5 minutes and clear lanes within 10 to 15 minutes for normal incidents.

Diversions

HCTRA and Harris County Police have the authority to divert traffic from the general purpose lanes into the managed lanes and waive tolls. The frequent entry and exit points on the express lanes as well as quick incident response and wide shoulders make the need for diversion from the managed lanes a rare occurrence. In the event of a major closure the police will not only perform traffic control on the freeway but will also place enforcement personnel at the traffic signals at the frontage roads/arterials.

Institutional Coordination

TIM

HCTRA has a robust TIM program in cooperation with the Harris County Police as well as local responders as appropriate. Elements of the program include routine coordination meetings, joint training, post incident reviews, and planning for special events.

Inter-agency Coordination/Agreements

HCTRA, TxDOT and Metro have a formal "tri-party" agreement that covers interagency coordination related to the express lanes. In general, the parties defer to HCTRA to operate and manage the lanes on a daily basis. The three agencies coordinate more frequently if there are changes to the system or operations that are being considered. In addition, the Harris County Police and HCTRA have entered into an agreement with a local wrecker service to ensure quick response, standard rates and equipment capability.

Resources/Funding

In general, resources are provided by HCTRA and Harris County Police and operations are funded from the toll revenues.

Design/Construction/Maintenance Coordination

There is close cooperation among these offices due to internal procedures and as provided by the tri-party agreement.

Other Issues

These issues were also identified:

- Future systems should be designed such that all HOV/tag type enforcement can be done in entrance/exit areas where speeds are low. It is very difficult to conduct this enforcement at highway speeds.
- The use of plastic posts as the express lane separator has both advantages and disadvantages. A key advantage is that the barrier can be temporarily removed or driven over to provide emergency access or diversion. A disadvantage is that lack of a strong physical separation can allow errant vehicles to encroach into adjacent lanes.

Summary of TMC Role in Managed Lane TIM

There are two 24/7 TMCs involved in incident management on the facility; the HCTRA TMC and the Houston TranStar TMC. The two TMCs are located separately. The HCTRA TMC is responsible for monitoring and managing the express lanes, whereas the Houston TranStar TMC is responsible for monitoring and managing the general purpose lanes. The two TMCs operate the whole system as a seamless facility, allowing both to coordinate operations and response during any incident.

The HCTRA TMC is staffed and operated by HCTRA personnel. It focuses on incident management on the express lanes. The Houston TranStar TMC focuses on multiagency operations and management of the region's transportation system. TranStar is a partnership among the principal transportation and emergency management agencies in Harris County, including:

- Texas Department of Transportation (TxDOT).
- Metropolitan Transit Authority of Harris County (Metro).
- Harris County, including:
    - Traffic & Transportation Group.
    - Harris County Toll Road Authority.
    - Office of Homeland Security & Emergency Management.
- The City of Houston.

The two TMCs coordinate TIM activities related to the Katy Freeway. Their roles include:

- Monitoring all lanes for operational status and incidents.
- Operation of ITS detection, DMS, and CCTV devices.
- Dispatch of motorist assist and incident response units for their respective operational responsibilities.
- Dispatch and/or coordination with enforcement and emergency responders.
- Authority to divert traffic during incidents between the express and general purpose lanes.
- Control of access to the express lanes to manage traffic entry volumes during incidents.
- Incident management coordination, as well as with operational partners such as Metro and the City of Houston.
- Sharing of traffic detection information and CCTV/DMS devices through the TranStar TMC to provide for optimum system monitoring and management during incidents.
- Distribution of incident-related traffic condition traveler information. HCTRA distributes information locally via DMS while TranStar merges information and distributes it regionally to the public and media.
- Multiagency TIM related operational agreements including the HCTRA/Harris County Police Quick Clearance policy as well as the HCTRA/TxDOT/Metro agreement governing express lane operations.
- Multiagency TIM program implementation including inter-agency training and debriefings.

The existence of both the HCTRA TMC and TranStar TMC to provide and coordinate focused local managed lane incident management activities, as well as to integrate response and traveler information on a regional level, provides a unique and powerful tool for effective TIM on the Katy Freeway corridor.

Findings

The Katy Freeway Managed Lanes have very strong interagency coordination as one of their key operating strategies. As a result, the Katy Freeway corridor operates as a seamless transportation entity, despite two public agencies having jurisdiction over different parts of the same roadway cross section. Each entity has procedures for responding to an incident on their portion of the roadway, and there are designated procedures in place for incidents that affect both operators. Each side understands their role and responsibilities prior to the occurrence of an incident, so that any incidents can be resolved as quickly as possible. The interagency arrangements used on the Katy Freeway corridor which allow co-location of some staff resources at one TMC are ideal for facilitation of interagency coordination, provided both agencies are on board and willing to very closely coordinate on a day-to-day basis.

5.3 CASE STUDY 3: FAIRFAX COUNTY, VIRGINIA'S I-495 EXPRESS LANES AND PRIVATE SECTOR OPERATORS

The I-495 Express Lanes in Fairfax County, Virginia are operated by the private firm Capital Beltway Express (CBE). This firm is a joint venture between a construction firm and a publicly traded firm that operates toll facilities in the United States and abroad. The private ownership of the I-495 Express Lanes introduces some additional complexities into the operation and TIM processes.

Figure 47. Photo. I-495 Express Lanes on the Capital Beltway in Fairfax County, VA, near Washington, DC.

CBE entered into a very comprehensive operating agreement with the Virginia DOT (VDOT) related to operation of the I-495 corridor. Each agency's roles and procedures are very clearly spelled out in the form of an operating procedures manual which covers a wide variety of potential scenarios. The scenarios contain specific thresholds for when a procedure is to be implemented. For example, some procedures are related to the issuance of an emergency declaration by the state government.

Capital Beltway Express operates its own TMC, called the HOT Operations Center (HOT-OC). This TMC has direct data links to VDOT's Smart Traffic Center for the Northern Virginia area, and it is via links that incident data and other ITS data is shared. A specified format is used for communication of incident information, and a protocol is in effect for notification from one agency to the other when an incident on one agency's facility is detected by the other. A specified arrangement for cost-sharing and which agency takes the lead for specific incident management are also included as part of the agreement.

Overview

Access Restriction

HOT

Physical Separation

Express lanes are separated from regular lanes by white flexible posts and a 4-foot painted buffer.

Location

The I-495 Express Lanes extend 14 miles along the Capital Beltway between the Springfield Interchange and just north of the Dulles Toll Road in Fairfax County, Virginia.

Design Type

There are 4 high-occupancy toll (HOT) lanes; 2 lanes in each direction (see Figure 45). The express lanes have left shoulders on each side.

Vehicle access is provided at 11 entry/exit points to and from other highways and major side routes. There is no access between the HOT lanes and the general purpose lanes except at the end points.

Vehicle Eligibility

Free access to the express lanes is allowed for vehicles with 3 or more passengers (HOV 3+) using E-ZPass Flex transponders. In addition, motorcycles, transit buses, and emergency vehicles can utilize the express lanes for free. Vehicles carrying 1 or 2 people have to pay a toll to ride in the express lanes. The tolling is dynamic based on the distance traveled and traffic congestion conditions in order to keep the express lanes congestion-free. There are 8 toll gantries in each direction, and tolls are collected electronically using E-ZPass/E-ZPass Flex transponders.

Figure 48. Photo. The I-495 Express Lanes are operated by a private firm and are separated from the publicly owned and heavily congested general purpose lanes by a 4 foot buffer with a plastic post barrier.

Operations

Capital Beltway Express (CBE) is a private firm responsible for the traffic management and operations of the express lanes from their HOT Operations Center (HOT-OC). The HOT-OC operates 24/7. On the other hand, the Virginia DOT is responsible for the operations of the general purpose lanes, and has their own ITS assets located in their TMC. The Virginia State Police (VSP) provides for enforcement for HOV 3+ on the express lanes.

TIM State of the Practice Related to the Express Lanes

Operation and Management

Regardless of the incident location (express or general purpose lanes), immediately following incident identification, the identifying agency shall notify 911 emergency dispatch. For incidents on the express lanes that do not impact the general purpose lanes, CBE takes responsibility for dispatching its Safety Service Patrol and clearing the incident, as well as providing incident data to VDOT. For incidents on the general purpose lanes only, VDOT takes responsibility for dispatching its Safety Service Patrol and clearing the incident regardless of where it started. For those incidents that affect both express and general purpose lanes, VDOT oversees the response and coordinates with the emergency first responders.

Response to Unplanned Incidents

In addition, for all unplanned incidents related to the express lanes, CBE shall transmit the following data to VDOT using the data connection between their respective TMCs:

- Location of the incident (by mile marker and nearest interchange).
- Lane(s) impacted.
- Severity of incident.
- Number of vehicles involved.
- Number of disabled vehicles.
- Whether there are any injuries.
- Whether hazardous materials are involved.
- Estimated time for response to incident.
- Estimated duration of incident.
- Updates regarding the status of incident.

Figure 49. Chart. Response to unplanned incidents along I-495.

Traffic/Incident Management (Surveillance/Control—Detection/Verification)

In addition to the pan-tilt-zoom (PTZ) CCTV cameras, the entire system is equipped with automated incident detection cameras that are capable of detecting lane blocking events, wrong way vehicles, false alarms, and medial/opposite direction locations. Moreover, it is equipped with the DYNAC GIS-based incident response system with multi-cast digital video to quickly and more accurately pinpoint incidents. Both CBE and VDOT provide each other access to the streaming videos and ITS data collected from the express and general purpose lanes, respectively.

Traveler Information

A variety of tools are used to notify the public of conditions that affect the express lanes, such as incidents, construction, diversions. These include the dynamic message signs (DMS) at each entrance, 495 Express website, VA511 website, and mobile apps. Typically, CBE and VDOT's communications teams are engaged only for those incidents categorized as "Level 3", which is the most severe type of on-road incidents. For incidents in the express lanes or express access ramps, CBE manages the crisis communications. For incidents in the general purpose lanes or ramps, VDOT manages crisis communications. For incidents blocking both general purpose and express lanes, VDOT oversees a coordinated communications response with CBE's assistance.

Diversions

Diversions can be performed using the designated access points in the system. In addition, as part of any declared emergency evacuation routing, CBE will follow VDOT's directives delivered by authorized representatives with respect to suspension of tolling, allowing VDOT to take control of the express lanes, diversion of traffic into the express lanes, controlling the CBE's DMS messaging for declared emergencies, and compliance with Virginia Department of Emergency Management's evacuation plans.

Institutional Coordination

Interagency Coordination/Agreements

As mentioned earlier, CBE (via its HOT-OC) and VDOT (via its Northern Virginia TOC) operate express and general purpose lanes, respectively. Since CBE is a private entity and VDOT a public sector transportation agency, coordination between VDOT and the private operators of the managed lanes is unique. Both agencies have formal agreements in place to facilitate coordination between the public and private sector, including a Joint Operating and Maintenance Protocols document. The Joint Operating and Maintenance Protocols address a wide variety of coordination issues including:

- An organizational structure and protocol for ongoing coordination through a management committee for non-real time coordination, and via contact between VDOT's Transportation Operations Center and CBE's Traffic Control Supervisor for real time coordination.
- VDOT's right to temporarily override DMS messages during a declared emergency or a significant incident involving fatalities.
- Situations in which each entity will implement a Unified Command Team to coordinate response to severe incidents.
- VDOT's ability to suspend tolling in the event the HOT lanes are designated for use as emergency evacuation routes or as an alternate route for diversion from other state highways or the general purpose lanes in the event of an emergency or significant incident involving fatalities. VDOT will have no financial liability for this action.

The operation system protocols require advance notifications from CBE to VDOT for any planned or unplanned maintenance/outages on the express lanes in relation to traffic detection, communications, traffic signals and intersection control, power and lighting systems. VDOT is also required to notify CBE with similar activities on the general purpose lanes.

Summary of TMC Role in Managed Lane TIM

The I-495 Express Lanes in Virginia are unique in that the managed lanes are operated by the private sector and run immediately adjacent to publicly operated general purpose lanes. This provides unique challenges to coordination and operation of the roadway corridor, since each entity has different operating strategies, resources, and equipment. A detailed agreement by both the private and public sector entities must be in place to ensure that each operator will keep the other informed, and that the transportation network operates seamlessly from the perspective of the public.

The HOT Operations Center (HOT-OC) of the Capital Beltway Express (CBE) is responsible for management and operations of the express lanes, while VDOT's Northern Virginia TOC is responsible for operation and management of the general purpose lanes. The CBE HOT-OC has CCTV and Automated Incident Detection cameras covering the whole system as well as DYNAC GIS-based incident response system to quickly and more accurately pinpoint incidents. CBE HOT-OC also has dedicated safety service patrols that are responsible for clearing incidents on the express lanes in coordination with Virginia State Police. CBE and VDOT have formal agreements and joint operation and maintenance protocols that facilitate the response and management of incidents on both sets of lanes.

The information in the agreement focuses on which entity is responsible for TIM and specific communication protocols for when one operator detects an incident in the other operator's lanes. Diversions between the express lanes and general purpose lanes are possible using existing ramp infrastructure. VDOT has ultimate responsibility and the ability to control ITS assets of both entities for large incidents that affect both the general purpose and managed lanes, as well as during declared emergencies.

Findings

Although there are few privately operated managed lane facilities in the United States, many more are expected in the future as transportation agencies discover the benefits of public-private partnerships. Careful negotiation of operating agreements is critical to the success of these facilities, and will ensure that the unique needs of the public sector agency and private entity are met during both normal operations and incidents. The I-495 Express Lane model of prior inter-agency planning resulting in a comprehensive operating procedures document is one that can be followed by other agencies desiring to establish successful public-private partnerships.

CHAPTER 6—CONCLUSIONS

Managed lanes are growing in popularity as a transportation strategy to address increasing congestion in urbanized areas. This guidebook provides a framework for successful development and implementation of a TIM program using a TMC in the managed lane environment.

The role of TMCs in TIM on managed lanes is an important topic for transportation professionals and incident responders with jurisdiction over managed lane facilities to understand. While much is known about TIM, TMC operations, and managed lanes, the confluence of these subjects is a specialized topic worthy of its own guidebook. Managed lanes present a unique operating environment for TIM activities, due to the unique physical designs, the presence of enhanced ITS assets, the potential need to coordinate between multiple transportation agencies operating in the same corridor, and financial considerations for TIM in priced managed lanes.

The TMC plays an important role in the operation of managed lanes. In order for managed lanes to function properly, the facility must operate reliably with minimal downtime. The TMC supports this by properly preparing for TIM activities that will occur on the managed lanes, and then by supporting the real-time TIM activities that occur during an incident.

Preparation activities should begin early in the conceptual stage of the managed lanes in order to ensure that the facility is designed with TIM activities in mind and that the TMC's assets will work properly alongside existing ITS assets in the region. Interagency coordination plans, an enforcement plan, and communication protocols between the stakeholders should be established prior to the opening of the managed lanes. Having a properly prepared TMC will ensure that when an incident occurs, the TIM activities involving multiple agencies occur seamlessly and smoothly.

During an incident, TIM procedures are conducted in the specialized managed lane environment. If multiple agencies are involved, each should have designated responsibilities. Detection and verification of an incident can often occur more easily in the managed lane environment due to robust deployment of ITS technology, but the response may be complicated by difficulty in accessing the managed lanes. In some cases, special coordination between the TMC and ground crews will be necessary to allow for provision of access to the managed lanes, diversion, and scene management at the incident site. Traffic control at an incident scene can be enhanced in the managed lane environment using an ATM system, which will allow for immediate and direct control directly from the TMC. Ideally, traffic control will occur on a system and corridor level, to effectively manage traffic long before it arrives at the incident scene. One of the most important goals of TIM in managed lanes is quick clearance and recovery in order to allow the managed lane facility to return to normal operations and minimize the loss of revenue. The TMC is instrumental in coordinating and directing all TIM activities and supporting the goals of quick detection, response, and clearance to an incident.

The guidebook presented an overview of the eight case studies that were examined during the course of researching managed lane facilities. Three case studies were examined in greater depth in the guidebook to highlight areas where the managed lane facility performed especially well in the context of using the TMC for TIM purposes. The first case study highlighted the use of an ATM system to manage an incident scene in a constrained environment. It was found that ATM can be used as a mitigation tool for managed lane facilities that do not have ideal geometrics. The second case study highlighted interagency coordination where two different public sector transportation agencies manage the corridor from two TMCs. It was found that the robust coordination agreements in place among multiple TMCs along the same stretch of freeway allows for extremely efficient TIM practices. The third case study examined a privately operated managed lane facility existing in the same right-of-way as publicly operated general purpose lanes. It was found that private and public TMCs can operate as partners and allow for successful roadway operations and TIM practices. Privately operated managed lane facilities are expected to grow as transportation agencies notice the benefits of public-private partnerships.

> The TMC is instrumental in coordinating and directing all TIM activities and supporting the goals of quick detection, response, and clearance to an incident.

GLOSSARY OF TERMS

511

The national 3-digit telephone number for traveler information used by most states to provide real-time traffic and transit information about current operation status, highway conditions, weather advisories, and emergency warnings.

Active Traffic Management (ATM)

Method used to manage the flow of traffic on busy major highways to increase mobility and safety, and reduce congestion. Strategies include: variable speed limits, hard-shoulder running and overhead variable message signs.

Adjustable/Variable Speed Limits

Speed limit signs located along the roadway that can change to direct motorists to reduce speed when necessary. These signs can be adjusted by TMC personnel.

Adjusting vehicle eligibility requirements

Strategy in which an existing vehicle occupancy requirement can be increased, an eligibility requirement could be implemented where none normally exists, or a HOT facility could suspend access for those paying tolls and restrict entry to HOVs only.

Automated Enforcement

Enforcement used on managed lanes that reduce the need for manual enforcement such as law enforcement patrols. Strategies including automatic license plate recognition are utilized.

Automatic License Plate Recognition (ALPR)

Surveillance method that uses optical character recognition on images to read license plates on vehicles.

Bus Lane

Lane that only buses are permitted to use.

Busway

A road, or section of a road, set apart exclusively for buses.

Closed Circuit Television (CCTV)

The use of video cameras to view traffic on roadways. TMC operators have the ability to control these cameras to pan, tilt, or zoom to show different views of the road.

Computer-Aided Dispatch (CAD)

Program used by TMC personnel to gather information about an incident and dispatch the appropriate emergency personnel by taking into account the type of incident and responder agency needed.

Contraflow

A contraflow lane uses a lane in the off-peak direction of travel for travel in the peak direction, and is typically created using a movable barrier to separate the two directions of travel.

Continuous Access Lane

Motorists may enter and exit the lane at any location. May operate as a typical freeway lane with some form of access restriction, can be closed or operated as an additional general purpose lane.

Department of Transportation (DOT)

A government department responsible for construction, operation, and maintenance of highways, railways, and other forms of transportation.

Diversions

Implemented in one of two ways where general traffic can be diverted into the managed lanes, or managed lane traffic can be diverted into the general purpose lanes.

Dynamic Message Sign (DMS)/Variable Message Sign (VMS)

Message signs used on roadways to communicate different types of information including incidents and travel times. TMC operators are responsible for entering the real-time information into the system to transmit these messages.

Express Toll Lane (ETL)

A priced managed lane that charges a toll for access to the lane. The toll rate is variable in order to manage congestion. Rate adjustments may be on a set schedule or dynamically based on real-time traffic conditions.

Eligibility Requirements Suspension

Strategy used to open the managed lanes to all traffic.

Facility Closure

Changeable message signs, signals, or gates at the entrances to the managed lane facility that is controlled by the TMC to completely close the facility to traffic.

Federal Highway Administration (FHWA)

A division of the United States Department of Transportation which oversees the construction, maintenance and preservation of the nation's highways, bridges and tunnels.

High Occupancy Toll (HOT) Lane

A priced managed lane where an occupancy requirement is set and those vehicles meeting that requirement can travel for free, and vehicles not meeting the occupancy requirement must pay a toll to travel in the lane. The toll rate for vehicles not meeting the occupancy requirement is variable in order to manage congestion.

High Occupancy Vehicle (HOV) Lanes

Lane with a vehicle restriction for the exclusive use of vehicles with a driver and one or more passengers, including carpools, vanpools, and transit vehicles. May operate at all times or only during peak hours.

Highway Advisory Radio (HAR)

Radio used to broadcast information to motorists.

Incident Management (IM)

Strategies designed to restore normal service operation safely and as quickly as possible following an incident while minimizing impacts.

Intelligent Transportation System (ITS)

A broad range of wireless and wire line communications-based information and electronic technology applications used by different modes of transport and traffic management.

Lane Control Signals

Green arrow and red "X" signals that appear over lanes to indicate if a lane is open or closed. On certain managed lanes, TMC personnel are able to remotely close and re-open lanes.

Managed Lanes

Highway facilities or a set of lanes where operational strategies are proactively implemented and managed in response to changing conditions.

Manual Enforcement

This type of enforcement involves placing law enforcement personnel along the managed lane to monitor traffic and stop motorists who violate policies.

Painted Buffer

Double white line or a wider painted “buffer area” used to separate a managed lane from the general purpose lanes, with openings to allow legal entry/exit points.

Painted Buffer with Electronic “Invisible” Barrier

Same as the painted buffer with the addition of an electronic system. This system can include a series of cameras, license plate readers, and/or toll transponder readers to detect when a car enters or exits the managed lane between legal entry/exit points.

Permanent Physical Barrier

A physical barrier used to separate the managed and general purpose lanes permanently. Designed so that the managed lanes will operate as a completely separate roadway from the general purpose lanes.

Plastic Post Barrier

Flexible plastic posts placed inside a painted buffer area to separate managed lanes and general purpose lanes.

Ramp metering

Used to reduce the volume of traffic entering the roadway.

Regional Architectures (RA)

Describes what type of TIM systems and services will be deployed and the information that is exchanged between them. Also identifies data and communications standards that apply.

Reversible Roadway

Entire roadways that can reverse direction and are typically built to handle large directional peaks in traffic volumes.

Road Weather Information System (RWIS)

Used to obtain weather information.

Roadway Management

Use resources to effectively manage the affected roadway and arterials during incidents.

Safety Service Patrol

Motorist assistance safety/service patrol programs that help keep incident scenes safe, clear incidents more quickly, and assist other emergency responders at incident scenes.

Scene Management

Strategies that involve the establishment of a safe and effective area where responders can deal with the incident response and clearance.

Shoulder Lane

Right or left shoulder lane is used as a full-time or part-time managed lane.

Strategic Plan

Identifies vision, goals and objectives for the managed lane TIM activities as well as deployment strategies, benefits and costs, funding plans and high level performance measures.

Toll Rate Adjustment

Dynamically adjusting toll rates that can increase the price for use of the managed lanes in order to discourage all but the highest value trips from utilizing the facility.

Traffic Control

Implementing effective traffic control at and around the incident management scene can help increase the safety of the responders as well as reduce the potential for secondary vehicle accidents.

Traffic Incident Management (TIM)

The process of coordinating the resources of a number of different partner agencies and private sector companies to detect, respond to, and clear traffic incidents as quickly as possible to reduce the impacts of incidents on safety and congestion, while protecting the safety of on-scene responders and the traveling public.

Transportation Management Center (TMC)

Center that provides real-time monitoring of the highway, detecting incidents, coordinating/supporting response and distributing traveler information. Normally open 24 hours a day, 7 days a week but are at least open during peak periods.

Zipper Barrier

A semi-permanent physical barrier for lane separation that can be moved by a special mobile machine.

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