CAPITAL AREA METROPOLITAN PLANNING ORGANIZATION
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NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

TRIANGLE STRATEGIC TOLLING STUDY

MANAGED LANE & TOLLING BEST PRACTICE

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1 INTRODUCTION

1.1 BACKGROUND

The Capital Area Metropolitan Planning Organization (CAMPO) is working in cooperation with the North Carolina Department of Transportation (NCDOT), North Carolina Turnpike Authority (NCTA), Durham-Chapel Hill-Carrboro Metropolitan Planning Organization (DCHC MPO), and other regional partner agencies to explore tolling and managed lane concepts for the Triangle Region. The effort will help to determine existing and future mobility needs for the regional freeway network, and the potential for the implementation of pricing tools to address those needs.

The purpose of the Triangle Strategic Tolling Study is to examine the regional freeway network to identify where tolling or managed lanes policies or actions could improve overall system efficiency. Those corridors where such strategies or policies are considered most promising will be included in an implementation plan that outlines a holistic tolling and managed lane strategy for the Triangle Region. The strategy will be developed through an evaluation of technology, operational structures, and an analysis of the potential impacts to the regional transportation network. Ultimately, this study will identify the feasibility and necessity of using either tolling or other managed lane concepts or technologies to achieve regional objectives associated with the Metropolitan Transportation Plan.

1.1.1 TOLLING CONTEXT

The practice of tolling on freeways may not be a new concept in North Carolina or the Triangle Region; however, many (if not most) travelers and residents in the Triangle may have no personal experience from which to rely upon. It is from this lack of personal experience that opinions may form contrary to experience and practice within the region and elsewhere around the U.S.

In 2002, the Turnpike Authority was created in response to rapid population growth and the associated increase in congestion that occurred in metropolitan areas throughout North Carolina. The NCTA is authorized by the General Assembly to study, plan, develop, construct, operate, or maintain tolling projects throughout the State. To date, the Triangle Expressway between Durham and Holly Springs is the only toll facility in operation. This implies that drivers within the Triangle Region are familiar with tolling in general. However, it also underscores the need for public outreach and education related to priced managed lanes, as the feasibility of such projects are further explored. The I-77 Express Lanes in the Charlotte region (currently under construction) will be the first priced managed lane facility in North Carolina.

The NCTA also oversees the NC Quick Pass program, which provides electronic transponders and facilitates toll payments on existing NCTA facilities. NC Quick Pass transponders can be used on NCTA facilities and priced facilities in Georgia that utilize the “Peach Pass,” and corridors in Florida which use the “Sun Pass” transponders. In addition, NCTA customers can purchase a premium transponder that

facilitates access to “E-Z Pass” locations in several other states. Any new priced roadway facilities in North Carolina will presumably be incorporated into this existing program. As such, considerations for statewide and regional interoperability will help to frame investigations and strategy development as part of the Triangle Strategic Tolling Study.

1.1.2 TOLLING CONCEPT

The concept of roadway tolling can be applied in many different forms. Although tolling itself currently exists in the Triangle Region, facilities such as priced managed lanes would be new to the area. An understanding of the goals and characteristics of each approach will be important as these concepts are further explored as part of this study, and possibly integrated into a regional tolling strategy. Each tolling approach has a unique intent, with different advantages and disadvantages:

- ***Priced Managed Lanes***: Managed lanes such as High-Occupancy Vehicle (HOV) and Bus Only Lanes have existed for decades. Their intent is to limit the number of vehicles in the designated lanes, based on occupancy or vehicle type, to maintain a more desirable level of service relative to adjacent general-purpose lanes. Priced managed lanes, often referred to as High Occupancy Toll (HOT) lanes, integrate pricing to allow toll-paying single-occupancy vehicles (SOV) to use the lanes. However, congestion pricing is used to manage SOV demand during peak traffic periods to ensure that the lane maintains a high level of service and does not become degraded. Qualifying HOVs may use these limited-access lanes for free or at a reduced cost. Drivers in vehicles that do not meet occupancy requirements may choose between the general-purpose lanes or paying for premium conditions in the managed lanes. Priced managed lanes use electronic toll collection and traffic information systems that make it possible to provide variable, real-time toll pricing for non-HOV vehicles. Drivers receive information on price levels and travel conditions via variable message signs, providing potential users with information they need to decide whether to use the managed lanes. In this way, priced managed lanes use price, occupancy, and access restrictions with the goal of maximizing corridor efficiency and person throughput. There are currently close to 40 priced managed lanes in operation in the United States, with over 10 additional facilities under project development (Figure 1-1).

- ***Express Toll Lanes (ETL)***: ETLs are priced managed lanes where all vehicles, including HOVs, must pay a toll to gain access. Although some traffic performance benefit is intended with this approach, these lanes do not explicitly incentivize ride sharing or person throughput (through discounts or toll-free use) to the extent of HOT lanes. However, tolls may be shared by all occupants of a vehicle, thereby providing an incentive for toll-sharing. Furthermore, to the extent HOV designation is agnostic towards the ability of other passengers to drive separately, ETL’s may be almost as effective as HOT Lanes towards average vehicle occupancies. Finally, these lanes are easier to enforce than HOV or HOT lanes because there are no occupancy requirements.

- ***Bus Toll Lanes (BTL)***: BTLs are priced managed lanes where capacity is first dedicated to bus transit. Other vehicles may pay a toll to use the lanes, but performance is maintained by variable pricing to ensure good operating conditions for transit vehicles. These lanes value person-

throughput as a higher priority than ETLs, and may also be implemented in coordination with transit agencies that serve the roadway.

- ***Toll Roads***: Traditional toll roads such as the Triangle Expressway charge a toll to all vehicles that enter the highway, not just on designated lanes. Toll roads are often proposed when other funding sources for the roadway are not feasible. Toll roads provide new capacity that can reduce congestion on the overall roadway network.

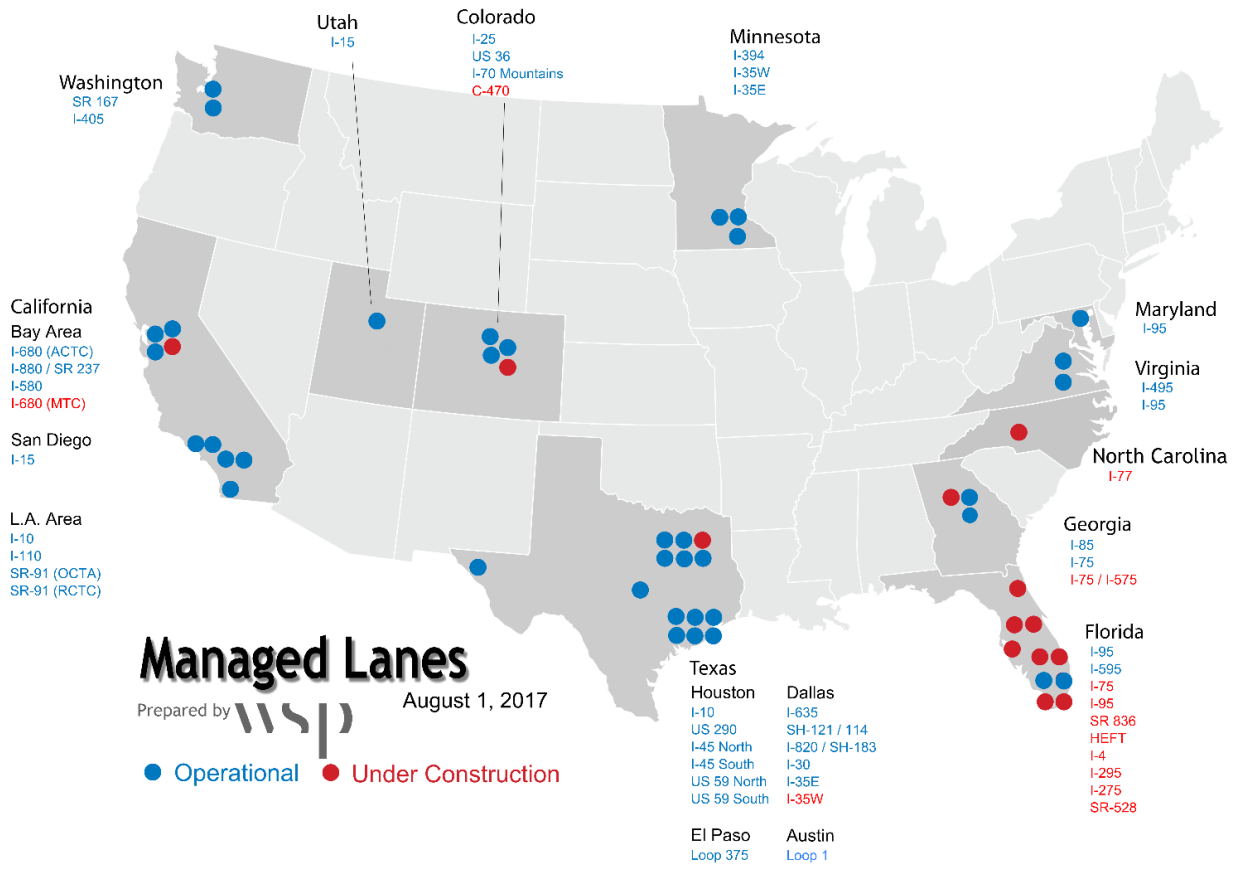

Figure 1-1: United States Priced Managed Lanes

1.1.3 DOCUMENT PURPOSE

This technical memorandum has been prepared to highlight the existing body of knowledge regarding the implementation of toll and managed lane facilities. This memorandum seeks to identify, examine, and document the relevant issues related to the state of practice for tolling and managed lane strategy development.in order to better enable the project team and regional partners to reach conclusions for tolling and managed lanes applications in the Triangle Region.

2 OPERATING POLICY

Implementing additional tolled facilities in the Triangle Region will require an indefinite commitment to actively manage traffic operations to maintain and optimize performance on any new capacity developed. This is especially important for priced managed lane facilities, which introduce an additional layer of complexity due to their proximity to general-purpose lanes, and unfamiliarity in the Triangle Region. While some aspects of operations overlap with the maintenance of the state highway system, the operations of priced managed lanes are more associated with optimizing travel time reliability and travel speed benefits for users. As such, priced managed lanes require different operating policies and procedures compared to the general-purpose lanes. These include toll collection methods, eligibility requirements, operating hours, and pricing plans. This section describes best practice applications of these concepts for consideration for future priced managed lane concepts in the Triangle Region.

2.1 TOLL COLLECTION

New tolled facilities in the Triangle Region will require a clear policy for toll collection agreed upon by project sponsors and stakeholders. As discussed previously, a regional precedent for toll collection has already been established by the NCTA and the NC Quick Pass program. Any new tolling initiatives would need to closely consider interoperability with the Triangle Expressway to provide the greatest flexibility and convenience to potential customers. However, as priced managed lanes would be new to the Triangle Region, there are certain unique toll collection aspects that would need to be established during the planning process.

2.1.1 ELECTRONIC TOLLING

Electronic toll collection (ETC) technology has become standard for tolled facilities and priced managed lanes throughout the country, with facilities often replacing its infrastructure every 7 – 10 years, depending upon new technologies. Its application allows for variably priced tolls as a tool to manage highway traffic demand based on time of day and prevailing traffic conditions. The use of ETC on priced managed lanes is essential to address safety issues and avoid the travel delay and congestion associated with manual toll collection at booths or toll plazas. ETC systems utilize automatic vehicle identification (AVI) technology using transponders to detect the unique identification of all vehicles passing toll collection points. License-plate cameras and optical character recognition (OCR) technology have been shown to further enhance the capabilities of capturing toll payments (and violations) from vehicles using priced managed lanes. As the coordinated use of AVI and OCR technology is already in place within the region as part of operations on the Triangle Expressway, it may be prudent to maintain this configuration for future tolling projects in the region to maintain consistency in business rules between facilities. It should be noted that some recent projects such as the I-10 / I-110 Express Lanes in Los Angeles require all users of express lanes to carry transponders, including HOVs, as it eliminates the need for the processing of license plate tolls.

2.1.2 TOLLING MECHANISM

The use of radio frequency identification (RFID) transponders has become the preferred means for tolling and enforcement of priced managed lanes throughout the country. In practice, each transponder is coded with a unique ID number linked to a member agency account, that is debited when a transponder is read at a tolling point. It should be noted that efforts toward national ETC interoperability standards and transponder protocols are currently under development by the International Bridge, Tunnel and Turnpike Association (IBTTA) in accordance with the requirements of the *Moving Ahead for Progress in the 21st Century Act* (MAP-21). License plate tolling using OCR technology is also used as a common method of tolling where an image of the license plate is captured and an invoice or violation notice is sent to the registered owner of a vehicle. Recent projects have treated license plate tolling as a secondary means of collection and enforcement, due to the higher cost associated with image processing and verification. As such, a toll premium is typically charged to offset the additional processing costs. This tolling practice is already the regional standard, as established by the Triangle Expressway.

Managed lanes provide travel time savings, but these are not often incorporated within contemporary routing programs. As such, it is incumbent upon the operator to make as much data regarding current operations available as possible (through web-based API's) to help routing programs leverage the differently operated infrastructure. Additionally, it should be noted that current pricing information has become a key topic within routing systems, with the closest analogue being the GTFS file format for transit routing data. Ultimately, priced managed lanes operators will be responsible for maintaining a live feed of current facility pricing to help travelers make decisions through these mechanisms.

As the feasibility of priced managed lanes are further explored in the Triangle Region, decisions will need to be made regarding policies for the eligibility of HOVs and other vehicle classes to use the lanes. Although these policies would be established later in the planning process, consideration should be given now to vehicle eligibility verification and enforcement. For the enforcement of HOVs, reliance on law enforcement personnel alone is expensive, and automated occupancy verification has not yet proven to be reliable enough for primary enforcement. Enforcement needs to be considered in planning, and advances in technology should be monitored.

- ***Lane Based***: On initial express lane implementations, such as the SR-91 in Southern California, vehicles that are permitted toll-free access or discounts are physically separated from toll-paying vehicles in toll-zones, creating a "carpool lane" and "toll lane" (Figure 2-1). This method reduces enforcement costs by reducing the total number of users that enforcement personnel must verify. The separation requires additional right-of-way to accommodate a separated lane, observation location, and enforcement zone (at least 28 feet), that is not always feasible in practice due to physical constraints. Additionally, lane separation may increase weaving ahead of toll zones, leading to increased congestion.

Figure 2-1: Lane Based Declaration

- ***Transponder Based***: "Switchable Transponders," as implemented on express lanes in Los Angeles, Colorado, Virginia, and Washington, provide a technical method for drivers to declare eligibility status. As shown in Figure 2-2, these devices allow drivers to self-declare the vehicle status as SOV, HOV, HOV2 or HOV3+, etc. (depending on local occupancy policies), and will automatically be charged the appropriate toll rate. Under this method, enforcement is focused on verifying the occupancy of vehicles with transponders set to "HOV", as there is no automated consequence to having an inappropriately identified HOV declaration. If no transponder is present, OCR would be used as a secondary means of enforcement and tolling to ensure full toll payment from the user. Some newer facilities, such as the LBJ Express in Dallas, rely on smart phone applications for carpool registration, essentially serving the same purpose as a RFID transponder. It should be noted that incorrect switch settings are commonplace on active facilities, but incidence is greatly reduced with regular, recurring, and visible police enforcement.

Figure 2-2: Switchable

2.1.3 PRICING MODELS

Another important aspect of priced managed lanes to consider during the planning process is the preferred pricing model. Managed lane projects throughout the country have showcased multiple pricing mechanisms, including time-of-day and dynamic pricing, as well as other considerations such as segment pricing, and differentiated payment classes. These different models are summarized below:

- ***Time of Day Pricing***: Variable pricing based on a set time schedule is currently used on the SR-91 in Southern California and all express lanes in the Denver and Houston areas. Although prices are fixed based on a time-of-day schedule, drivers are charged differently based on direction, day of travel, and hour. This method provides a level of price certainty and predictability for drivers.

The most effective applications of this method involve a high degree of variability by time of day and day of the week, and a system for altering toll rates over time. On the SR-91 Express Lanes, performance is monitored daily, with evaluation and adjustments to pricing made every three months.

- ***Dynamic Pricing***: Variable pricing based on real-time traffic conditions is the most common mechanism used in the United States. This practice is enabled by vehicle detectors that provide a stream of traffic performance data, and tolling algorithms that determine appropriate toll rates based on real-time managed lane and general-purpose lane conditions. This method allows the greatest level of control and flexibility for corridor traffic operations, as the rate can be raised or lowered based on real-time demand to maximize the performance of the lane.

- ***Segment Pricing***: Segment pricing sets a specific toll for a specific segment of roadway. Any given toll facility can have one segment, or multiple segments. The segments are usually defined by freeway ingress and egress points, by minimum or maximum distance thresholds, or by spatial relation to an important decision point or common destination. From an operations perspective, segmental pricing allows segments with higher demand to be better managed through higher toll rates. On the I-15 Express Lanes in Salt Lake City, segmental pricing has been shown to be easily understood by the public.

- ***Minimum and Maximum Tolls***: Dynamically priced express lane facilities often use maximum and minimum toll rates to provide context for system management. The intent is to ensure that some level of revenue is collected during periods of low-demand to defray operational costs (minimum tolls), and that toll rates do not reach a level that can result in negative public perception (maximum tolls). HOT Lane facilities can revert to "HOV only" status if overall demand becomes too high. On the I-10 and I-110 Express Lanes in Los Angeles, the toll system switches to HOV-only mode once the maximum toll can no longer maintain reasonable operating conditions, until the overall demand is returned to a manageable status. If used, minimum and maximum toll rates should be evaluated and adjusted periodically to account for changes in the ability of the maximum toll to maintain operating conditions as demand grows. For example, if a maximum toll rate is set too low, system performance goals may be degraded.

2.2 OCCUPANCY & VEHICLE ELIGIBILITY

Toll projects can introduce an opportunity to establish different payment classes based on overall goals of the facility. On priced managed lanes, applied toll rates can vary for different users depending on policy priorities and the goals of the facility. For instance, toll discounts or exceptions may be made based on vehicle occupancy, vehicle type (e.g., hybrids, Electric Vehicles, etc.), vehicle classification (e.g., passenger vehicle, truck, etc.), or other criteria. Whatever the priorities of the priced managed lane, protocols for changing or updating these payment classes periodically should be considered. This practice can better enable the facility to meet desired goals and result in better performance over time.

2.2.1 HOV EXEMPTIONS

Although a new concept in the Triangle Region, HOT lanes may prove to be a feasible option, and meet stakeholder goals, as part of a regional tolling strategy. A HOT lane would provide free or discounted access to carpool vehicles (of varying occupancy), while charging single occupancy vehicles (SOV) a toll to utilize the lanes. There are many HOV access policy examples from existing managed lanes facilities. These policies vary based on occupancy, such as whether a vehicle with two of more people (HOV 2) or three or more people (HOV 3) qualifies for access, and can also vary on payment class and schedule. Over time, some facilities in Colorado, Florida, and Washington have changed their HOV policies to meet current levels of demand, after significant data review and stakeholder engagement. Several of these options are summarized below:

- ***HOV Toll-Free***: Qualifying HOV vehicles are offered free access to priced managed lanes throughout the country, but occupancy policies vary. For example, some facilities such as the I-15 Express Lanes in San Diego offer free access to HOV 2 vehicles, while other facilities such as the 95 Express in Miami or the I-85 Express Lanes in Atlanta require HOV 3 for free access. Both facilities require HOVs to have transponders, and qualifying carpools in Miami must pre-register. These policy decisions are based on HOV demand, as well as the revenue needs or congestion relief goals of a given facility. This underscores the need to establish priorities and protocols for agencies to adjust HOV occupancy if necessary. As an example, CDOT Express Lanes in Colorado were initially implemented with an HOV 2 free access policy. However, growing HOV demand resulted in a change to a HOV 3 free access policy on January 1, 2017.

- ***Peak-period HOV***: In several priced managed lane corridors, HOV demand or facility goals have resulted in more complex HOV access policies. Instead of 24-hour toll-free access for HOV 2 or HOV 3 vehicles, some facilities rely on different HOV policies during peak traffic periods. As an example, the I-10 Express Lanes in Los Angeles allow free access to HOV 2 vehicles during off-peak periods, but HOV 2 vehicles are charged a toll Monday-Friday between 5-9 AM and 4-7 PM. A similar policy is in place for HOV 3 vehicles on the SR-91 Express Lanes in Orange County, California. Although this policy may improve the functionality of the facility during peak-periods, different peak versus non-peak policies can result in driver confusion.

2.2.2 VEHICLE ELIGIBILITY

In addition to HOV access policies, project sponsors may find it viable to explore additional payment classes based on vehicle type. As with other access policies, free-access, discounts, or toll premiums based on vehicle type will depend on performance goals for the facility. They may also consider other economic and environmental priorities at a regional or state level. Some examples for vehicle type payment classes are outlined below.

- ***Clean-Air Vehicles***: Several managed lanes throughout the country allow certain energy efficient single occupancy vehicles free or open access to lanes. Examples can include EPA certified hybrids, inherently low-emission electric vehicles (ILEV) or partial zero-emission vehicles

(PZEV), or motorcycles. As an example, the State of California has issued a limited number of colored stickers to PZEV or ILEZ drivers to allow free or discounted access to regional express lanes. However, recent projects in Southern California have recommended that free express lane access to energy efficient SOVs be prohibited during peak-periods because of existing facility degradation.

- ***Multi-Axle Trucks***: Depending on regional goals, and the design of the priced managed lane facility, larger trucks, particularly those with more than two axles may be prohibited from using the express lanes. Many facilities prohibit large trucks due to their poor performance compared with light vehicles. The lower acceleration rates of these large vehicles can degrade lane performance, particularly on facilities with only one lane in each direction. However, some express lanes in Colorado, Florida, and Texas have allowed for their use. For example, the US-36 Express Lanes in Denver and the LBJ Express Lanes in Dallas allow large trucks to use the lanes, but both facilities charge a premium to trucks based on the impact to pavement and traffic performance. The US-36 facility charges an additional $25.00 to trucks on top of the base toll rate, while the LBJ Express applies a toll rate factor of 3X, 4X, or 5X, depending on size. Other facilities such as the I-70 Express Lanes in the mountains of Colorado prohibit large trucks due to pavement and cross section design.

- ***Transit Vehicles***: Most existing priced managed lanes allow free access to transit vehicles, such as buses and van pools. In many cases, express bus service is considered an important and essential feature of the express lanes, with transit service fully integrated into facility design and marketing. Transit considerations are discussed further in Section 5.

2.3 HOURS OF OPERATION

The time periods that a priced managed lane facility operates is another important policy consideration for the development of a regional tolling strategy. Depending on factors such as traffic conditions and performance goals for different corridors, agency priorities, and public perceptions, it may be reasonable for managed lanes to operate 24/7 or just during peak periods. About half of all HOV lanes in the United States operate only during peak-periods. This approach is intended to provide reliability and time savings to carpoolers during the most congested times, while ensuring the lane is not unnecessarily underused at other times. However, the integration of toll paying SOVs into a managed lane can allow a facility to be more fully utilized during expanded periods, ensuring reliability and time savings are maintained outside of traditional peaks.

There are advantages and disadvantages to part-time or full-time managed lane hours of operation. Operating priced managed lanes only in the peak-periods can result in lower operations and maintenance costs, and possibly fewer public challenges since the operation would only be part-time. However, part-time operation can also cause confusion among drivers and limit the ability to effectively manage demand outside of peak-periods. Full-time 24/7 managed lane operations would result in less confusion among drivers, enable revenue collection throughout the day, and provide an option that could provide a reliable trip time at any time of the day.

Most priced managed lanes in the United States operate full-time. Exceptions include the I-680 in Bay Area of California and SR-167 in Seattle which operate during "daytime" hours (e.g., 5:00 AM to 7:00 PM), and the reversible I-15 and I-25 Express Lanes in San Diego and Denver. There are also part-time facilities that use priced shoulder lanes on the I-35W in Minneapolis and the I-70 Mountain Corridor in Colorado. It should also be noted that the I-77 HOV lanes in the Charlotte area were operated 24/7.

3 PUBLIC OUTREACH

An effective public outreach strategy is an essential component of any tolling or managed lane initiative. When done well, an effective campaign will help develop public awareness of the benefits of pricing, as well as to build public and political support. Without a robust strategy of public outreach and education, a new priced facility may be met with skepticism or challenges from the public or elected officials. This is especially true of priced managed lanes in North Carolina because they will be a new concept for the Triangle. A carefully planned and executed outreach strategy will help agency stakeholders and the public better understand how the facility would work, understand the benefits of the concept, and encourage drivers to become customers.

Although public outreach campaigns are commonplace for transportation infrastructure projects and improvements, outreach for priced roadway facilities can require different strategies and a greater scope of agency and public involvement. The element of pricing transforms drivers into paying customers, which changes driver perceptions and expectations. **As such, a multifaceted strategy of public involvement, government relations, media relations, and full-fledged educational outreach is necessary to build consensus and avert public challenges.**

3.1 COMMON ISSUES

While becoming more widespread throughout the United States and North Carolina, priced facilities are still a new concept in many metropolitan areas. As these projects are inherently different from more conventional highway improvements, they can cause certain concerns among drivers unfamiliar with the concept. These concerns are commonly voiced during the development of priced facilities throughout the country. Sponsors of the concept should be aware of these issues to address stakeholder concerns during planning, outreach, and project development. The following issues are likely to be of interest to elected officials, government agencies, and public stakeholders, particularly those drivers likely to be using or impacted by the new facility.

- ***Project Goals***: A typical issue of immediate interest is the purpose or goal of the tolled facility. Specifically, what are the advantages of pricing versus more traditional roadway capacity improvements? Best practices from managed lanes projects, such as the MnPass program of the Minneapolis / St. Paul region and the ExpressToll program in Denver, has shown that consistent and succinct key messaging of the advantages of pricing is essential to clearly communicate project rationale to a variety of public interests. This is especially important in areas such as the Triangle where priced managed lane concepts may be new or not widely understood.

- ***Travel Impacts***: The impact of the new lane(s) on adjacent general-purpose lanes and other routes in the project area is a common concern. Although these impacts will vary depending on the facility, outreach should include findings from other facilities, which shows that travel behavior varies from day to day. For example, some regular priced lane users may choose to avoid heavy tolls and use general-purpose lanes on some days. Drivers who do not regularly use priced lanes

choosing to use these lanes on certain days due to schedule concerns are other issues. Outreach should include messaging on how tolling offers new travel options, while allowing the entire corridor to function more efficiently.

- ***User Fees***: Other common concerns may be related to the fees themselves. Specifically, how much will it cost? How are fees determined and when will they change? The public outreach process allows an opportunity for planners to discuss how fees may be established and describe potential ranges in fees. This input can then be used to help shape and further refine pricing concepts. One important distinction of priced managed lanes is the idea of premium service, where a customer is paying for greater travel time reliability and less congestion compared to general-purpose lanes. This message is an important component in any outreach campaign.

- ***Revenue***: Another common concern is the use of toll revenue. To address this issue, best practice shows that greater support is possible when toll revenues are used to support the maintenance and operations of the project itself or other improvements in the priced corridor. As an example, the I-15 Express Lane project in San Diego requires any excess revenue (after covering toll system operating and maintenance costs) to be spent improving transit service. To date, toll revenues have funded nearly $1 million per year in premium express bus services in the corridor.

- ***Equity***: One of the most common concerns with roadway pricing is that it favors higher income individuals, since paying drivers are given an opportunity to bypass congestion. While usage data of existing managed lane facilities suggests that drivers from all income brackets use the facilities on any given day, managing this perception and communicating the overall benefits of such facilities is likely the most important part of any outreach or education effort. Additionally, public sentiment may indicate the need for specific programs geared towards lower income travelers. These strategies are discussed further in Section 6.

4 DESIGN CONSIDERATIONS

The planning and implementation of priced managed lanes presents unique design considerations compared to more traditional highway infrastructure. Previous managed lane project efforts have shown that the design of individual facilities will vary, depending on existing roadway geometrics and traffic conditions, as well as local and regional priorities. However, an understanding of general managed lane design guidance and principles is an important consideration for the development of a regional tolling strategy in the Triangle. This section outlines best practices for priced managed lane design so that potential managed lane corridors within the region may avoid inconsistencies and incompatibilities that could impact a regional tolling network. While local conditions will impact facility design, and best practice principles should be considered, the development of individual projects will ultimately be governed by prevailing NCDOT and Federal design standards.

4.1 SEPARATION & ACCESS

As priced managed lanes are developed as a premium travel option for toll paying customers or otherwise eligible vehicles, consideration should be given as to how priced lanes are separated from general-purpose lanes in the same corridor, and how customers will access those lanes. Successful priced managed lane projects have deployed different separation and access treatments. This section describes the advantages and disadvantages of these options.

4.1.1 SEPARATION TREATMENTS

Priced managed lanes typically operate at higher speeds than adjacent general-purpose lanes during congested periods, and effective strategies for separating managed lanes from other lanes are important for corridor safety. Positively separated managed lane vehicles may even operate at a higher posted speed (e.g., 75 mph) than general purpose lane vehicles (e.g., 55 mph), as is found on facilities in Texas and Virginia. To accomplish these speed differentials, various types of separation have different impacts on operations and constructability, as well as maintenance, enforcement, and incident management. These factors, and the local context of individual project corridors, will ultimately determine which separation treatment is most appropriate. However, the pros and cons of each method should be considered early in the planning process to understand the impacts of potential design tradeoffs later in project development. Most priced managed lane facilities in the United States use painted buffers or striping, traffic channelizers, concrete barriers, or various combinations as described below:

- ***Painted Line / Buffer*:** Multiple priced managed lane corridors, including the US-36 Express Lanes between Denver and Boulder, use a painted buffer separation indicated by solid double white lines at a four-foot (or sometimes less) spacing. This option is the least expensive in terms of capital and maintenance costs and provides the greatest flexibility for operations and access to emergency vehicles. However, this option is also shown to have the lowest traffic reliability and performance due to friction with general-purpose lanes, and potential turbulence from vehicles illegally crossing the painted lines.

Figure 4-1: Sample Buffer Separation, U.S. 36 Express Lanes, Denver, Colorado.

- ***Channelizer / Delineator***: Priced managed lane facilities such as the I-95 in Miami, SR-91 in Orange County California, and I-10 in Houston employ traffic channelizers or delineators as a separation method. Channelizers are placed at frequent intervals within a buffer area to create a perceived physical barrier to prevent drivers from exiting or entering the managed lanes at undesignated areas. This configuration reduces the risk of buffer crossings and associated revenue leakage, while also allowing emergency vehicle access. However, this option also has the highest ongoing maintenance cost. On the I-95 and SR-91 facilities, illegal buffer crossings and vehicle strikes require 30 to 50 percent of channelizers to be replaced annually.

Figure 4-2: Sample Channelizer Separation with HOV Declaration Zone, SR-91 Express Lanes, Riverside, California

- ***Concrete Barrier or Grade Separated***: Some priced managed lane projects use concrete barriers or grade separations to designate priced lanes from general-purpose lanes. This option is usually deployed only on reversible or contra-flow facilities due to the major implication of buffer crossings. The I-25 Express Lanes in Denver are an example of this strategy. Barrier or grade separation may also be part of large-scale corridor reconstruction efforts such as the LBJ Express in Dallas. Operationally, this option allows for the highest speed differential from general-purpose lanes, prevents buffer crossings and revenue leakage, and has relatively low maintenance costs. However, this option is also the most expensive due to capital and right-of-way costs. Access and egress is also more complicated. This option can also complicate incident management and allows little flexibility for future operational changes.

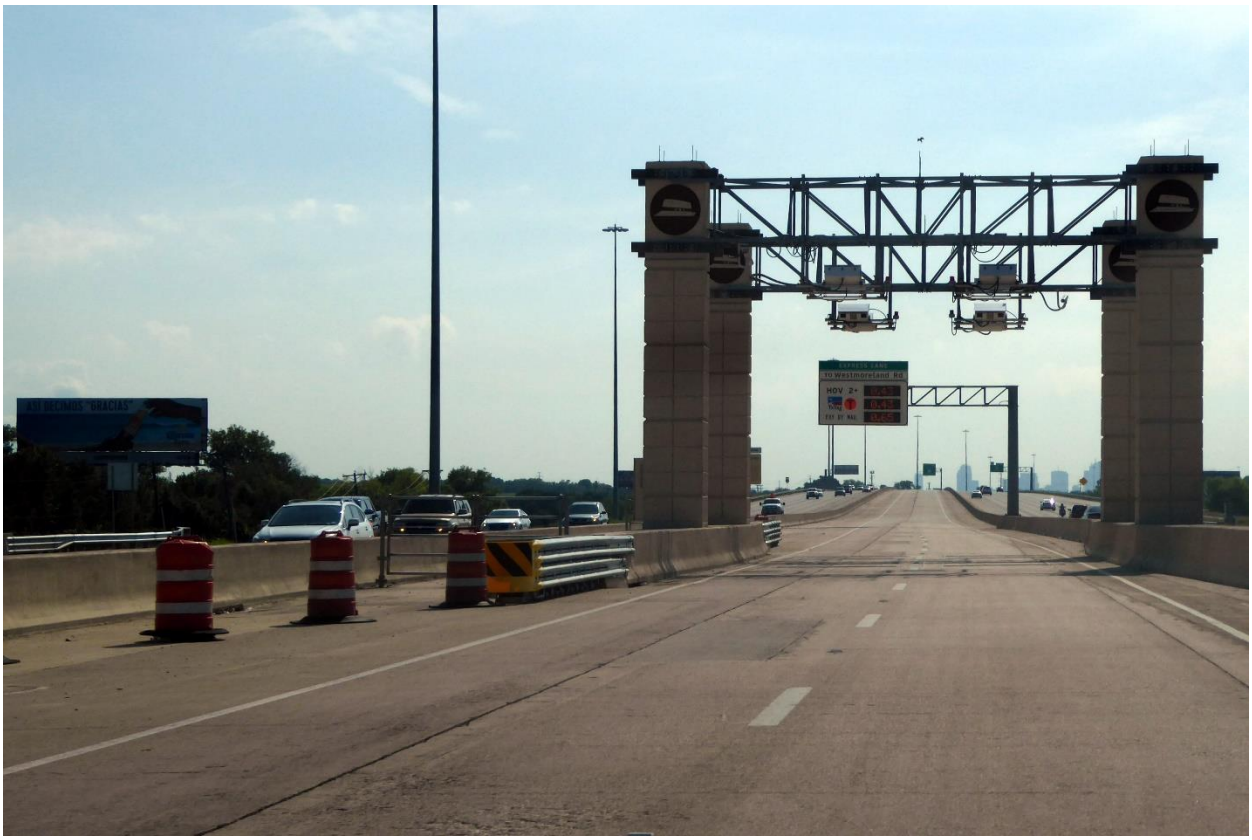

Figure 4-3: Sample Barrier Separation, I-30 Express Lanes, Dallas, Texas

4.1.2 ACCESS TREATMENTS

The development of a regional tolling strategy should also consider appropriate methods for drivers to access and egress priced managed lanes. Existing priced managed lane facilities provide several examples of regulating entry and exit, which are related in part to the planned separation treatment for the facility. The two major types of express lane access treatments are limited access, which regulate where vehicles may enter and exit the facility, and continuous access., which allows customers to enter and exit the facility at any point. The pros and cons of two limited access options and continuous access are described below.

- ***Direct Connector (Limited Access)***: Direct connector ramps provide direct access to manage lanes via median drop ramps from overpasses of direct freeway to freeway connections. Direct connectors provide greater efficiency, safety and capacity, while greatly reducing the operational impacts of weaving and merging movements. However, direct connector ramps have high capital costs, significant right-of-way impacts, and can require accommodation on arterial overpasses. Best practices suggest they should only be considered where there is substantial general-purpose lane congestion that would complicate weaving or a significant amount of local demand for access to or from the managed lanes.

- ***At-Grade Weave (Limited Access)***: Most existing priced managed lane facilities use at-grade access and egress treatments. In this approach, access points represent breaks in designated locations within physical barrier or striped separations. The design of these at-grade weaves is normally accommodated through striping, and there are multiple configurations currently used such as a striped single-line, striped transition or weave lane, or slip ramps. The Manual on Uniform Traffic Control Devices (MUTCD) provides guidance for these types of access/egress points. At-grade access and egress points reduce toll evasion and provides additional access control at a relatively low cost. However, the dedicated locations do result in a concentrated area of weaving that can result in traffic conflicts. They also require adequate enforcement resources to reduce access violations.

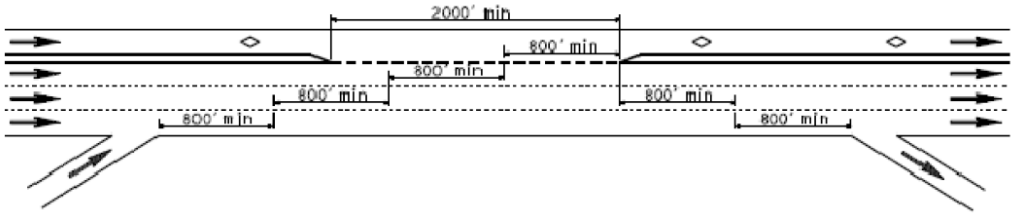

Figure 4-4: Weave-Zone Access Design

- ***Continuous Access***: Continuous access allows drivers to enter the priced managed lane facility at nearly any point, with separation from general-purpose lanes normally provided by a single striped or solid line. With continuous access, there are no designated access or egress locations, which results in potentially lower cost, reduced weave concentrations, and greater operational flexibility. However, this method also has the highest potential for toll violations and revenue leakage and requires significant enforcement resources. Existing continuous access facilities are relatively rare, with only I-35W in Minneapolis and SR 167 in Seattle currently using this access method.

Source: Minnesota Department of Transportation

Figure 4-5: Continuous Access on I-35W

4.2 SIGNAGE

Priced managed lanes include many unique aspects such as entry and exit locations, occupancy requirements, operating hours, costs, and violations that are essential to clearly communicate to users and future users of the facility. Accurate and informative signage is necessary to ensure that operational procedures are easily understood and to enable efficient and productive use of the priced facility. Effective signage provides drivers with adequate time and information to decide to use the managed lane

facility, and how to access it safely. The MUTCD provides guidance on signage for managed lanes of all types, and FHWA is currently concluding a report on signage for managed lanes networks.

4.2.1 ACCESS & EGRESS SIGNAGE

Adequate signage is critical to direct drivers to access and egress points for the managed lane facility. Signage for the start of a managed lane facility and entrance points should include a combination of advance overhead advance overhead signs and Variable Message Signs (VMS) to let drivers know that they are approaching a managed lane entrance. Signage should also provide information on the price to travel in the managed lane, transponder requirements, and HOV and vehicle eligibility. In addition, static signage is necessary to inform drivers of upcoming managed lane exits, as well as local freeway exits if applicable. Example entrance signage is shown in Figure 4-6 below.

Figure 4-6: Express Lane Entrance Signage

4.2.2 VARIABLE MESSAGE SIGNS

The current pricing level to access and use the managed lanes is one of the most important pieces of information to share with drivers and potential customers. Nearly all existing priced managed lanes use overhead pricing signs to display the toll amount to a given downstream location, and to convey HOV requirements and discounts, if applicable. Variable message elements can be used to indicate variable or dynamic toll rates. Typically, VMS signs used to display toll pricing information are either a combination of static signs with VMS insets or full matrix VMS (Figure 4-7). Each sign type provides toll rates for downstream destinations, but have various advantages and disadvantages. Static signs are generally less expensive, and can be more readable. Fully changeable VMS signs provide messaging flexibility, but can be less readable and costlier to deploy.

Figure 4-7: Variable Message Signage

4.3 TOLL COLLECTION ZONE

As described previously, contemporary tolling systems and priced managed lanes rely on ETC and RFID technology to allow tolling at freeway speeds. Traditional toll plazas are not used in managed lanes. As such, any future priced managed lane in the Triangle will need to incorporate toll zone considerations into the facility design. Toll collection zones include lane controllers, antennas to communicate with transponders, automatic vehicle classification systems for identifying vehicle types, video enforcement systems (VES) for imaging and reading license plates, and other ITS devices such as closed circuit television cameras (CCTV), and vehicle detectors. The ETC and ITS equipment is essential for the toll collection zone to properly detect passing vehicles, read transponders, collect traffic volumes, capture vehicle images, and transmit all information from the roadside equipment to the back office for processing.

4.3.1 ENFORCEMENT CONSIDERATIONS

Enforcement is an important element to consider as part of a regional tolling strategy. On priced managed lanes, enforcement systems are necessary to mitigate violations and reduce revenue leakage, and to facilitate secondary license plate tolling, if applicable. Video enforcement systems and manual enforcement areas should be considered early in the planning process for any priced facility.

- ***Video Enforcement System***: Any effective ETC system should include roadside VES elements, such as cameras and lighting mounted on overhead structures, as well as colored LED enforcement beacons to aid enforcement personnel. An example of a managed lane toll zone with these elements is shown in Figure 4-8. During operation of most typical systems, an image is captured of every vehicle's rear license plate as it traverses the toll zone. If a valid transponder is not detected, LPR software reads the vehicle's license plate and matches information to a customer database. If there is a positive match, a toll is charged to the account. If no match is made, the image and associated time

stamp is stored and sent to the back office for violation processing.

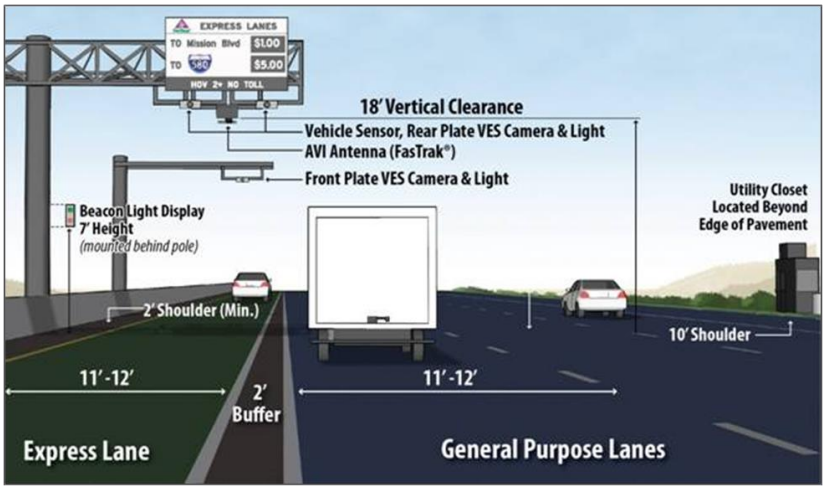

Figure 4-8: Typical Toll Zone Design

- ***Enforcement Observation Areas***: Current technologies for vehicle occupancy detection have not yet proven to be reliable enough for automated enforcement. Manual enforcement of HOV occupancy is still standard on contemporary managed lane facilities. Priced managed lane facilities should include locations from which enforcement officers can monitor traffic and identify unauthorized vehicles. The areas should be wide enough to accommodate safety enforcement action and located near tolling points, allowing officers to monitor traffic and enforcement beacons and provide a visual deterrent to potential violators (Figure 4-9). Ongoing costs for police enforcement typically range between $200,000 and $1,000,000, with costs offset from fees associated with violations.

Figure 4-9: I-45 Enforcement Area, Houston

5 TRANSIT

5.1 TRANSIT INTEGRATION

Existing priced managed lanes have shown that they create a valuable opportunity for transit agencies to expand express bus service and enhance regional transit options. When managed through variable pricing to maintain a minimum level of service, managed lanes create efficient and reliable transit corridors from previously congested freeways. Operating express bus service on priced managed lanes has demonstrated several key benefits to transit services including:

- Shorter travel times and greater reliability by maintaining minimum travel speeds and avoiding unpredictable congestion
- Lower operating costs due to improved travel time and reliability and less schedule uncertainty
- Increased transit ridership due to improved reliability
- Potential new revenue sources from toll revenues
- Broader public support and fewer equity concerns by enhancing transportation options and mitigating negative public perceptions

For these reasons, many transit agencies have introduced express bus service on managed lanes, albeit few have used the opportunity to implement in-line stations for Bus Rapid Transit (BRT) deployment.

Figure 5-1: In-line BRT station on I-35W Express Lanes, Minneapolis, Minnesota

Multiple managed lane initiatives have also considered transit to be an essential component of priced facilities and have included transit at the forefront of all marketing and messaging efforts. The performance of managed lane transit service is dependent on design and policy factors, which should be considered early in the planning process. This section provides an overview of three successful transit operations on priced managed lanes, and summarizes lessons learned from these services.

5.1.1 CASE STUDIES

To better understand how transit agencies have integrated bus service into express lanes, three cases are presented in this section: Los Angeles Express Lanes, Miami 95 Express, and San Diego I-15 Express Lanes.

- ***Los Angeles Express Lanes***: Transit has been considered a key component of the I-110 and I-10 Express Lanes in Los Angeles since the beginning of the planning process, when one of the major project goals was to move more people, not more vehicles. The Los Angeles Express Lanes opened in November 2012. As of June 2014, the combined annual transit ridership on the I-110 and I-10 Express Lanes exceeded 15 million riders per year. In addition to converting existing carpool lanes to express lanes, LA Metro used a sizable portion of a $210 million Urban Partnership Agreement/Congestion Reduction Demonstration (UPA/CRD) grant from USDOT to expand transit services on those lanes. Transit enhancements included improved headways, new routes, new vehicles, and station infrastructure (including park and ride facilities and direct access

ramps for buses). As an example, implementation of the 26-mile LA Metro Silver line along I-110 increased ridership 103 percent with 5-minute headways during peak periods.

- ***Miami 95 Express***: Miami also received federal funding through the UPA/CRD Program to alleviate traffic congestion on the I-95 corridor through the implementation of priced managed lanes. The project replaced the existing single HOV lane in each direction with dual HOT lanes. The HOV occupancy requirement was also increased from HOV 2 to HOV 3. Transit improvements included enhancements of existing routes, new express routes, increased park-and-ride lot capacity, and arterial signal coordination. Following implementation, average bus travel times decreased from 25 minutes to 8 minutes, and average speeds increased from 18 mph to 57 mph. Weekday ridership on the 95 Express lanes increased 57 percent. Based on passenger survey results, 53 percent of new riders stated that the opening of the express lanes influenced their decision to use transit. Of the new riders, 45 percent previously used another form of transit, and 38 percent used to drive alone.

- ***San Diego I-15 Express Lanes***: In 2012, a $1.4 billion expansion of I-15 was completed, including replacement of the prior dual lane reversible priced managed lanes with a four-lane facility featuring a moveable median barrier. The project also included enhancements to the Rapid Express bus service, such as the completion of direct access ramps from the managed lanes to transit park-and-ride facilities along the 20-mile corridor between Escondido and San Diego. Direct access ramps connect park-and-ride lots and transit stations with the managed lanes, which allows buses to enter the lanes without crossing the general-purpose lanes. Rapid Express bus service improvements included transit signal priority, real time arrival signage, enhanced passenger shelters, fewer stops, and 29 new express buses.

5.1.2 LESSONS LEARNED

The review of existing priced managed lane facilities with successful transit services provides a valuable set of lessons learned from both physical and policy perspectives. Managed lane facilities must be designed to efficiently move buses to integrate transit successfully. There are also numerous policy considerations that can influence transit success along a corridor.

DESIGN CONSIDERATIONS

Based on the characteristics of existing managed lane facilities that have successfully integrated transit, the following considerations should be considered in the planning and design of transit service on express lanes[1]:

- ***Maintain Level of Service***: Toll pricing levels should be managed to maintain a minimum level of service (LOS) for transit vehicles. If minimum speeds and LOS are maintained on priced

[1] Newmark, 2014

managed lanes through variable or dynamic pricing, transit services have witnessed benefits from travel time reliability, improved headways, and associated ridership increases.

- ***Direct Access Ramps***: Priced managed lanes should be designed where possible with direct access ramps for transit vehicles. Direct access and egress locations avoids vehicles having to cross multiple general-purpose lanes to access the managed lanes, which is particularly challenging for large buses. Shoulder-running express lanes also provide flexibility for access and egress locations.

- ***Park-and-Ride Lots***: Effective managed lane transit services should integrate park-and-ride lots close to the facility. In several cases, toll revenue has been used to fund construction of new park-and-ride lots, expanding transit access. In an ideal situation, park-and-ride lots would be located directly adjacent to the managed lanes, with access provided by direct access ramps.

- ***Station Facilities***: The most effective managed lane transit services include transit stations along the facility, which directly interface with the managed lane. These stations are either "In-line," which are within the footprint of the managed facility, or "Off-line," facilities that are located near the managed lanes, but not directly within the roadway footprint. In-line stations, such as those deployed on the I-110 Express Lanes in Los Angeles (Figure 5-2), are intended to serve pedestrian passengers, bicycle riders, and feeder transit lines. Benefits include less right of way, less ramp construction, and time savings for passengers. Drawbacks longer walking distances and expensive handicap access. Off-line stations are often located at park-and-ride lots, large employment centers, or major transit centers close to the managed lanes corridor. These stations might require a direct connector ramp to be most effective, and can also result in somewhat longer total travel times for passengers. However, they can also facilitate easier pedestrian access and parking.

POLICY CONSIDERATIONS

Each priced managed lane project has unique policies in place that influence how well transit is integrated in a particular corridor. The most successful facilities for enhancing transit service consider transit an integral part of the facility and may establish revenue sharing policies to facilitate transit operation. Establishing a set of policies that improves transit service and capacity is often essential in building public support

Figure 5-2: In-Line Station on I-110

for often controversial toll lane projects and helps to neutralize the concept of "Lexus Lanes." The following key policy considerations relate to transit integration into priced managed lanes[2]:

- ***Dissuade Shifts to Driving***: One potential consequence of priced managed lanes is that some existing transit riders on the facility may start to pay to drive alone. To address this, some agencies have instituted minimum toll rates that are at least as high as transit fares, so there are not price advantages for solo driving. In Los Angeles, tolls in the morning and afternoon peak periods for the full trip on the Express Lanes must be at least 1.5 times the Metro Bus Rapid Transit fare of $2.45.

- ***Transit Outreach***: As priced managed lanes are still a relatively new concept and require a broad public outreach campaign, there is an opportunity to highlight transit improvements as part of the project. As an example, the US-36 Express Lanes in Denver advertised the transit improvements at the forefront of the project outreach effort. This approach underscores that managed lane projects can benefit multiple modes.

- ***Revenue Transfer***: One of the most critical considerations for successful managed lane transit integration is the distribution of toll revenue. Several priced managed lane facilities have established policies that dictate how toll revenue remaining after toll system operations and maintenance is distributed. The I-10 / I-110 Express Lanes in Los Angeles, 95 Express in Miami, and I-15 Express Lanes in San Diego all receive toll revenue to support existing transit services and potential improvements.

- ***Interoperable Fare System***: Toll system interoperability between different tolling facilities is becoming increasingly commonplace. To establish a transit rewards program, tolling accounts must be linked, or better yet, interoperable with transit accounts. If multiple agencies are involved in the operations of the toll lanes and transit service, this will require close interagency coordination. The LA Metro Express Lanes Transit Rewards program serves as a best practice example, where toll credits can be earned on 10 express bus routes throughout Los Angeles County.

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At some point, tolling approaches and the Wake Transit
Plan will be required to be integrated in a coordinated
manner.
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[2] Newmark, 2014

6 EQUITY CONSIDERATIONS

As interest in roadway pricing has grown, and more priced managed lane facilities have been developed, the concern that pricing proposals may be unfair to some drivers or population groups has also grown. A key reason for public reluctance toward acceptance of roadway pricing can be the failure to address equity concerns adequately. Despite the many social and economic benefits of road pricing, educating the public of the value of tolling requires a careful analysis of the distribution of costs and benefits across different socioeconomic groups, especially where the impacts may be felt by a large and diverse number of people. Many congestion pricing proposals have encountered substantial public resistance and even intense opposition.

Tolling opponents have raised objections including: (1) drivers are paying for what has traditionally been "free"; (2) drivers are paying twice for same facilities (gasoline taxes plus tolls); and (3) there are disproportionate distributions of costs/benefits. A successful tolling strategy for the Triangle should include an open, transparent, and inclusive process for evaluating potential social equity and environmental justice (EJ) concerns that may arise as part of the development of a regional tolling network. This section outlines best practice considerations for an equity analysis and framework process and highlights mitigation strategies that have been included in successful priced managed lane facilities.

6.1.1 EQUITY ANALYSIS & FRAMEWORK

The main purpose of an equity analysis should be to understand how a tolling or priced managed lane strategy will affect specific EJ communities and how it can be made fairer for all. The analysis should consider both short term and long term impacts, and build in flexibility to respond if conditions change. As described in section 3, project experience has shown that public engagement is crucial in addressing concerns about and building public support for tolling initiatives. Agency and public stakeholders should be engaged in a process that provides meaningful public dialogue about the proposed tolling strategy, how it will be financed, how the revenues will be collected and spent, what the equity impacts may be, and how any negative consequences can be minimized and mitigated. The direct costs of a tolling project will be borne primarily by those who pay tolls to access the facility. The focus of the equity assessment should be to determine whether these costs fall disproportionately on certain groups, and if that is reasonable when considering the ability to pay, benefits received, or costs imposed. Some equity issues that should be considered while undertaking an EJ analysis for priced managed lanes include:

- ***Income Equity***: Depending on the financing plan, some individuals could pay gasoline or sales taxes and the revenue collected is spent to fund managed lanes that they will not use, rather than some other services. The equity evaluation should consider how sources of funding may impact different groups and whether any imbalance can be mitigated by changing the way that any revenues from tolling are spent.

- ***Modal Equity***: The equity evaluation should also consider the distribution of indirect costs and other non-economic factors, like whether general-purpose lane users would experience more traffic congestion, and which groups change their travel modes or trip-making behavior.

- ***Geographic Equity***: Noise, air quality, and traffic impacts on local communities and neighborhoods should also be evaluated. Additional long-term potential impacts could include changes in land use patterns that might take place due to changes in accessibility or local traffic patterns affecting residents and businesses in low-income or disadvantaged areas.

6.1.2 MITIGATION STRATEGIES

Although priced managed lane initiatives can face equity challenges, it is important to note that all income groups can benefit from the implementation of pricing. Freeway users, even low-income, may benefit indirectly from additional road capacity because toll paying drivers will not be competing for space on existing general-purpose lanes. In addition, a survey of drivers on the 91 Express Lanes in Orange County found that households earning below $50,000 annually used the lanes about as often as those earning $200,000 or more. Another study showed that 19 percent of peak period users had household incomes below $40,000 and only 21 percent above $100,000[3]. A study of the I-15 express lanes in San Diego found strong support among all income levels[4].

One of the most frequent criticisms of priced managed lanes is that they primarily benefit high-income drivers who can afford to pay a toll for premium travel, while low-income drivers are forced onto more congested general-purpose lanes. The impression that express lanes are just "Lexus lanes" is a powerful impediment to achieving public acceptance for priced lanes. To mitigate these concerns, several priced managed lane projects have included policies of targeted revenue allocation, discounts for low-income drivers, and opportunities to earn toll credits by traveling on other modes. Regarding best practices, the LA Metro Express Lanes on I-10 and I-110 are integrated with one of the most comprehensive equity programs in the United States. Some applicable LA Metro policies aimed at addressing concerns over toll prices include:

- **Revenue Allocation:** The LA Metro revenue policy is that all gross toll revenues from the Express Lanes are first used to pay for their maintenance, administration, and operation. All remaining revenue that is produced must be used in the respective corridor from which it was collected. Revenue allocation guidelines include enhanced transit service to address equity concerns.

- **Discounts:** LA Metro offers low-income residents of Los Angeles County a per-household account set-up fee waiver equal to the cost of the required transponder ($25) for accounts related

[3] Sullivan, 2000
[4] Zmud and Arce, 2008

to the I-110/I-10 Express Lanes. Eligible participants must be Los Angeles County residents, and meet low-income thresholds that are double the current Federal poverty level.

- ***Toll Credits***: LA Metro has addressed the needs of transit riders along the two toll corridors by offering frequent transit riders (many of whom are low-income) a $5 per month toll credit for using certain routes more than a set minimum number of times each month.

- ***Carpool Loyalty***: LA Metro also operates a carpool loyalty sweepstakes. As part of the program, FasTrak account holders enter a monthly drawing every time that they use the Express Lanes with their transponder set to HOV mode. The monthly drawing awards winners with toll credits and gift cards.

REFERENCES

— Federal Highway Administration. *Manual on Uniform Traffic Control Devices*, 2009

— Federal Highway Administration, 2012. Priced Managed Lane Guide.

— Newmark, Gregory 2014. HOT for Transit? Transit's Experience of High-Occupancy Toll Lanes in the *Journal of Public Transportation* 17 (3): 97-114.

— Southern California Association of Governments (SCAG). *Regional Concept of Operations*, September 2017

— Sullivan, Edward, 2000. Continuation Study to Evaluate the Impacts of the SR 91 Value-Priced Express Lanes. Final Report. State of California, Department of Transportation, Traffic Operations Program. HOV Systems Branch, Sacramento. December.

— University of California at Berkeley. *A Comparative Safety Study of Limited versus Continuous Access HOV Facilities*, Task Order 6601 Traffic Safety Center, September 2007

— U.S. Department of Transportation, Federal Highway Administration, December 2008. Income-Based Equity Impacts of Congestion Pricing, A Primer

— U.S. Department of Transportation, Federal Highway Administration, April 2013. Guidebook for State, Regional, and Local Governments on Addressing Potential Equity Impacts of Road Pricing.

— U.S. Department of Transportation 2014. Los Angeles Congestion Reduction Demonstration (LA CRD) ExpressLanes Program; National Evaluation: Technical Memorandum on Congestion, Tolling, Transit, and Equity Results.

— Zmud, J. and C. Arce. 2008. NCHRP Synthesis 377. Compilation of Public Opinion Data on Tolls and Road Pricing. Transportation Research Board of the National Academies, Washington D.C.