

## 4.0. RAMP METERING COORIDOR EVALUATION ISSUES

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### 4.1. Problem Analysis

The decision to implement additional ramp meters in Las Vegas, the Southern Nevada region or elsewhere in the state should largely be based on existing conditions and problems and/or stated needs. In other words there should be an existing condition or problem that the implementation of ramp meters will fix or lessen. For instance, ramp meters may be deployed to address safety issues that occur at or immediately upstream of the ramp/freeway merge point. Ramp meters may also be an appropriate solution for reducing freeway congestion, and increasing travel time reliability. Despite these benefits, however, the decision to implement ramp meters cannot be made solely the problems they address, but rather the decision must also take into consideration whether or not ramp meters is the best solution, when compared to others, and whether or not it is feasible.

#### 4.1.1. Safety

High collision rates on freeways or in the vicinity of freeway/ramp merge/weave areas may warrant the implementation of ramp meters to improve traveler safety. Of particular importance are collisions linked to ramp operations, including rear-end collisions upstream of ramps at the merge, diverge, and weave areas of ramps. High collision rates at these locations may indicate that freeway operations are being jeopardized by the quantity or manner in which vehicles are entering the freeway facility. For instance, turbulence from vehicle platoons entering the freeway may cause an unexpected decrease in vehicle speeds at freeway/ramp merge areas, resulting in an increased likelihood of rear-end collisions immediately upstream of the merge area and sideswipe or lane change collisions at the ramp/freeway merge point. Analysis of recent collision rates, by total collisions and by collision type, should include the entire length of freeway for which ramp meters are proposed. Results from this analysis can be used to conclude whether collisions are more prevalent at a single ramp, or longer section of freeway. Based on this information, the scope of ramp metering program is made more apparent.

##### 4.1.1.1. *Rear-end Collisions*

Rear-end collisions may occur on entrance ramps and at points upstream from the ramp/mainline merge points, as a result of poor operations at the ramp/freeway merge point. Vehicles that enter freeways in platoons have to slow considerably to find gaps in traffic and to merge safely. For motorists upstream of the ramp/freeway merge point, who may be unaware of slowing traffic, this reduction in speed may occur rather sharply. If an adequate following distance is not allowed, or if other conditions are present that affect the braking distance or reaction time, rear-end collisions may occur. Similarly, the same situation applies to motorists traveling on the entrance ramp who have yet to approach the ramp/freeway merge point. Ramp metering, can reduce the number of rear-end collisions on both the ramp and at points upstream of the ramp/freeway merge point by enabling vehicles to enter the freeway more smoothly. This reduces the impact on vehicles on the freeway and lessens the chance that a rear-end collision will occur.

#### *4.1.1.2. Sideswipe and Lane Change Collisions*

Similar to rear-end collisions, sideswipe and lane change collisions at or immediately downstream of ramp/freeway merge areas may also be reduced through ramp metering. Merging traffic may force their way into smaller gaps that are safe or drivers already on the freeway may swerve to avoid a collision or make an unsafe lane change when large platoons enter from a ramp. By splitting up the platoons, ramp metering allows entering traffic to more easily find a safe gap to enter and drivers already on the freeway can more easily allow the merging traffic onto the freeway.

#### *4.1.2. Congestion*

High collision rates and incidents are major causes of freeway congestion. Other causes include; bottlenecks, geometric deficiencies including those that limit motorists' ability to smoothly enter the freeway facility, increases in demand (i.e., entering demand exceeds exiting demand), and vehicle queuing on exit ramps that spill back onto the freeway. It is critical that the causes of congestion are known and understood before selecting a ramp management strategy such as ramp metering. In some cases, ramp meters may not be applicable or less favored when considered side-by-side with other types of improvements.

##### *4.1.2.1. Level of Service*

Freeway Level of Service (LOS) or freeway speed is a good indicator of whether or not a freeway or segment of freeway is congested. Low freeway speeds suggest a problem and may in part be due to the fact that traffic from one or more ramps is entering the freeway in platoons or that the overall demand on the freeway exceeds its capacity. Freeway conditions approaching LOS D or worse may be candidates for ramp metering, depending on if other problems are present and the appropriateness of other ramp management strategies in resolving problems.

##### *4.1.2.2. Mainline Speeds*

Another common indicator of congestion is mainline speed. If mainline speeds on urban freeways drop below desirable levels, ramp metering should be considered. The definition of "desirable levels" is generally a local decision based on what the goals of the agency are and what local travelers believe is desirable. Generally speaking, in urban areas with 60 mph speed limits, speeds consistently under 50 mph may not be desirable, indicating ramp metering should be considered. In most areas, peak period average speeds under 40 mph are likely to be considered unacceptable and ramp metering should be considered.

##### *4.1.2.3. Travel Time and Travel Time Reliability*

Travel time is another indicator of congestion. Travel time is simply the time it takes for a vehicle to travel between points on a specific stretch of roadway. Actual travel time measurements can be compared with travel times collected under ideal conditions (i.e., free-flow) to assess the impact congestion is having on travel. Travel time reliability is also an important measure of congestion. More predictable travel times allow travelers to better budget their travel schedules and help avoid unexpected delays. Ramp metering systems have been shown to reduce travel times and improve travel time reliability.

Percent variation of travel time is one way to measure reliability. It is similar to standard deviation, but can be used to compare trips of different lengths. It is like standard deviation in the fact that the resulting value represents a window of time that equally surrounds the mean in which 68% of all travel times fall. Instead of providing a value expressed in minutes, percent variation produces a value expressed as a percentage. For instance, if the average travel time were 30 minutes, a 5% variation would indicate that 68% of all travel times fall within a range that is 30 minutes +/- 5%, or between 28 minutes 30 seconds to 31 minutes 30 seconds.

There are no firm guidelines for the values of travel time or travel time reliability that would indicate the need for ramp metering. If NDOT wants to use travel time as an indicator of the need for ramp metering, an acceptable ratio of peak hour travel time to desirable travel time would need to be determined. This becomes essentially the inverse of the mainline speed indicator mentioned above, and therefore would be redundant if mainline speed is used as an indicator. If travel time reliability was to be used as an indicator, an acceptable percent variation would need to be determined. (The Washington State Department of Transportation uses a measure similar to percent variation for their HOV lanes. Acceptable performance of an HOV lane is when it operates above 40 mph 90 percent of the time, similar to a percent variation of 10 percent. However, general purpose travel is unlikely to be as reliable as travel in an HOV lane, so a higher percent variation is probably needed.) In either case, if the actual measure was greater than the acceptable level, ramp metering should be considered.

## **4.2. Location Analysis**

The extent and location of problems are two key considerations in the deployment of ramp meters.

### **4.2.1. Problem Extent**

The geographic extent of ramp metering (i.e., whether or not one or more ramp meters will be deployed, and on which ramps on which freeways) is primarily based on program goals and objectives and the extent and locations of congestion or other traffic or safety problems. The geographic extent of ramp metering is determined by assessing whether or not problems are isolated or linked. In other words, are problems confined to a single location (i.e., one ramp) or do problems extend along a stretch of roadway or a corridor containing two or more ramps? The result of this assessment will affect the selection of an appropriate metering approach.

#### **4.2.1.1. Individual Ramp**

If traffic or safety problems on a freeway are isolated (i.e., occur at specific locations not adjacent to each other), ramp meters may be used independently to reduce the impact of the problem. Since problems are isolated, a single ramp meter may be deployed at the location where the problem is occurring to resolve or reduce the impact of the problem. With that said however, impacts of ramp meter installations should be considered before meters are deployed. Any time a meter is deployed the potential exists for impacts to occur such as traffic diversion.

#### **4.2.1.2. Multiple Ramps (Single Corridor)**

If traffic or safety problems on a freeway extend beyond the area of a single ramp, to include two or more adjacent ramps, ramp meters may need to be coordinated to effectively address the problem(s). Depending on the extent of the problem, ramp meters may need to be deployed along a freeway segment or an entire corridor.

#### **4.2.1.3. Multiple Ramps (System wide)**

If traffic or safety problems are severe, and present on two or more freeways, ramp meters may need to be implemented system wide to effectively address problems.

#### **4.2.1.4. Adjacent Facilities**

Facilities adjacent to ramps (i.e., freeways and arterials) should be examined to determine if problems occur at these locations and if operations on the nearby ramps contribute to the problem. Operations on adjacent arterials may be affected by traffic that backs up on the ramp and spills onto arterial. Therefore, ramp meters are often applied with other improvements that can be made at the ramp terminal to eliminate or minimize to the maximum extent possible the effects of traffic queues at these locations. Possible solutions may include adjusting signal timing, adding capacity to the ramp or adjacent arterial, adding or modifying pavement markings, etc.

### **4.2.2. Site Characteristics**

Ramps where problems have been observed should be analyzed in greater detail to understand problems better, assess whether or not ramp meters best address problems and to determine the feasibility of deploying ramp meters. For instance, ramps that are thought to have congestion or safety related problems may not be suitable for ramp metering because there isn't adequate storage on the ramp to hold vehicles waiting to enter the freeway. Lack of storage on the ramp may cause vehicle queues to back up onto the adjacent arterial which may cause additional safety or congestion problems on the arterial. Besides storage, other characteristics, including merge length, communications availability, and ramp geometry may influence NDOT's decision to deploy ramp meters.

#### **4.2.2.1. Geometry and Spacing**

Before a decision is made to implement additional ramp meters, NDOT should first determine if poor geometry is attributing to observed problems at the ramp in question. For instance, ramps with inadequate acceleration or merge distances and major weaves are some examples of problems closely tied to ramp geometry. Others include closely spaced ramps (e.g., ramps located within one mile of each other), limited sight distances, narrow shoulders, and narrow lane widths. Fixing geometric deficiencies like these may improve problems observed at the ramp, without having to invest significant capital into ramp metering systems.

#### **4.2.2.2. Ramp Demand and Capacity**

If metering is initially indicated, NDOT will need to determine if ramp demand can be accommodated by ramp metering, and if it can, what type of flow control will be necessary. Flow control is the general term given to the configuration ramp meters to permit vehicles to enter a freeway facility. Under normal conditions a single-lane,

uncontrolled ramp may have a throughput capacity of 1800 to 2200 vehicles per hour (vph). When flow controls are implemented on a ramp, the throughput capacity is reduced, and excess demand is held on the ramp. Selection of appropriate flow controls depends on answers to the following questions.

- 1) What is the pre-metering demand on the ramp?
- 2) What is the available storage on the ramp?
- 3) What is the extent of diversion expected after meters are deployed?

The pre-metering demand on the ramp will be used to determine the frequency at which vehicles must be released so queues do not back up into the ramp/arterial intersection. Depending on traffic volumes, ramp meters will employ one of the following flow control schemes. Characteristics associated with each flow control scheme are provided in Table 4-1.

- ▶ Single Lane, One Car per Green - Permits a single vehicle to enter the freeway facility per cycle for one lane only.
- ▶ Single Lane, Two Cars per Green - Permits two or more vehicles to enter the freeway facility per cycle, for one lane only.
- ▶ Dual Lane, One Car per Green – Permits a single vehicle to enter the freeway facility per cycle, per lane (2 or more lanes).
- ▶ Dual Lane, Two Cars per Green – Permits two vehicles to enter the freeway facility per cycle, per lane (2 or more lanes).

**Table 4-1: Types and Characteristics of Ramp Metering Flow Controls**

| <b>Flow Control Scheme</b>     | <b>No. of Lanes</b> | <b>Cycle Length</b> | <b>Capacity (VPH)*</b> |
|--------------------------------|---------------------|---------------------|------------------------|
| Single Lane One Car Per Green  | 1                   | 4 – 4.5 sec.        | 900-1000               |
| Single Lane Two Cars Per Green | 1                   | 6 – 6.5 sec         | 1100-1200              |
| Dual Lane One Car Per Green    | 2                   | 4 – 4.5 sec.        | 1600-1700              |
| Dual Lane Two Cars Per Green   | 2                   | 6 – 6.5 sec         | 1800-1900              |

\* Minimum Value Recommended for Analysis

Generally speaking, if a decision is made to deploy ramp meters on a ramp and hourly traffic volumes do not exceed 900 vph, a single lane, one-car-per-green flow control scheme will be adequate. A single lane, one-car-per-green approach may also be adequate if hourly traffic volumes slightly exceed the 900 vph threshold, so long as the number of hours which traffic volumes exceed 900 vph are minimal and as long as traffic volumes do not greatly exceed 900 vph. However, ramps where traffic volumes exceed 1000 vph should be closely monitored to determine if the single lane, one-car-per-green approach is appropriate. In addition, if ramps have inadequate queue storage, or if diversion from the ramp is not acceptable, the single lane, one-car-per-green release rate may not be suitable.

Ramps that have traffic volumes that exceed 900 vph for several hours, or that significantly exceed 900 vph (i.e, greater than 1000 vph) for one or more hours are candidates for single lane, multiple-cars-per-green flow control schemes. However, the single lane, multiple-cars-per-green flow control scheme is only practical so long as hourly traffic volumes do not exceed the optimal capacity of 1,100 vph. As was the case with the single lane, one-car-per-green approach may be applicable if traffic volumes

slightly exceed 1,100 vph for one or at maximum, a couple of hours. If traffic volumes exceed 1,200 vph the two lane metering should be investigated.

Two lane meters can be operated at one or two-cars-per-green release rates. Dual lane ramp metering at one-car-per-green has an optimal capacity of 1,600 vph. If a dual lane, two-cars-per-green release scheme is applied, the optimal capacity may extend up to 1800 vph.

#### *4.2.2.3. Ramp Storage Capacity and Queues*

Ramp storage capacity and estimated queue lengths and delays should be taken into account before ramp metering is selected and deployed. Ensuring that metered ramps have adequate storage capacity for the estimated queues will ultimately lead to a more successful metering campaign. NDOT and partner agencies should discuss and decide how they wish to manage queues that form as a result of ramp metering operations. One acceptable practice for estimating the vehicle storage requirements for any given ramp is calculated by taking 10% of the pre-metered peak hour volume. Therefore, 70 vehicles is an adequate storage for a ramp with a peak hour volume of 700vph. The required storage distance therefore, can be calculated by multiplying the vehicle storage requirement (i.e., 70 vehicles) by the average assumed vehicle length (usually 25ft.). This is a general guide that can be used for early planning stages. For a better estimate, macroscopic modeling, such as *FREQ*, should be used. *FREQ* will provide estimates of queued vehicles, metering rates, and delays.

NDOT and partner agencies should also determine the acceptable queues and resulting delays. When possible, efforts should be made to hold traffic to the ramp without having traffic backup onto adjacent arterials. Traffic that backs-up onto local arterials may disrupt traffic operations on the arterial and other streets that feed into it. In addition, average delays over a certain amount will likely be unacceptable to drivers. Initially, average delays should exceed the metering period by 5 minutes. Average delay over a fifteen minute period exceeding 10 minutes may also be unacceptable. As mentioned above, *FREQ* will estimate average ramp delays.

The following strategies are available to manage queues:

- ▶ Available storage space must be considered. If arrival rate exceeds metered rate, a queue will build and could extend onto the cross street. Proper storage should be provided so disruption to other facilities doesn't occur. Storage should be contained on the ramp, if possible. Estimate the length of queue to determine if sufficient space is available on the ramp.
- ▶ If sufficient space is not available, geometric changes should be considered, such as widening the ramp to provide 2 lanes to expand the number of vehicles that can be stored.
- ▶ Modified metering rates could be considered to increase the flow on the ramp and reduce queuing.
- ▶ Improvements to local streets may be necessary to provide adequate storage
- ▶ Signal timing revisions to streets feeding the ramp may enhance storage capabilities by not allowing an influx of vehicles greater than the ramp storage capacity – care must be taken to not cause significant delay.

- ▶ If no solutions can be found to reduce queuing to that point that it doesn't disrupt side street traffic, then NDOT needs to consider not metering the ramp. This may well mean an entire section of ramps can't be metered, unless there are special circumstance at the ramp in question, such as feeding an add lane on the freeway.

#### *4.2.2.4. Merge Length*

The distance from the ramp meter to the ramp/freeway merge point must be a length long enough to allow all types of vehicles to adequately accelerate to freeway speeds. If acceleration distances are inadequate, safety along the ramp, freeway or at the freeway/ramp merge point may be jeopardized. First, vehicles entering the freeway at speeds lower than those observed on the mainline may force vehicles approaching the freeway/ramp merge point to slow down or change lanes to allow vehicles from the ramp to enter safely. As a result, rear-end and sideswipe collisions are more likely to occur at locations immediately upstream of the freeway/ramp merge point. In severe cases, slow moving vehicles entering from a ramp may be forced to wait for gaps in mainline traffic at the freeway/ramp merge point before entering the freeway facility. This action may contribute to increases in sideswipe collisions at the freeway/ramp merge point as well as rear-end collisions on the ramp.

The NDOT Project Design Development Manual (PDDM) or Chapter 10 of the AASHTO Green Book should be used to determine the minimum merge distances needed. Minimum acceleration lengths for entrance terminals with flat grades of 2 percent or less as presented in the Green Book (2001) are shown in Figure 4-1. It is important to use the freeway speeds that will be in place during ramp metering operations.

#### *4.2.2.5. Power and Communications Availability*

Ideally, all ramp meter controllers would communicate to a central location. However, sometimes communication is not feasible because of the area in which ramps are to be metered or the temporary nature of the ramp metering project (for example, for a special event or construction). Communications may also be too expensive or take too long to implement for the initial operation of the system. In the Las Vegas area, a centrally managed system has been selected to operate the metering system. This allows agency staff to monitor and control the ramp metering operation from a central location. This also allows a central algorithm to be used and operators can make adjustments to metering parameters in real-time from a central location.

This approach is the preferred ramp metering approach in general. When NDOT expands ramp metering, a central management system should be planned, unless the metering is intended only for special events or construction. Meters can be turned on and operated in advance of the central system being operational, but this practice should only be used when absolutely necessary.

### **4.3. Impact Analysis**

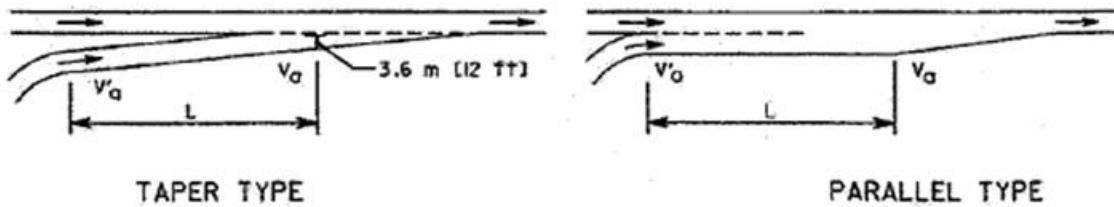
NDOT should thoroughly assess the potential impacts of ramp meters on existing conditions and operations before deciding where and if to implement meters. This process includes analyzing traffic patterns (diversion, queuing), impacts to adjacent

neighborhoods, and safety. Additionally, practitioners should determine the geographic extent of the problems to be addressed.

**Figure 4-1: Minimum Acceleration Lengths for Entrance Terminals with Flat Grades of 2 Percent or Less**

| US Customary                                                      |           |                                |      |      |      |      |      |      |      |     |
|-------------------------------------------------------------------|-----------|--------------------------------|------|------|------|------|------|------|------|-----|
| Acceleration length, L (ft) for entrance curve design speed (mph) |           |                                |      |      |      |      |      |      |      |     |
| Highway                                                           | Stop      | 15                             | 20   | 25   | 30   | 35   | 40   | 45   | 50   |     |
| Design                                                            | condition |                                |      |      |      |      |      |      |      |     |
| speed, V                                                          | reached,  | and initial speed, $V_a$ (mph) |      |      |      |      |      |      |      |     |
| (mph)                                                             | $V_a$     | 0                              | 14   | 18   | 22   | 26   | 30   | 36   | 40   | 44  |
| (mph)                                                             | (mph)     |                                |      |      |      |      |      |      |      |     |
| 30                                                                | 23        | 180                            | 140  | —    | —    | —    | —    | —    | —    | —   |
| 35                                                                | 27        | 280                            | 220  | 160  | —    | —    | —    | —    | —    | —   |
| 40                                                                | 31        | 360                            | 300  | 270  | 210  | 120  | —    | —    | —    | —   |
| 45                                                                | 35        | 560                            | 490  | 440  | 380  | 280  | 160  | —    | —    | —   |
| 50                                                                | 39        | 720                            | 660  | 610  | 550  | 450  | 350  | 130  | —    | —   |
| 55                                                                | 43        | 960                            | 900  | 810  | 780  | 670  | 550  | 320  | 150  | —   |
| 60                                                                | 47        | 1200                           | 1140 | 1100 | 1020 | 910  | 800  | 550  | 420  | 180 |
| 65                                                                | 50        | 1410                           | 1350 | 1310 | 1220 | 1120 | 1000 | 770  | 600  | 370 |
| 70                                                                | 53        | 1620                           | 1560 | 1520 | 1420 | 1350 | 1230 | 1000 | 820  | 580 |
| 75                                                                | 55        | 1790                           | 1730 | 1630 | 1580 | 1510 | 1420 | 1160 | 1040 | 780 |

Note: Uniform 50:1 to 70:1 tapers are recommended where lengths of acceleration lanes exceed 1,300 ft.



Source: A Policy on Geometric Design of Highways and Streets (American Association of State Highway and Transportation Officials). Table 10-56. P. 830.

Sketch planning models such as the ITS Deployment Analysis System (IDAS), can be used to estimate the impacts of ramp metering. Staff should use their understanding of existing situations or problems, along with estimated impacts to determine if ramp metering will offset the impacts likely to occur after implementation. If ramp metering is shown to offset impacts, staff can continue to analyze ramp metering by comparing it against other appropriate strategies to come to a final decision on the best strategy or strategies to implement. Even though the benefits of ramp meters offset their potential impacts, it is possible that ramp metering may not offer the greatest potential for improvement when compared against other ramp management strategies.

Once ramp metering is determined to be an appropriate improvement for the area being analyzed, additional analysis will need to be undertaken to help address some of the issues mentioned in previous paragraphs. Specifically, NDOT will need to get an idea of what the metering rates and resulting queues and delays will likely be in order to determine the flow control and needed queue storage, as indicated above. The best way

to determine rates and queues is by using a model, such as FREQ. FREQ will determine metering rates and provide impacts on the ramp (number of vehicles queued) and on the mainline (speeds and volumes). Other tools or analytical methods can be used, but it is important that they provide (1) suggested meter rates, (2) ramp queues and delays, and (3) mainline impacts (high level impacts are provided by IDAS).

In addition to analyzing ramp queues and delays and mainline impacts, some analysis of diversion, equity, and public perception should be undertaken.

#### 4.3.1. Diversion

Ramp metering may result in a portion of the existing traffic being diverted from freeways to arterials. Motorists may elect to bypass queues that form on metered ramps in lieu of arterials that parallel a freeway facility. This is especially true for motorists who take short trips, in which case wait times at meters may exceed the additional travel time that results in slower arterial speeds.

Diverted traffic may or may not be a problem depending on available capacity on routes able to carry diverted traffic. If a sufficient number of routes are available, diversion may be a benefit as it is making more efficient use of existing capacity. However, if available routes cannot support diverted traffic, operations on nearby arterials may be negatively affected. This may also cause jurisdictional disputes and conflicts as ramp and arterial facilities are typically managed by different agencies, and one agency's operations may negatively impact another's.

FREQ can estimate the level of diversion. However, this is not one of the strengths of the model. The most important consideration in determining if diversion is likely to be an issue is to look at the ramp queues from FREQ with no diversion allowed. If the delay times are substantial (certainly over 10 minutes per vehicle and may be as low as 5 minutes per vehicle) and there are ways to divert to another ramp, drivers will likely divert. If diversion can be accommodated to downstream ramps, diversion may not be a problem. If diversion can't be easily accommodated on the arterial network, if the likely diversion will carry traffic through neighborhoods or other sensitive areas, or if diversion is a politically sensitive issue, then NDOT and its partner agencies should consider ways to reduce delay times, accommodate diversion by making improvements on alternate routes, or both. If there are no ways to accommodate or lessen the likelihood of diversion to a politically acceptable level, metering may not be feasible. If the agencies are unsure of the impact of diversion, a pilot metering implementation could be used to determine the diversion level and the impact.

#### 4.3.2. Equity

When analyzing the appropriateness of ramp meters for specific ramps, NDOT should consider the distribution of benefits and drawbacks of ramp meters and their operation before selecting and implementing them. Ramp meters may produce benefits for some motorists at the expense of others. This is viewed as unfair and is politically unfavorable. For instance, the argument can be made that ramp meter implementations favor suburban motorists who make longer trips, versus those that live within metered zones who make shorter trips. This argument is based on the assumption that the suburban motorist lives outside a metered zone and is not delayed by ramp meters when entering a freeway and

traveling through a metered zone. As such, the possibility exists that the motorist, who lives closer to a downtown area, may have a proportionally unfair negative impact on their commute when comparing travel time to travel distance.

The best way to address this concern is to make sure that ramps that carry a significant amount of traffic into the congested area are metered, even if congestion does not reach that ramp. Origin-destination studies or estimates are the best ways to determine if a significant number of travelers from unmetered ramps will receive an undue benefit.

Equity should also be considered when setting metering rates or establishing the parameters in an algorithm that calculates or selects metering rates. Those who benefit the most from mainline travel time savings should be willing to experience the most delay on the ramps.

#### **4.3.3. Public Perception**

Similar to equity issues, managers within NDOT need to take into consideration possible public opposition to ramp meter implementation and devise strategies for improving it. It is very likely that a certain percentage of the public may incorrectly perceive ramp metering as a solution that doesn't work. In addition, these individuals may focus on the few negative aspects of ramp meters, and fail to realize that these negative aspects are typically off-set by the benefits ramp meters provide. Knowing this, NDOT staff must be proactive in disseminating information and demonstrating the benefits of ramp metering to the public, as well as others within and outside their respective organizations. This includes other agencies, local businesses, and the media. Without public support, ramp meters may be viewed as costly and ineffective, which may lead to problems with receiving funding to expand the system or to support on-going operation and maintenance of the system. Recommended approaches to outreach and public information are presented in Section 5 of this document.

#### **4.4. Geometric Improvements**

NDOT should consider whether or not ramps need to be widened before implementing ramp meters. There are several reasons why entrance ramps may need to be widened. First, widening metered ramps will provide additional storage capacity for ramps with inadequate storage (see section 4.2.2.3). Second, ramps may need to be widened to provide enforcement zones, where enforcement personnel can be stationed safely and where ramp meter operations are clearly visible. Similarly, ramps without adequate room to perform maintenance activities may also need to be widened. Lastly, ramps may need to be widened if providing designated lanes for special classes of vehicles. The additional capacity in these situations would promote use of transit and carpooling/vanpooling by proving benefits in terms of reduced delay for these vehicles. When ramps are metered, HOV lanes allow HOVs (i.e., public transit vehicles, carpools, vanpools) and emergency vehicles to bypass metered vehicles without having to stop. Transit-only lanes may be provided in lieu of HOV-lanes if HOV volumes exceed desired thresholds and little travel time savings are obtained. HOV/Managed Lanes should not be considered unless state and/or regional policy support HOV/Managed Lane treatments.

If storage on the ramp is exceeded, and neither the metering rate can be adjusted nor the ramp widened, NDOT should consider adding turn/storage lanes on the adjacent arterial to hold vehicles waiting to turn onto the ramp. Construction of arterial turn/storage lanes may be implemented with other treatments, such as signal timing, to limit traffic entering the ramp to prevent queues from spilling back through the intersection.