7.0. SELECTING A RAMP METERING APPROACH

7.1. Geographic Extent

Selecting a metering approach begins by defining the geographic extent in which ramp meters ought to be deployed. The geographic extent is largely based on existing problems, and whether or not these problems are confined to a single ramp, or exist at several locations along a corridor or within the system. Besides existing problems, the geographic extent of ramp metering is also influenced by: jurisdictional and political boundaries, ability to limit diversions, and extent of recurring congestion. Similarly, ramp metering may not be feasible at locations where geometric characteristics make it unsafe or not practical. Consider:

- Add lanes
- Inadequate storage
- Drivers diverting from metered ramps
- Political/institutional issues.

There are two general approaches used to meter ramps depending on the geographic extent of observed problems. Each approach is described in the following sections.

7.1.1. Isolated

If traffic or safety problems on a freeway are isolated (i.e., occur at specific locations not adjacent to each other and control at a single ramp can solve or sufficiently reduce the problems), ramp meters may be used independently. 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, NDOT should consider the impacts of ramp meter installations before the decision is made to implement them. Any time a meter is deployed the potential exists for impacts to occur such as traffic diversion (see Section 4.3.1).

7.1.2. Linked

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, meters may need to be deployed along a freeway segment, an entire corridor or system-wide to effectively address the problem(s).

7.2. Local versus System-wide Metering

7.2.1. Isolated

Isolated control, also known as local control, is a process of selecting ramp meter rates based solely on conditions present at an individual ramp, not considering conditions along a segment of freeway, along a freeway corridor, or anywhere else in the regional freeway network. When local ramp metering is used, one or more ramps may be metered, however, there is no effort made to coordinate the effects of ramp meters. The primary concern is improving conditions and reducing congestion near the ramp itself. In some cases, when local ramp metering is used, congestion problems at the ramp may appear to be fixed, when in reality problems are transferred to or uncovered at downstream locations. In these situations, local ramp metering is not recommended.

7.2.2. Coordinated

Coordinated or system-wide control is a process of selecting metering rates based on conditions throughout the entire length of the metered corridor. In other words, coordinated control takes into account conditions beyond those adjacent to the ramp when determining metering rates for an individual ramp. To this extent, system-wide control can be used for a freeway segment, an entire corridor, or several freeway corridors. The primary concern therefore, focuses on improving freeway conditions for an entire region. This makes system-wide control more flexible in handling reductions in capacity that occur as a result of delay, collisions, and road blockages, compared to local control.

7.3. Pre-timed versus Traffic Responsive

When the decision has been made to install ramp meters, NDOT must decide whether meters will be pre-timed or traffic responsive. The selection of a pre-timed or traffic responsive metering approach is independent of the decision to implement isolated or coordinated control. Pre-timed metering can take into account impacts throughout a corridor and traffic responsive control can use only local conditions to determine metering rates. The primary consideration in selecting pre-timed or traffic responsive metering is the ability to install traffic detectors. If NDOT cannot install traffic detectors on the ramp and on the mainline, traffic responsive metering cannot be used, and therefore; pre-timed metering must be selected. For example, detectors may not be able to be installed for budgetary purposes, because the system will only be temporary for a work zone project, or there may not be time or funding available to install detectors in the initial operation. Another factor that may affect the decision of whether pre-timed or traffic responsive metering should be selected is cost. At first glance, it may appear as though traffic responsive metering will have a higher cost, since there are more components to install (e.g., loop detectors), and traffic responsive systems appear to be more complex. However, these costs are typically off-set by the day-to-day monitoring and operating tasks associated with pre-timed meters. If there is no mainline or ramp detection, agencies must regularly collect data by alternative means in order to analyze traffic conditions on the freeway and determine the appropriate metering rates. The metering operation will require frequent observation so operators can adjust rates to meet traffic conditions, whereas traffic responsive systems complete this task automatically.

7.3.1. Pre-timed

Pre-timed metering is best applied to address traffic problems that are a direct result of recurring congestion or localized safety problems that can be reduced by simply breaking up queues of vehicles entering the freeway. This is because pre-timed metering rates are based on historical data, and unlike traffic responsive systems cannot make adjustments for real-time conditions, including non-recurring congestion (i.e., congestion that occurs as a result of weather, collisions, etc.). Since rates are pre-timed, and cannot adjust to real-time conditions, metering rates will almost always be either too fast or too slow for current conditions. Despite this fact, however, pre-timed systems are often perceived as an easy-to-implement, low-cost approach. The low capital costs of pre-timed metering makes it attractive as a backup to other metering approaches or for situations when the primary approach fails.

7.3.2. Traffic Responsive

Traffic responsive metering systems use data from freeway loop detectors or other surveillance systems to calculate or select ramp metering rates based on current freeway conditions. A traffic responsive approach can be used either locally or system-wide. Both of these approaches are discussed below.

7.3.2.1. Local Traffic Responsive

Local traffic responsive metering approaches base metering rates on freeway conditions near the metered ramp (i.e., upstream, downstream, or at the merge point). Similar to pre-timed systems, local traffic responsive systems are proven strategies that are often used as backups when communication to a central control system fail. Unlike pre-timed systems, surveillance of the freeway using traffic detectors is required.

7.3.2.2. System-wide Traffic Responsive

System-wide traffic responsive systems optimize traffic flow along a metered stretch of roadway versus a specific point on the freeway (as is the case of local traffic responsive systems). System-wide traffic responsive systems operate similar to local traffic responsive systems, however system-wide approaches base metering rates on conditions throughout a section of freeway. As such, metering rates at any given ramp will be influenced by conditions at other ramps within the system or corridor that is metered. Like local traffic responsive systems, system-wide traffic responsive systems require data from ramp detectors and mainline freeway detectors. In addition to these components, system-wide traffic responsive systems are unique in the fact that data is also needed from downstream detectors, upstream detectors, and detectors at other ramps. System wide traffic responsive systems have the most complex hardware configuration of the three metering approaches discussed.

7.3.3. Operator Control

Operator control/selection is a method, initiated by an operator, to select a metering rate based on prevailing conditions. Usually, operator selection is used to address special conditions such as incidents or special events, where traffic patterns and volumes are not as predictable.

7.4. Flow Control

The theoretical maximum rate that vehicles merge with traffic on a freeway facility and the length of queues that result from metering applications is in part a result of the type of flow control implemented at the ramp. The selection of a flow rate depends on several factors. These factors include; ramp length, number of lanes, and traffic volume.

There are three strategies for controlling the flow of vehicles entering freeway facilities from a ramp. These strategies are discussed in more detail in Section 4.2.2.2.

7.4.1. One Vehicle per Green

Single entry metering permits vehicles to enter the freeway facility one-by-one, as vehicles are detected. When a vehicle approaches the ramp meter, it passes over the presence detector which notifies the signal to turn green. As a vehicle passes over the passage detector, the signal is then notified to terminate the green cycle. If a vehicle is not present the signal indication remains red until a vehicle is detected. One vehicle per green metering has a throughput of 800 to 900 vehicles per hour (vph). If a throughput greater than 900 vph is desired, a multiple vehicle per green metering approach may be suitable.

7.4.2. Multiple Vehicles per Green Metering

The multiple vehicles per green approach (also known as platoon or bulk metering) allow two or more vehicles to enter the freeway facility per green cycle. Typically two and in some cases three vehicles are permitted to pass the ramp meter per each green signal indication. Although this approach doubles or triples the throughput of vehicles per green indication, similar results cannot be expected for vehicle throughput as longer cycle lengths are required. Compared to the one vehicle per green approach, the multiple vehicle per green approach results on average, in an increase in throughput of 300-400 vph.

7.4.3. Dual Lane Metering

Tandem or two-abreast metering permits two or more vehicles to enter the freeway facility per cycle, depending on the number of lanes at the meter (one vehicle per lane). To smooth the flow of vehicles merging with freeway traffic, vehicles in each lane are released in a staggered fashion.

Tandem metering may be combined with multiple vehicles per green in some locations when demand is extremely heavy.

7.5. Ramp Storage and Queues

In part, the success of a ramp metering approach depends on the ability to smooth the flow of traffic on to the freeway while adequately holding demand on the ramp. When demand exceeds the metering flow rate, and storage on the ramp cannot handle the excess demand, traffic may back up on the adjacent arterial, causing delays and increased risk of rear-end crashes.

Most metering algorithms include a mechanism to increase metering rates when queues reach certain levels. This queue adjustment or queue override feature requires detectors to be placed on the ramp at locations that indicate critical queue lengths. Some systems have more than one detector that is used to adjust for queues. The one farthest upstream on the ramp may be placed at the point of longest acceptable queue. If traffic backs up to this detector, the metering rate is increased dramatically to keep the queue from getting worse. The next detector downstream is used to increase the metering rate a smaller amount in hopes of keeping the queue from extending to the point of longest acceptable queue.

7.6. Special Use Bypass

Special use bypasses give "special" consideration to a vehicle class or classes to improve safety, improve traffic conditions, and/or encourage specific types of driving behavior at a metered ramp. The most popular special use ramp management application is the designation of HOV bypass lanes on metered ramps (see Section 4.4).

NDOT will need to decide how HOV bypass lanes will affect metering rate selection and meter signal timing. Three approaches are possible:

1) "Pre-empt" the ramp meter when an HOV is approaching. A detector will need to be installed in the HOV lane upstream of the stop bar. When an HOV actuates the detector, the ramp signal will remain red and additional number of seconds, usually 2, to provide the HOV an unimpeded merge on the freeway.
2) Adjust the metering rate to account for the HOV traffic. In other words, if the metering rate is set to be 10 vehicles per minute and there is one HOV vehicle in the minute, only 9 vehicles would be allowed on the freeway through the ramp meter. This approach assures that the number of vehicles that are intended to be allowed on the freeway actually are.
3) Do not take HOVs into account at all. The ramp meter operates the same if there is an HOV or if there isn't.

The HOV pre-empt is usually not needed, therefore the second option is recommended.

8.0. RAMP METERING TESTING AND START-UP

Ramp meters should be analyzed for problems and tested to see if they work correctly before they are first turned on in live traffic. This reduces the likelihood that drivers will become confused and/or frustrated by improperly operating meters. When testing ramp meters it is good practice to review existing documentation for accuracy. Documentation should be made available to operators to minimize delay in responding to technical problems during start-up. Efforts should be made to update documentation on a periodic basis or when system changes occur.

Prior to turn-on, preparations should be made to accommodate questions and concerns likely to be posed by the public after meters begin operation. Automated messages may be recorded to give callers basic details pertaining to the ramp metering campaign. Messages should provide a toll-free number that may be dialed to obtain additional details via an operator or other information source. The public information number should be passed along to other local and regional agencies, so these agencies can direct callers to the toll-free number.

Approximately one week before ramp meters are implemented, signs indicating the date and time of metering or closure should be placed on selected ramps and also along the mainline. Additionally, NDOT should contact the media to announce the details of ramp management strategy operation. These actions serve as a final reminder to those that use ramps targeted for strategy deployment.

9.0. RAMP METERING PERFORMANCE MONITORING, EVALUATION AND REPORTING

After ramp meters are implemented, tested and initially operated, they should be monitored and managed to determine if and how the strategies should be adjusted for optimal performance. System operation should be observed in the field and confirmed in the operations center. If problems are observed or reported, ramp meters should be adjusted, or maintenance or other responsive action should be performed. Likewise, problems reported via other agencies and the public need to be investigated, addressed and corrected in a timely manner. At a minimum, system operation should be analyzed on a continual basis and more formal evaluations should be conducted several times within the first year.

Evaluations at two weeks, six months, and one year after initial operation often meet the needs to report how the system is doing in the first year of operation. However, more frequent evaluations may be needed, depending on local conditions and whether there was reluctant support for the system. Evaluations should address whether the system is performing as expected and system goals and objectives are being met.

Public surveys may also be conducted on an annual basis to assess public reaction to ramp meter operations and improvements that have been made. Results of this monitoring and adjustment period should be reported to partner agencies, the media, and the public.

Monitoring and managing initial operation also includes documenting the software and hardware that has been installed and the control parameter settings used to control systems. Documentation should include system errors, how they were resolved, and any system updates that were incorporated to prevent the errors from occurring in the future. In the initial phases of a ramp metering program, documentation will help keep an up-to-date record of activities that may be used to address future hardware and software problems. Documentation should be carried beyond the initial operation of ramp meters and should be viewed as a life cycle activity that needs to be continually conducted.

For more information, refer to the NDOT Ramp Metering Monitoring Plan.

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