

Legal and Regulatory Review



*M-0468 Ramp Metering Feasibility Study for
Cabarrus, Gaston, Iredell and Mecklenburg
Counties*

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Table of Contents

| Chapter | Page |
|--|-----------|
| Introduction | 1 |
| 1. MUTCD Standards | 2 |
| 1.1. Application of Freeway Entrance Ramp Control Signals | 2 |
| 1.2. Design of Freeway Entrance Ramp Control Signals | 2 |
| 1.3. Operation of Freeway Entrance Ramp Control Signals | 3 |
| 2. Office of Administrative Hearings | 4 |
| 3. Review of General Statutes | 5 |
| 3.1. Ramp Meter Authority | 5 |
| 3.2. Potential Issues Related to Current State Statutes | 6 |
| 3.3. Ramp Meter Violation Enforcement | 8 |
| 3.4. Jurisdictional Code Review and Assessment | 9 |
| 3.5. Enforcement | 10 |
| 4. NCDOT Policies, Practices, and Procedures | 11 |
| 4.1. National Environmental Policy Act | 11 |
| 4.2. Noise Abatement Policy | 12 |
| 4.3. Traffic Engineering Polices, Practices, and Legal Resources | 13 |
| 4.4. Transportation Mobility and Safety Division Traffic Engineering and Intelligent Transportation Systems Manual | 14 |
| 5. Other States' Legal and Operational Experience with Ramp Metering | 15 |
| 5.1. Arizona | 15 |
| 5.2. California | 15 |
| 5.3. Kansas City, Kansas/Missouri | 15 |
| 5.4. Twin Cities, Minnesota DOT | 16 |
| 5.5. Atlanta, Georgia/Georgia DOT | 16 |
| 5.6. Nevada | 16 |
| 5.7. Virginia | 16 |
| 5.8. Other States | 16 |
| 5.9. Summary | 17 |
| 6. Conclusions and Recommendations | 18 |
| 6.1. Alternatives | 18 |
| 6.2. Recommendations | 18 |
| References | 20 |

List of Tables

| Table | | Page |
|--------------|---|-------------|
| Table 1. | Summary of State Statutes and Ramp Meter Operations | 17 |

Introduction

This report summarizes the research and review that Atkins conducted, including:

- Recent requirements for ramp metering according to the most current (2009) *Manual of Uniform Traffic Control Devices (MUTCD)* and whether statutory or policy revisions are needed to support the implementation, operation, and enforcement of ramp meters.
- *North Carolina Administrative Code (NCAC)*.
- North Carolina General Statutes (NCGS) concerning operation and enforcement of future ramp metering systems installed in North Carolina.
- North Carolina Department of Transportation (NCDOT) policies that might have bearing, including the new NCDOT Noise Policy and various Transportation Mobility and Safety Division policies and procedures.
- Municipal codes and local law enforcement patrol practices.
- Experiences of other states when they began their ramp meter programs.

1. MUTCD Standards

Chapter 4I of the Traffic Control Signals for Freeway Entrance Ramps of Federal Highway Administration's (FHWA) *MUTCD*, 2009 Edition, covers the application, design, and operation of freeway entrance ramp control signals. It defines ramp control signals as "...traffic control signals that control the flow of traffic entering the freeway facility. This is often referred to as 'ramp metering.'"

1.1. Application of Freeway Entrance Ramp Control Signals

This section of the *MUTCD* provides guidance that: "The installation of ramp control signals should be preceded by an engineering study of the physical and traffic conditions on the highway facilities likely to be affected. The study should include the ramps and ramp connections and the surface streets that would be affected by the ramp control, as well as the freeway section concerned." It states that additional support regarding ramp control signals can be found in FHWA's *Ramp Management and Control Handbook*.

1.2. Design of Freeway Entrance Ramp Control Signals

Section 4I.02 defines the standards to follow when installing ramp meter signals. All standard design requirements for regular traffic control signals must be followed for ramp meter signals, except as otherwise noted. These exceptions are:

- *The signal face shall be either a two-section signal face containing red and green signal indications or a three-section signal face containing red, yellow, and green signal indications. Note that the option to use a two-section signal face (red and green signals only) does not conflict with NCGS, as long as the two-section face otherwise meets all traffic signal head requirements.*
- *A minimum of two signal faces shall face entering traffic at the ramp meter location if the ramp consists of only one lane or if the ramp consists of more than one lane and the signal indications for all lanes are displayed simultaneously.*
- *If more than one lane is present on an entrance ramp and the ramp control signals are operated such that green signal indications are not always displayed simultaneously to all of the lanes on the ramp, then one signal face shall be provided over the approximate center of each separately controlled lane. Note that the section includes guidance that additional side-mounted signal faces should be considered for ramps with two or more separately controlled lanes.*

This section also states that ramp control signals should be located and designed to minimize their viewing by mainline freeway traffic. This section provides the following options:

- Ramp control signals may be placed in dark mode (no indications displayed) when not in use.
- Ramp control signals may be used to control some, but not all, lanes on a ramp, such as when non-metered high-occupancy vehicle (HOV) bypass lanes are provided on a ramp.

- Ramps with only one lane may mount the two required signal faces on the side of the roadway on a single pole, with one face at normal mounting height and the second face mounted lower, such that the height of the bottom of the signal housing of the signal face is between 4.5 and 6 feet. Note that this is a specific exception to the normal 8-foot minimum lateral separation of signal faces required by Section 4D.13.

This section provides guidance that “...regulatory signs... such as XX VEHICLE(S) PER GREEN should be installed adjacent to the ramp control signal faces. When ramp control signals are installed on freeway-to-freeway ramps, special consideration should be given to assuring adequate visibility of the ramp control signals, and multiple advance-warning signs with flashing warning beacons should be installed to warn road users of the metered operation.”

As written, Section 4I.02 requires that separately controlled, multi-lane ramp meters must have two signal heads per lane and one signal head must be mounted overhead for each lane. However, subsequent to the publishing of the *MUTCD*, FHWA received and responded to two requests for an official interpretation. FHWA ruled in January 2011:

- Each single-lane ramp meter and multi-lane ramp meter with simultaneous green indications must have two signal heads
- Separately controlled multi-lane ramp meters must have two signal heads per lane and they do not have to be overhead mounted. The two signal heads per lane may be overhead, post-mounted, or a combination of both.
- If the ramp meter has three separately controlled lanes, then one signal head shall be mounted over the approximate center of each lane and additional side-mounted signal heads should be considered.

In February 2013, FHWA made a second official interpretation to require only one signal head per lane for two separately controlled lanes of a ramp meter.

1.3. Operation of Freeway Entrance Ramp Control Signals

This section provides guidance that, prior to the installation of ramp control signals, the operating agency should determine operational strategies for ramp control signals, such as periods of operation, metering rates and algorithms, and queue management. The operating agency should closely monitor and adjust these ramp control strategies after installation.

This section also provides guidance that ramp control signals that are only operated during certain periods of the day (which is the case for most existing ramp meters), include a RAMP METERED WHEN FLASHING (W3-8) sign. This sign should be “installed in advance of the ramp control signal near the entrance to the ramp, or on the arterial on the approach to the ramp, to alert road users to the presence and operation of ramp meters.” Additionally, the standard is included that “the RAMP METERING WHEN FLASHING sign shall be supplemented with a warning beacon (see Section 4L.03) that flashes when the ramp control signal is in operation.”

2. Office of Administrative Hearings

The Office of Administrative Hearings is an independent, quasi-judicial agency of the state of North Carolina. One of its major functions is to establish uniform procedures for rulemaking. Under Article 2A of the Administrative Procedure Act (Chapter 150B), which provides for a uniform procedure for the adoption of rules, both permanent and temporary, the Office of Administrative Hearings is authorized to publish the *North Carolina Register (Register)* and the *NCAC* and to review temporary rules. Except for minor exemptions found in G.S. 150B-1(d), all state agencies are required to follow this uniform procedure for conducting public rulemaking hearings, adopting proposed rules, and filing the adopted rules for codification.

Title 19A of the *NCAC* contains the procedures under which NCDOT operates. Similarly, the North Carolina State Highway Patrol (NCSHP) is governed by the procedures established in Title 14A, Crime Control and Public Safety.

Upon review of these procedures, none affect the ability of NCDOT and NCSHP to install, maintain, and enforce ramp meter signals. Further, none of the present *NCAC* procedures would be affected by the implementation of ramp meters.

Conclusion: *NCAC* does not present any issues for implementing ramp metering.

3. Review of General Statutes

Ramp meters are tools used to manage traffic on freeways by regulating the rate vehicles can enter the freeway, typically one or two vehicles at a time, in order to improve the average speed of all vehicles traveling on the freeway. Ramp meters consist of traffic signals, stop bar striping, and regulatory signs located on freeway on-ramps. Atkins researched and reviewed the North Carolina General Statutes (NCGS) with respect to operation and enforcement of future ramp meters on interstate and state highways.

In addition, Atkins researched and reviewed the NCDOT Ordinances at Connect NCDOT (<https://connect.ncdot.gov/resources/safety/Pages/Safety-Ordinances.aspx>) for updates pertaining to the implementation and operation of ramp metering. This review included identification of new or changed ordinances since 2013, as well as updates to the NCAC, the *Uniform Policies Relating to Traffic Offenses*, and the Traffic Engineering Policies, Practices, and Legal Authority (TEPPL).

3.1. Ramp Meter Authority

In 2014, the State Legislature enacted changes to NCGS §20-4.01 (32a) that have bearing on ramp metering. NCGS §20-4.01 (32a) now defines a ramp meter as:

“A traffic control device that consists of a circular red and circular green display placed at a point along an interchange entrance ramp.”

NCGS §20-158 (c) was also amended in 2014 to include paragraph (6):

“When a ramp meter is displaying a circular red display, vehicles facing the red light must stop. When a ramp meter is displaying a circular green display, a vehicle may proceed for each lane of traffic facing the meter. When the display is dark or not emitting a red or green display, a vehicle may proceed without stopping. A violation of this subdivision is an infraction. No drivers license points or insurance surcharge shall be assessed as a result of a violation of this subdivision.”

NCGS §20-158 (a) authorizes the Department of Transportation (DOT) to control vehicles “...at intersections and other appropriate places, by erecting or installing steady-beam traffic signals and other traffic control devices, signs, or signals.” The statutes do not specifically mention ramp meters or ramp control signals. However, NCGS does address traffic control devices that are located at appropriate places to control vehicles, which fits the function of a ramp meter. Vehicles must follow the same rules and regulations when interacting with a ramp meter signal as they would for a traffic signal at places other than intersections, which are described in NCGS § 20-158 (c)(2):

“When a traffic signal has been erected or installed at a place other than an intersection, and is emitting a steady red light, vehicles facing the red light shall come to a complete stop. When the traffic signal is emitting a steady yellow light, vehicles facing the light shall be warned that a red light will be

immediately forthcoming and that vehicles may not proceed through such a red light. When the traffic signal is emitting a steady green light, vehicles may proceed subject to the rights of pedestrians and other vehicles as may otherwise be provided by law.”

Additionally, NCGS §136-30 (a) states: “...All traffic signs and other traffic control devices placed on a highway in the State highway system must conform to the Uniform Manual [Federal Highway Administration’s *Manual on Uniform Traffic Control Devices (MUTCD)*, 2009 Edition]...” Since ramp meters fit the description of a traffic control device, they must conform to the *MUTCD*.

Conclusion: Presuming NCDOT compliance with the *MUTCD*, it has the statutory authority to erect ramp meters or traffic signals as deemed justified by an engineering study.

3.2. Potential Issues Related to Current State Statutes

Since ramp meters are not specifically addressed in the NCGS, law enforcement and other legal stakeholders should further evaluate ramp meter operational issues not clearly presented to determine if general statutes, procedures, or policy revisions are necessary:

- Specific number of cars that may proceed per green interval
- Driver’s obligation when ramp meters are not in operation
- Driver’s obligation when other vehicles are stopped on the ramp at the signal or queue

3.2.1. Specific Number of Cars to Proceed per Green

The ramp meter concept is predicated on allowing only a certain number of cars to proceed during each green interval. Current ramp meter deployments typically use signs to instruct drivers that only one car may proceed during each green interval, the duration of which is typically short. Some agencies employ platoon ramp metering, which generally allows two or three cars to proceed during each green interval. NCGS § 20-158 (c)(2), cited above, allows any number of vehicles to proceed through the green interval until the signal turns red. Since the statute is silent on how many cars may proceed on a green light, there is really no conflict and the sign takes precedence.

Conclusion: The timing of the ramp meter will likely be such that it will be difficult for multiple vehicles to proceed through the green without violating the red light. Therefore, enforcement should be based simply upon whether a driver violated the red light.

3.2.2. Ramp Meters Not in Operation

Ramp meters typically operate only during peak hours in the mornings and evenings on weekdays. Most existing ramp meter systems turn the ramp meter signals off when ramp meters are not operational. The *MUTCD* Option in Section 4I.02 (07) states: “Ramp control signals may be placed in the dark mode (no indications displayed) when not in use.”

Prior to 2014, the NCGS did not specify how a vehicle should proceed at a dark traffic signal other than at an intersection. NCGS §20-158 (b)(6) states: “When a traffic signal is not illuminated due to a power outage or other malfunction, vehicles shall approach the

intersection and proceed through the intersection as though such intersection is controlled by a stop sign on all approaches to the intersection...” This prescribes a response by the motorist that is not desired for a non-illuminated ramp meter signal. The statute is silent concerning signage indicating how to proceed when a ramp meter signal is dark.

In 2014, NCGS §20-158 (c) was amended to address signals not at intersections to say: “When a traffic signal has been erected or installed at a place other than an intersection, and is emitting a steady red light, vehicles facing the red light shall come to a complete stop. When the traffic signal is emitting a steady yellow light, vehicles facing the light shall be warned that a red light will be immediately forthcoming and that vehicles may not proceed through such a red light. When the traffic signal is emitting a steady green light, vehicles may proceed subject to the rights of pedestrians and other vehicles as may otherwise be provided by law.”

NCGS §20-4.01 (16) defines an intersection as “...the area embraced within the prolongation of the lateral curb lines or, if none, then the lateral edge of roadway lines of two or more highways which join one another at any angle whether or not one such highway crosses the other.” Since the ramp meter is not located at an intersection, then Statute §20-158 (b)(6) would not appear to be applicable and there would be no legal conflict.

NCGS §20-4.01 (32a) now defines a ramp meter as: “A traffic control device that consists of a circular red and circular green display placed at a point along an interchange entrance ramp.” Please note this states there will be two section heads.

NCGS §20-158 (c)(4) states that a traffic signal with a flashing yellow light that is not at an intersection can be used to indicate that vehicles may proceed with caution. It specifically states, “When a flashing yellow light has been erected or installed at a place other than an intersection, approaching vehicles facing the light may proceed with caution, yielding the right-of-way to pedestrians and other vehicles.”

However, in most current ramp meter deployments, a flashing yellow light is not commonly used when ramp meters are not in operation; ramp meter signals are more typically dark when not in operation. Some existing ramp meter deployments use flashing yellow to indicate ramp meters are entering operational mode, or during times when ramp meters are typically operational, but low traffic volume conditions do not warrant stop-and-go ramp metering. While the use of a flashing yellow light is not the typical method used for a non-operational ramp meter, its use would satisfy the regulations of traffic signals not at an intersection and the function of a non-operating ramp meter.

Conclusion: NCGS §20-158 (b)(6) does not apply because the statute only addresses the operation of a dark traffic signal at an intersection. By its legal definition, a ramp meter is not at an intersection.

NCGS §20-14.01 defines a ramp meter and clearly distinguishes it differently from a traffic signal. NCGS §20-158 (c)(4) addresses when a flashing light is installed at a location other than an intersection. It does not stipulate that a flashing light has to be installed, and as long

as the *MUTCD* is followed for the appropriate signage and signal displays, there is no conflict. NCGS §20-158 (c)(6) specifically addresses control at a ramp meter.

3.2.3. Vehicles Stopped at a Ramp Meter Signal/Queue

A ramp meter's purpose is to control the flow of traffic on the ramp before vehicles enter the freeway mainline, and then release them at a desired rate. As vehicles approach the ramp meter, they are either stopped by the ramp meter signal or by the queue awaiting the ramp meter signal. This inherent characteristic of ramp meters could be considered as a conflict with NCGS §136-89.58 (5), which states that it shall be unlawful for any person ... to stop, park, or leave standing any vehicle, whether attended or unattended, on any part or portion of the right-of-way of said highways [controlled access facilities], except in the case of an emergency or as directed by a peace officer, or as designated parking areas."

Conclusion: Vehicles stopped in a queue or on a freeway due to congestion as well as vehicles stopped at a traffic signal are not actions for which someone would be cited under this statute. Therefore, this statute is not an issue.

3.3. Ramp Meter Violation Enforcement

Ramp meter signals must be enforced to ensure motorist compliance, which is critical to the success of a ramp management system. Potential violations at ramp meter sites include vehicles running red lights, more than the allowed number of cars proceeding per green, driving around the ramp meter to avoid the queue, and HOV bypass violations (where applicable).

One unaddressed issue relates to a unique aspect of ramp meter signal operation. Typically, ramp meters allow only one vehicle to proceed per green interval (although platoon ramp metering allows two or more). If more than the allowed number of vehicles proceed through the green signal, but do not violate the red signal, they have not run the red light, but have violated the intent of ramp meter operations.

For ramp meter enforcement to be effective, good enforcement access and a safe area to cite violators should be designed into the ramp meter project. The FHWA *Ramp Management and Control Handbook* states: "Law enforcement agencies that have enforcement jurisdiction in the project area should be consulted in the project development and design stages in order to gain their input and buy-in. Working jointly, agency staff can determine the appropriate design element, such as the number and design of enforcement areas." Additionally, it states that it is important for law enforcement to have "...adequate staff, support by the courts, and well-designed signs and signals that are enforceable."

Conclusion: In the early stages before ramp meter deployment, NCDOT should coordinate with local and state law enforcement agencies to determine how to enforce ramp meter operations within the general statutes. State and local agencies should coordinate to ensure that violations are equitably processed between agencies.

3.3.1. Establishment of Traffic Fines

Traffic fines are established in the General Statutes as \$25 plus court costs unless specific legislation stipulates otherwise. Court costs, periodically revised by the General Assembly, are established under NCGS §7A-1. Annually, a committee for the Office of Administrative Courts establishes the “standard costs,” fine plus court costs, for each type of traffic offense for dissemination to state and local police officers. It is important to note that any signage identifying fines must comply with the General Statutes.

Conclusion: If it is determined the fine should be higher than the standard \$25 plus court costs, it will need to be specifically written into the legislation.

3.4. Jurisdictional Code Review and Assessment

In this section, Atkins has reviewed the Cities of Gastonia, Charlotte, and Concord Codes of Ordinances to determine if they have any regulations or ordinances that may affect the operation and enforcement of ramp meters to address changes since the last report.

The codes were reviewed and cross-referenced to the NCGS §20-158 "Vehicle Control Signs and Signals." This cross-reference is aimed at identifying potential conflicts or other discrepancies between state and local codes.

The review consisted of an evaluation of code and ordinances directly and indirectly related to the configuration and operations of primary ramp metering system components, including, but not limited to:

- Stop signs
- Traffic signals
- Junction alignment and configuration
- Other signage

NCDOT, under the authority of the General Statutes, has established an administrative process for the Division Traffic Engineer, Regional Traffic Engineer, or State Traffic Engineer to authorize traffic ordinances. This process does not require concurrence or further legal approval from a municipality for legal enforcement.

3.4.1 City of Gastonia

The review revealed no conflicts with NCGS §20-158 "Vehicle Control Signs and Signals." In addition, the review of the City of Gastonia's "Code of Ordinances," Division 1 "Provisions Relating Primarily to Vehicles and Passengers," revealed no conflicts with any specific statute regarding the implementation and operations of metered junctions or ramp metering.

3.4.1. Recommendations

- No changes related for sites in Gastonia.

3.4.2 City of Charlotte

A review of the City of Charlotte's municipal code, Chapter 14, "Motor Vehicles and Traffic," Article III - "Traffic Control Signs, Signal and Devices," and Article IV - "Operation of Vehicles," was conducted. The review revealed no direct conflicts with State Code 20-158 "Vehicle Control Signs and Signals." The review also identified no conflicts in the City of Charlotte code that would conflict with the implementation and operations of ramp metering.

3.4.2. Recommendations

- No changes related for sites in Charlotte.

3.4.3 City of Concord

The City of Concord's City Code, Part II, Chapter 58, was also reviewed and cross-referenced with State Code 20-158, "Vehicle Control Signs and Signals," in order to identify any potential conflicts.

The code and statute research and review for the City of Concord included Chapter 58, "Traffic and Vehicles," Articles I through VI. No conflicts were identified with State Code.

3.4.3. Recommendations

- No changes related for sites in Concord.

3.5. Enforcement

The State Highway Patrol (SHP) is the lead agency for traffic enforcement on the state highways including the Interstates. The municipal police departments provide support and assistance to SHP. Except for the items below, the city police departments do not regularly patrol and provide traffic enforcement:

- Charlotte Police Department: Patrols I-277
- Gastonia and Belmont Police Departments: Patrols sections of I-85 within their municipalities
- Mint Hill Police Department: Patrols section of I-485 within their municipalities

It would appear that since the local police departments provided very limited enforcement patrols of the Interstates, the potential for different interpretations of the statutes is limited.

4. NCDOT Policies, Practices, and Procedures

4.1. National Environmental Policy Act

The National Environmental Policy Act (NEPA) of 1969 and Chapter 23 of the Code of Federal Regulations (CFR) addressed a mandate to consider potential environmental consequences related to balanced decision making for transportation projects. Section 23 CFR § 771.105 stipulates:

- “To the fullest extent possible, all environmental investigations, reviews, and consultations be coordinated as a single process, and compliance with all applicable environmental requirements be reflected in the environmental document required by this regulation.
- Alternative courses of action be evaluated and decisions be made in the best overall public interest based upon a balanced consideration of the need for safe and efficient transportation; of the social, economic, and environmental impacts of the proposed transportation improvement; and of national, state, and local environmental protection goals.
- Public involvement and a systematic interdisciplinary approach be essential parts of the development process for proposed actions.
- Measures necessary to mitigate adverse impacts be incorporated into the action.”

To further define the analysis processes, FHWA and, in turn, NCDOT have issued numerous regulations regarding NEPA implementation. Once a project has been recommended, the NCDOT procedures require a scoping process to identify the extent of the environmental analysis. Most projects of the size and complexity of ramp metering installations would fall under the definition of the categorical exclusion. A categorical exclusion is a category of actions that do not individually or cumulatively have a significant effect on the human environment and for which neither an environmental assessment nor environmental impact statement is required as per Section 40 CFR 1508.4. The following relevant types of projects fall under the categorical exclusion process subject to FHWA approval:

- Modernization of a highway by resurfacing, restoration, rehabilitation, reconstruction, adding shoulders, or adding auxiliary lanes (e.g., parking, weaving, turning, climbing);
 - Restoring, resurfacing, rehabilitating, and reconstructing pavement (3R and 4R improvements);
 - Widening roadway and shoulders without adding through lanes;
 - Modernizing gore treatments;
 - Constructing lane improvements (merge, auxiliary, and turn lanes); and
 - Performing minor bridge widening (less than one through lane);
- Highway safety or traffic operations improvement projects, including the installation of ramp metering control devices and lighting:
 - Installing ramp metering devices;

- Installing lights;
- Adding or upgrading guardrail;
- Upgrading medians, including adding or upgrading median barriers;
- Improving intersections, including relocation and/or realignment;
- Making minor roadway realignment;
- Channelizing traffic; and
- Implementing traffic aid systems, signals, and motorist aid.

4.2. Noise Abatement Policy

The NCDOT *Traffic Noise Analysis and Abatement Manual*, 2011, discusses the evaluation of traffic and construction noise and the development of appropriate noise reduction measures. The manual was revised to comply with FHWA guidance for the analysis and abatement of highway traffic noise. Ramp meters are not specifically addressed in the *Traffic Noise Analysis and Abatement Manual*.

The manual defines three types of projects (Types I-III). The definition of a Type I project includes conditions that might warrant traffic noise analysis and abatement measures, such as increasing road capacity and additional heavy vehicle use as follows:

1. Construction of a highway on a new location.
2. Physical alteration of an existing highway where there is either:
 - a. Substantial horizontal alteration. A project that halves the distance between the traffic noise source and the closest receptor between the existing condition to the future build condition.
 - b. Substantial vertical alteration. A project that removes shielding, exposing the line-of-sight between the receptor and the traffic noise source. This occurs when either the highway vertical alignment is altered, or the intervening topography between the highway traffic noise source and receptor is altered.
3. Addition of through-traffic lane(s). This includes the addition of a through-traffic lane that functions as an HOV lane, high-occupancy toll lane, bus lane, or truck climbing lane.
4. Addition of an auxiliary lane, except when the auxiliary lane is a turn lane.
5. Addition or relocation of interchange lanes or ramps added to a quadrant to complete an existing partial interchange.
6. Restriping existing pavement for the purpose of adding a through-traffic lane or auxiliary lane.
7. Addition of a new or substantial alteration of a weigh station, rest stop, rideshare lot, or toll plaza.

If a project is determined to be a Type I project under this definition, then the entire project area as defined in the environmental document is a Type I project. From these criteria it would appear that ramp metering does not meet the standard for a required noise study unless there is widening of the ramp.

A Type II project involves a federal project or federal-aid funding on existing highway. In this case, NCDOT would have to develop a Type II program under 23 CFR 772.7(e). Type III projects are federal projects or federal-aid projects that do not meet Types I or II and do not

require a noise study. The deployment of ramp meters should not affect traffic noise and no noise abatement measures will need to be taken according to the NCDOT *Traffic Noise Analysis and Abatement Manual*, 2011. A request is being prepared for submission to FHWA to verify that the project locations are Type II sites.

4.3. Traffic Engineering Polices, Practices, and Legal Resources

NCDOT's Transportation Mobility and Safety Division maintains investigative study, planning and design directives, and procedures on a wide variety of topics that provide accessible and consistent guidance. There are more than 75 procedures, some of which are references to the NCGS or national standards published by FHWA, the Institute of Transportation Engineers, the American Association of State Highway and Transportation Officials, or others. These directives were reviewed for their impacts on ramp metering signals. These materials may be found online at: <http://www.ncdot.org/doh/preconstruct/traffic/teppl/>

4.3.1. Procedures Potentially Impacting Ramp Meter Implementation

Standard Practice T-31 for part-time traffic signals states that it is "...standard practice of NCDOT, to operate traffic signals in a steady (stop-and-go) mode at all times except during periods of traffic signal equipment malfunctions or for programmed late-night flashing operation during off-peak, overnight hours based on engineering judgment." If a signal is dark it could be construed by the general public as malfunctioning, which would require the vehicle to stop. However, if the *MUTCD* standard is followed and the sign "RAMP METERED WHEN FLASHING" is installed, any conflict as to whether or not a driver should stop should be eliminated.

Upon completion of this project, NCDOT may need to develop a new practice that addresses criteria for ramp meter justification and design, and installation consistent with the format of the Standard Practices.

4.3.2. Procedures Impacted by Ramp Meters

A large number of the previously described procedures address special purpose signing. These signing procedures will not be affected unless the special purpose signing is in the way of the ramp meter installation. Since the ramp meter installation is a regulatory device with a higher priority, the signing would have to be relocated or removed. These procedures would be unaffected by a ramp meter program.

One group of procedures describes a process for study or analysis such as signal warrants, crash analysis, and driveway access requests. These procedures would be unaffected by a ramp meter program.

Another group of administrative procedures describe polices or procedures on issues such as email usage, ethics, project funding, etc. These procedures would be unaffected by a ramp meter program.

4.4. Transportation Mobility and Safety Division Traffic Engineering and Intelligent Transportation Systems Manual

NCDOT's Transportation Mobility and Safety Division maintains a design manual for traffic signals and intelligent transportation systems (ITS) devices. Presently, this manual does not address ramp meters and their unique signing, signal, and pavement marking issues.

4.4.1. Recommendations

If ramp metering is implemented, it is likely that the Traffic Engineering and ITS Manual will need to be amended to include ramp metering topics or a separate ramp metering planning and design manual will need to be developed consistent with the Design Manual.

5. Other States' Legal and Operational Experience with Ramp Metering

A number of agencies with ramp meter deployments were surveyed to determine their legal and enforcement experiences deploying ramp meters—specifically, if any policy or statute revisions were made.

5.1. Arizona

The state of Arizona uniquely addresses the issue of legally defining the ramp as not being an intersection. Similar to the language in other states, Arizona General Statute 28-645 C, Traffic Control Signal Legend, states: “The driver of a vehicle approaching an intersection that has an official traffic control signal that is inoperative shall bring the vehicle to a complete stop before entering the intersection and may proceed with caution only when it is safe to do so...” Arizona statutes go further in 28-771 C, Vehicle at Intersection; exception; entering freeway to define: “Intersecting road crossings between the main roadway of a freeway and acceleration lanes, ramps or any other approach roads are not intersections as defined in section 28-601, and subsection A of this section does not control questions of right-of-way at the crossings. A vehicle entering a freeway from an acceleration lane, a ramp or any other approach road shall yield the right-of-way to a vehicle on the main roadway of the freeway entering the merging area at the same time.”

Arizona has a standard “RAMP METERED WHEN FLASHING” warning sign with flashing beacons upstream of every ramp meter. These beacons are activated only during ramp meter operation. The ramp meter signals and flashers are dark when not in operation.

5.2. California

California did not make any statute changes to support its ramp meter operation, and does not define ramp meters in the statutes.

Advance-warning signs with flashers upstream of the meter are only required when sight distance is restricted. They may be used in conjunction with an internally illuminated “METER ON” sign when the ramp meter is operating. Ramp meter signals and flashers are dark when not in operation.

5.3. Kansas City, Kansas/Missouri

The Kansas City Scout program includes installations in both Kansas and Missouri. Due to their multi-state program, both states' policies and statutes were reviewed before their ramp meters were deployed. The legal review concluded that if the ramp meter signals met the requirements of the *MUTCD*, there would be no legal issues and no changes to the general statutes would be needed. The ramp meters are enforced under the statutes pertaining to traffic signals. The practice of signing the ramp meter for one or two cars per green has not become an issue.

The Kansas City Scout ramp meter program uses a “RAMP METERED WHEN FLASHING” warning sign with flashing beacons upstream of every meter. The beacons are activated when the ramp meter is in operation. Ramp meter signals and signs are dark when not in operation.

5.4. Twin Cities, Minnesota DOT

Minnesota has installed 433 ramp meters since 1969. The general statutes have no specific mention of ramp meters; ramp meter signals are considered a traffic signal and the same laws apply if located at an intersection. To date, Minnesota DOT has had no legal issues with enforcement or legal authority.

The system has no advance-warning signs indicating a ramp meter is in operation. Advance-warning signs are used only for locations where sight distance is restricted, typically on curved ramps. Ramp meter signals are dark when not in operation.

5.5. Atlanta, Georgia/Georgia DOT

Georgia DOT (GDOT) determined that no statutes or law enforcement policies needed to be changed in advance of the deployment of ramp meters in Georgia. GDOT felt that both the public and the law enforcement community generally understood the basic concept of “stop on red.” Ramp meter promotional materials stated that ramp meters are just like any other traffic signal, and may be enforced as such.

Georgia utilizes an advance-warning flasher with an internally illuminated sign that is activated when the ramp meter is in operation. The ramp meter signals and signs are dark when not in operation.

5.6. Nevada

The Regional Transportation Commission of Southern Nevada (RTC) deployed ramp meters in 2005. As part of its marketing outreach campaign prior to ramp meter deployment, RTC worked closely with Nevada Highway Patrol. Together they determined that no statutes or law enforcement policies needed to be changed in advance of ramp meter deployments. Ramp meter signals and signs are dark when not in operation.

5.7. Virginia

Virginia did not make any statute changes to define a ramp meter, nor were any changes made to support ramp meter operation. The system does not use any advance-warning signs indicating a ramp meter is in operation. The two-section ramp meter signals are dark when not in operation.

5.8. Other States

During non-operational periods, the following states keep ramp meter signals dark—Washington DOT, New York DOT, and Utah DOT. In addition, Illinois DOT and Wisconsin DOTs’ ramp meter signals display green indications during non-operational periods.

5.9. Summary

Table 1 summarizes how each state operates its ramp meters as well as what statute changes each may have made.

Table 1. Summary of State Statutes and Ramp Meter Operations

| State | Statute Changes | Advance-Warning Signs/ Signals | Operational Displays | Non-Operational Display |
|-----------------------|-------------------------------------|---------------------------------------|------------------------------|-------------------------|
| Arizona | Defined ramp as not an intersection | "Ramp Metered When Flashing" required | Two- and three-section heads | Dark |
| California | None | Optional | Two- and three-section heads | Dark |
| Georgia | None | "Ramp Metered When Flashing" required | Three-section heads | Dark |
| Illinois | None | Optional | Two-section heads | Green |
| Kansas/Missouri Scout | None | "Ramp Metered When Flashing" required | Two-section heads | Dark |
| Minnesota | None | Optional | Three-section heads | Dark |
| Nevada | None | Optional | Two-section heads | Dark |
| New York | Not Verified | Optional | Two-section heads | Dark |
| Utah | Not Verified | Optional | Three-section heads | Dark |
| Virginia | None | Optional | Three-section heads | Dark |
| Wisconsin | Not Verified | Optional | Three-section heads | Green |
| Washington | Not Verified | Optional | Three-section heads | Dark |

6. Conclusions and Recommendations

SHP raised concerns about the enforcement of ramp meters when not in operation during the *Ramp Metering Feasibility Study in Durham and Wake Counties* project. SHP felt an indication must be displayed when not in operation; otherwise, NCGS 20-158 (b)(2) would require drivers to stop as if the signal was not operating and, therefore, the four-way stop rule would apply.

6.1. Alternatives

Our previous research resulted in five alternatives to address enforcement when ramp meters are not in operation:

1. Statutory Alternatives

- a. Do nothing. Do not modify the statutes. Operate the ramp meters with no signs/signals to indicate what to do when they are not in operation. Current NCGS only describe what to do when traffic signals located at intersections are dark. The statutes are silent with regard to dark traffic signals not at intersections. By doing nothing, the issue does not address SHP's comments and concerns.
- b. Revise NCGS 20-158(c) to incorporate text (similar to Arizona statute 28-771 C) to specifically define ramps as not intersections, thereby providing an exception to 20-158 (b)(6) that requires vehicles to treat a dark or inoperative traffic signal at an intersection as a four-way stop.

2. Design/Construction Alternatives

- a. Provide an advance-warning flasher with an internally illuminated sign that is activated when the ramp meter is in operation, similar to the Georgia system.
- b. Provide a "RAMP METERED WHEN FLASHING" warning sign with flashing beacons upstream of the ramp meter. When the ramp meter is in operation the flashing beacons are activated; otherwise, the flashing beacons are dark. This follows the design standards of Arizona, Kansas, and Missouri, and is similar to that employed in Georgia.
- c. Utilize three-section signal heads. When not in operation, display steady green indications. This mode of operation would be consistent with the *MUTCD*; however, it would be inconsistent with the majority of the states. This mode of operation also consumes more electrical power.

6.2. Recommendations

Atkins recommended in 2011 that the General Statutes be amended (as described in alternative 1b). This would provide NCDOT the most flexibility in the design of ramp meters. It would also result in the lowest capital costs since no additional construction is required. If it is not practical to revise the General Statutes, Atkins recommended using a "RAMP METERED WHEN FLASHING" warning sign with flashing beacons upstream of the ramp meter to indicate when the ramp meter is in operation (as described in 2b). This would be a relatively low-cost addition. If regarded as beneficial, the advance-warning flasher with an internally

illuminated sign activated when the ramp meter is on, could be included in the typical design, although this feature adds significant cost to the ramp meter.

After the *Ramp Metering Feasibility Study in Durham and Wake Counties* was completed, NCDOT proposed changes to the State Legislature as described in alternative 1b above and in Section 3.2.2. That legislation was passed in 2014. As a result of those legislative changes two-section signal heads (red and green balls) will be used at ramp meter signals.

Atkins foresees no other legal issues to operation and enforcement of ramp meters.

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