

Executive Summary



M-0446 Ramp Metering Feasibility Study for Durham and Wake Counties

Executive Summary

The Need for Ramp Metering

Congestion along North Carolina's limited access highways has continued to grow and congestion is increasing while the state's ability to widen existing facilities and build new ones is declining. NCDOT is looking for innovative solutions to address this increasing congestion. One method is to employ ramp metering technology on the entrance ramp of limited access highways. This technology meters the flow of entering vehicles proportionate to the available gaps in traffic. This will help to maintain travel speeds and capacity and mitigate the potential for crashes where the entrance ramps meet the freeway.

NCDOT contracted with Atkins to conduct a feasibility study for the implementation of ramp metering in the Raleigh/Durham area. This study serves as a pilot study statewide. The study's final recommendations were based on tasks that included: Data Collection, Screening and Detailed Analysis, National Research, Legal and Regulatory Review, Typical Design Criteria, Typical Cost Estimates, Performance Measures, Implementation Plan and Marketing and Outreach. This project included implementation recommendations for the Raleigh/Durham area with guidance on design criteria and costs.

Data Collection

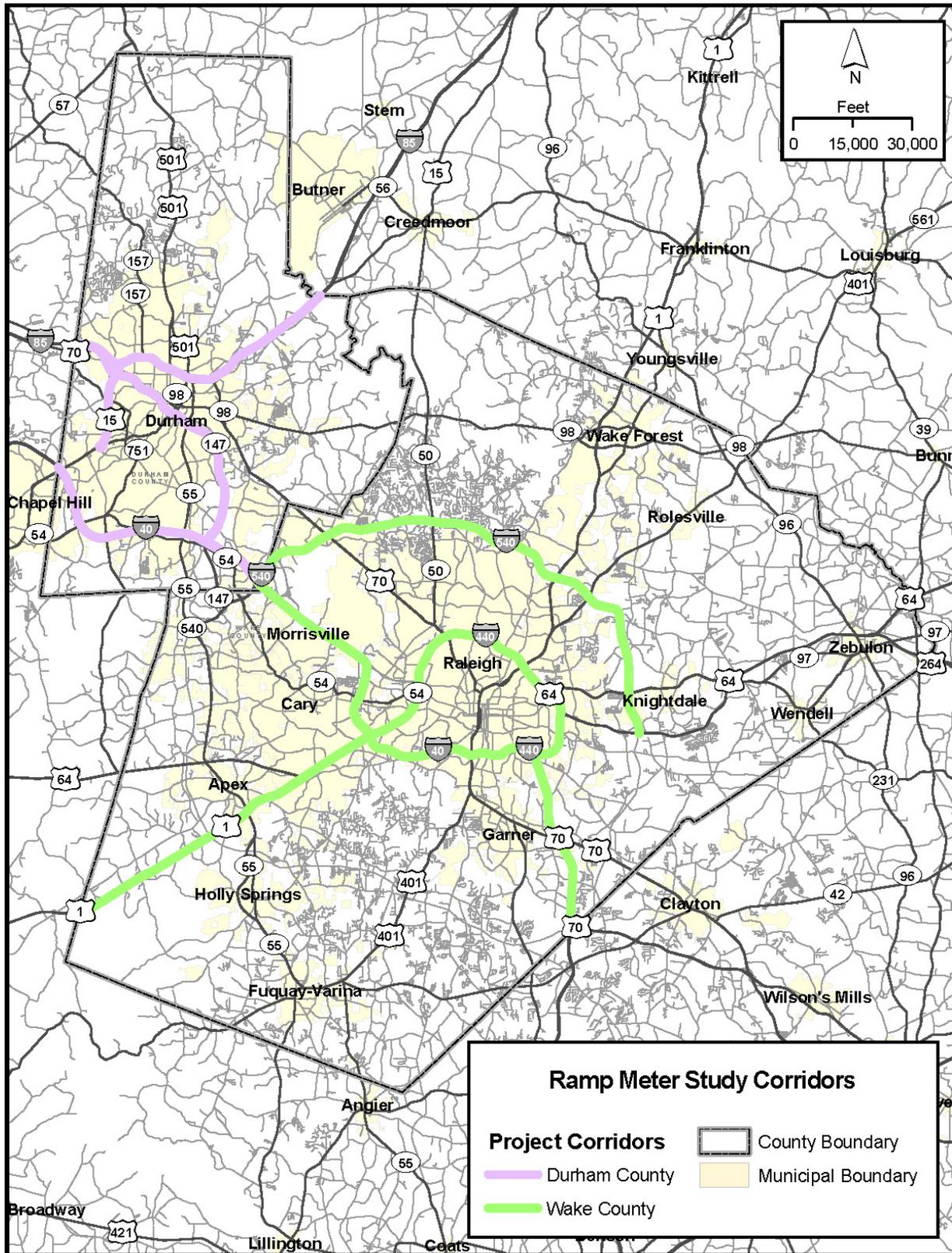
The project study began with 208 sites in Durham and Wake Counties on sections of I-40, I-440, I-540, US 1, US 15/501, and NC 147. Initially traffic congestion data and basic geometric data was collected to ascertain whether sites are freeway-to-freeway ramps and to determine if they have an appropriate level of traffic congestion.

This initial data was organized into a master database, designed to accommodate the additional data collected, analyses performed and any other relevant data collected over the course of this project.

National Research

The national research report summarized the state of ramp metering systems throughout the United States and Europe. It discussed ramp metering hardware, technology, site selection criteria, costs, implementation methods, and design standards currently used by agencies that employ ramp meters. A key element of this research was to draw upon the experiences of other areas to prepare NCDOT for successful implementation of ramp metering.

The report included a review of marketing and outreach strategies used by other states when implementing new ramp metering systems. Additionally, the research included the measures of effectiveness or benefits that ramp meters have provided to those areas.



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Legal and Legislative Review

A thorough review was conducted of North Carolina state law to ascertain if there are any restrictions on the implementation of ramp metering and whether any changes were needed to North Carolina state laws and NCDOT policies. The effort also summarizes the experiences of other states with regard to legal and regulatory issues.

The requirements of the most current (2009) *Manual of Uniform Traffic Control Devices* (MUTCD) were evaluated to assess any impacts on the implementation of ramp metering.

The review identified some potential issues with the enforcement of the ramp meters during non-operational periods. The review recommended several alternatives to address these issues. A recommendation was proposed to make minor changes in the state statutes to explicitly allow motorists to proceed past a non-operating ramp metering signal without stopping first.

Screening and Detailed Analysis

The analysis of the candidate study sites consisted of a four-step review and analysis process that examined a higher level of detail to evaluate sites as being good candidates. This process provided a cost effective means to evaluate and rule out sites that were not suitable without collecting unnecessary data.

The initial step of the screening and detailed analysis was to create a Master List of all sites within the study area. This review included a geometric data review and analysis to categorize each site as freeway-to-freeway, direct semi-direct and indirect ramp types. A complete inventory of the geometric features, including number of lanes, lane additions and deletions, ramp lengths, grades, shoulder and lane widths, and observations of traffic flow, was conducted.

During a review of the Master List by NCDOT, it was agreed that five F2F sites that have high volumes and experience frequent congestion should be included in further analysis. This provided the Department a better appreciation of the particular issues, safety concerns, associated costs, and potential for future improvements at these locations, and would provide a baseline for further evaluation and consideration in the future.

The second step of the screening and detailed analysis was an initial screening of the data that identified those sites suitable for carrying forward to a more detailed analysis. The bottleneck ranking application of the Vehicle Probe Project (VPP) software suite developed by the University of Maryland CATT Lab was used to determine if a bottleneck is causing congestion. The bottleneck ranking application is an algorithm that compares the current speed to the free flow speed at night to determine if a bottleneck is causing congestion. If the current speed fell below 60% of the free flow speed, the location was flagged as a potential bottleneck. This location is observed for 5 minutes, and if the speed stays below 60%, the bottleneck was confirmed. The bottleneck is not cleared until conditions have risen above the 60% threshold and held for 10 minutes. Data was collected using this application for at least one month each in the spring and fall of 2011.

Many of the bottleneck locations coincided with the merge of an entrance ramp, suggesting that the merge could be the cause of congestion. Entrance ramps adjacent to the bottleneck and the associated congestion spilling back upstream were considered “congested” and were identified and recorded in the Master List. There were 77 “congested” candidate sites in 42 “significant” bottlenecks.

In the third step of the screening and detailed analysis the sites were reviewed to identify any factors that would obviously rule them out as suitable sites in the future. The three main reasons for ruling out sites were:

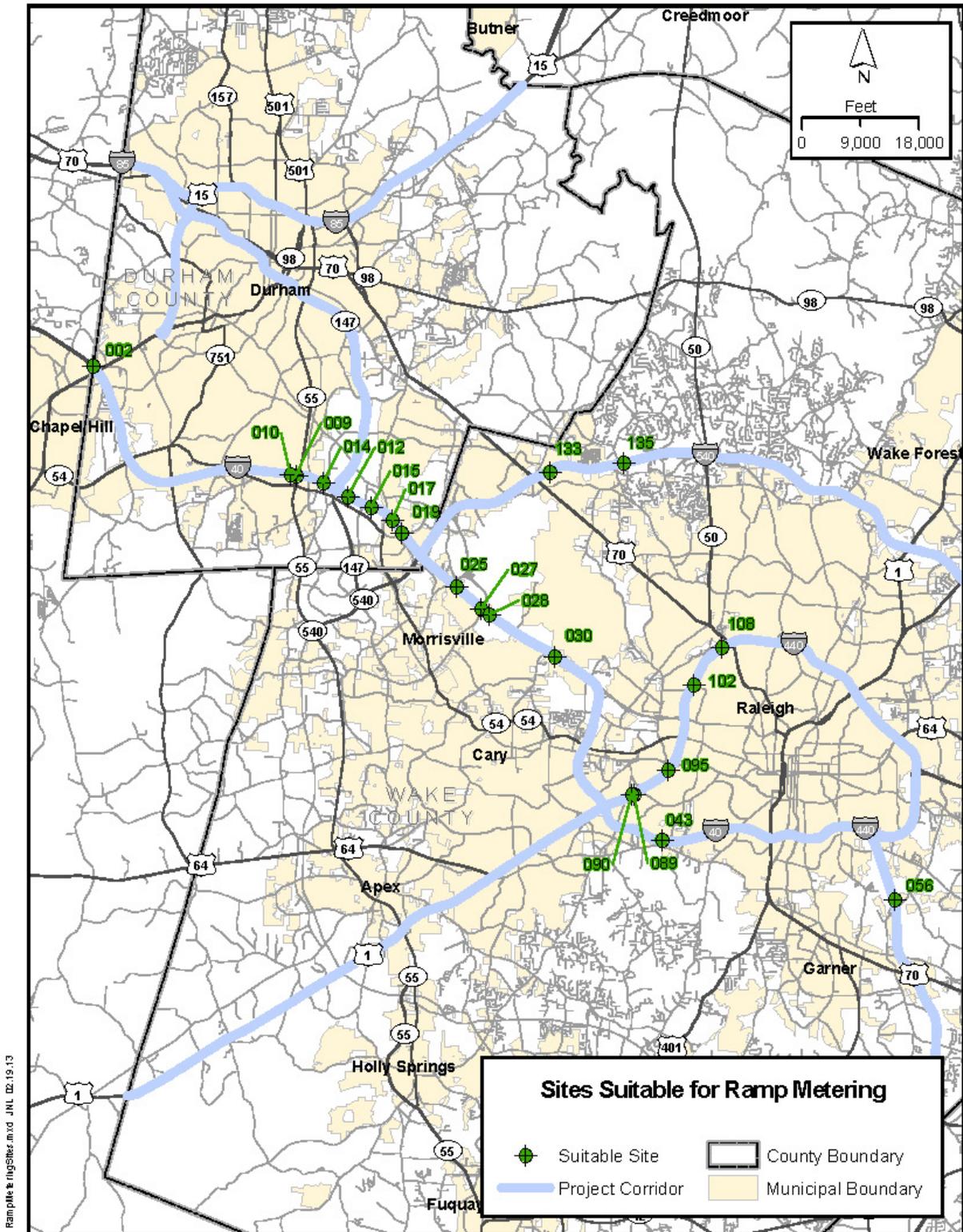
- Site subject to congestion that could be attributed to lane closures for current roadway project
- Site upstream of a primary site already ruled out due to it being freeway-to-freeway site
- Site at the back of, or beyond the back of, congestion

At the conclusion of this screening analysis, 34 sites were carried forward for the detailed analysis. The detailed analysis included:

- Collecting and analyzing traffic flow data to identify whether volumes at each site were within acceptable limits for ramp metering
- Collecting data concerning the locations and type of traffic signals
- Verifying that the period of congestion coincided with the period of suitable volumes
- Analyzing crash data
- Conducting field visits to each site
- Investigating the cause of congestion
- Quantifying the amount of congestion in the vicinity of the site
- Grouping sites by the congestion source
- Performing an analysis of crash data

For each of these 34 sites, a site summary was prepared that summarized the data collected and analyzed with recommendations as to whether a site should be carried forward for further analysis. Following the detailed review, the sites were categorized as follows:

- Not Suitable: A critical reason for the site not being suitable for ramp metering has been identified, such as very low entrance ramp volumes.
- Review in Future: In some locations with more than one site in proximity, upstream sites may no longer be congested once the downstream sites have been implemented. In this case, the site would be reviewed and evaluated at a future time.



- **Suitable for Taking Forward:** These sites have good characteristics and demonstrated potential to reduce observed congestion and will be taken forward to the next phase of the study.

There were 21 sites identified as having significant recurring congestion and suitable for ramp metering.

Typical Design Criteria

This task included the development of recommended standards for site selection, locating the ramp meter, design criteria, operational strategies, and the design standards. The design standards included geometric layout, signalization design, signing, and pavement markings. Guidance is provided on the appropriate use of the standards and typical designs details. Six typical details were developed showing conceptual designs for the following configurations:

- Single lane ramp meter
- Single lane loop ramp meter
- Two-lane ramp meter
- Single lane ramp meter with a restricted use transit bypass lane
- Single lane freeway-to-freeway ramp meter
- Two lane freeway-to-freeway ramp meter
- Optional enforcement features

Typical Cost Estimates

Utilizing the above typical design configurations for ramp meters, typical planning level cost estimates were developed. The report includes for each typical ramp meter configuration the type-specific capital, design, and construction administration, costs associated with the:

- Geometric construction (pavement, drainage, structures, and guardrail)
- Signal displays and supports
- Detection
- Controllers
- Traffic control
- Signing
- Pavement markings

Additionally, the report included program costs including procurement and integration of the central control software and controller firmware, and training. Annual operations and maintenance costs were estimated using information from other areas.

Each typical ramp configuration included certain assumptions of typical quantities. In the implementation plan, type-specific costs were developed for each of the 21 sites that address the specific conditions and recommended solutions.

Performance Measures

The 21 sites suitable for ramp metering were evaluated to determine if each site has sufficient estimated benefits versus the estimated costs to ascertain if they are financially viable. Based upon the availability of data, only reduction in delay (vehicle-hours) was used. However, other studies have found benefits such as trip reliability, crash reduction, and air emissions can be realized. A range of delay reductions (10%, 15% and 20%) were evaluated. The results of this analysis show that there is a wide range of estimated annual financial savings due to the delay reduction, from \$22,170 per year to \$405,096 per year for the 20% reduction scenario.

Implementation Plan

In the Implementation Plan, a site specific estimated cost was developed for the recommended improvement at each of the 21 sites. These improvements include:

- Single lane
- Single lane loop
- Two lane loop
- Two lane
- Single lane freeway-to-freeway
- Two lane freeway-to-freeway

The development of the implementation plan considers planned projects and their potential impacts on ramp metering and whether ramp metering might mitigate existing traffic congestion.

Using the estimate of 20% reduction in travel time, five- and ten-year horizon years were studied to determine if each candidate site produced a positive benefit-cost ratio greater than 1.0, indicating financial feasibility.

A sensitivity analysis was performed to test the impact on the decision-making if a 10% or 20% reduction in travel time was realized. The analysis validated the ranking of the 21 sites.

Sixteen sites have a benefit cost ratio greater than 1.0 in both horizon years. Using the 20% delay reduction, the benefit-cost ratios of the 16 sites range from 12.72 to 1.81. Five sites had benefit-cost ratios less than 1.0. Several strategies were developed to determine a logical order for implementation. Factors that were considered were financial viability, correct sequencing of upstream and downstream sites, relationship to STIP projects, risk, and ease of construction. Fourteen sites were recommended for implementation.

Using the predicted costs and benefits of the sites taken from the list of the 21 sites, a benefit-cost analysis was performed. This analysis took into account implementation costs, maintenance costs, and program costs. The financial benefits were only for the reduction in travel time expected from the system.

From this analysis, two strategies were identified:

- Strategy 1: Included all sites suitable for ramp metering that pay back within 5 years (i.e., have a 5-year benefit-to-cost ratio greater than 1.0), did not include one site that overlapped an STIP project, and did not include three sites that are freeway-to-freeway sites.
- Strategy 2: This lower-risk strategy included only sites with a 5-year payback that have an effectiveness factor of 1.0, did not include one site that overlaps an STIP project, and did not include three sites that are freeway-to-freeway sites.

Strategy 1 offered more potential to learn about the performance of the system in different scenarios—knowledge that could then be used to decide where to apply ramp metering elsewhere in North Carolina.

Strategy 2 removed some sites that have a slightly higher chance of not performing as expected. The key results of these two strategies are shown in the table below.

The benefits were conservatively estimated based upon other states’ implementations and without the benefit of estimating emissions, safety, etc. Since this a pilot study, a logical goal of the project would be to gain as much knowledge about a variety of sites. Therefore, it was recommended the Strategy 1 implementation sites be installed.

Strategy Results

Strategy	Number of Sites	10-Year Total Cost	10-Year Total Benefit	10-Year BCR
1	14	\$3,210,274	\$22,900,932	7.13
2	10	\$2,465,848	\$17,823,120	7.23

Each site in Strategy 1 was ranked based upon four criteria—benefit-cost ratio, congestion importance, and relative difficulty of design. Each site was graded as follows:

- For benefit-cost ranking, B/C ratio > 5 is a 1, B/C ratio > 4 is a 2, B/C ratio > 2 is a 3, and B/C ratio > 1 is a 4.
- For congestion importance ranking, each site was graded with a score—primary congestion site = 1, median site = 2, and every secondary site = 3.
- For relative difficulty of design, each site was scored—low design difficulty site = 1, medium-low difficulty design = 2, medium difficulty design = 3, and high difficulty design = 4. The lowest overall score is the highest ranking.
- Each site was given a score of 1 if there is no conflict with a STIP project, a score of 2 if there was a potential conflict, and a score of 3 if there is a definite conflict with a STIP project.

The following table presents those results in the order of recommended implementation.

Recommended Order of Implementation

Log	Freeway	Cross Street	Exit	Direction	F2F?	TIP Conflict	Congestion Location	Design Difficulty	Ramp Meter Configuration	Location Notes	TIP Conflict	B/C Ranking	Congestion ranking	Design Difficulty	Total Score	Ranking
017	I-40	S Miami Blvd	281	EB	No	No	primary	Low	Single Lane	downstream	1	1	1	1	4	1
095	I-440	SR 1012 - Western Blvd	2	SB-M2 (EB to SB)	No	No	primary	Low	Single Lane	downstream	1	1	1	1	4	1
102	I-440	Lake Boone Trail	5	NB	No	No	primary	Low	Single Lane	downstream	1	2	1	1	5	2
135	I-540	SR 1829 - Leesville Rd	7	EB	No	No	solo site	Low	Single Lane	downstream	1	2	1	1	5	2
028	I-40	SR 1002 - Aviation Pkwy	285	EB-M2 (NB to EB)	No	No	primary	Low	Single Lane	downstream	1	3	1	1	6	3
030	I-40	SR 1652 - N Harrison Ave	287	EB	No	No	secondary	Low	Single Lane	upstream of 019	1	1	3	1	6	3
108	I-440	US-70 / NC-50 / Glenwood Ave	7	WB-M2 (SB to WB)	No	No	secondary	Low	Single Lane	upstream of 019 and 017	1	1	3	1	6	3
009	I-40	NC-55 / Apex Hwy	278	EB	No	No	secondary	Low	Single Lane Loop	(F2F) and 011 (unsuitable)	1	2	3	1	7	4
010	I-40	NC-55 / Apex Hwy	278	WB	No	No	secondary	Low	Single Lane	upstream of 028	1	2	3	1	7	4
019	I-40	Page Rd	282	EB	No	No	secondary	Medium	Two Lane Loop	upstream of F2F one and non-suitable one	1	1	3	3	8	5
027	I-40	SR 1002 - Aviation Pkwy	285	EB-M1 (SB to EB)	No	No	secondary	Low	Single Lane Loop	upstream of 028	1	3	3	1	8	5
056	I-40	SR 5220 - Jones Sausage Rd	303	WB	No	Potential	secondary	Low	Single Lane	TIP Conflict	2	2	3	1	8	5
002	I-40	US-15 / US-501	270	WB	No	No	secondary	Low	Single Lane	upstream of non-suitable site 104	1	4	3	1	9	6
015	I-40	Davis Dr	280	EB	No	No	secondary	Medium-Low	Two Lane	upstream of 019 and 017	1	3	3	2	9	6

For sites 015 and 019 the ramp meter would be two lanes and would include some ramp widening.

NCDOT might not deploy ramp metering projects in the order that they are ranked, due to other considerations and constraints.

Marketing and Outreach

The key to success in the deployment of new technology such as ramp metering is the successful education of the various constituent groups in the goals and the benefits of ramp metering. Based upon the significant database built up from multiple ramp metering deployments, both nationally and worldwide, issues with ramp metering focus on two principal areas of concern:

- Concern that ramp meters will back up traffic onto crossing arterials, impacting the operation of these facilities.
- Concern that motorists will take another route to avoid ramp metering sites.
- Perception from the public that ramp meters are going to unfairly increase their trip time.

The overall approach to these concerns is similar, to present the benefits and dispel the myths of ramp metering. The method of engaging groups with these concerns is different in both the content and amount of detail, because the important issues and the technical knowledge of each stakeholder group is not the same.

From research and discussions with other agencies that have ramp meter deployments, public support of ramp meters is essential for a successful implementation. Opposition toward ramp metering usually stems from public perception that delays increase due to ramp metering implementation, while their associated benefits may not be obvious. There is also a perception that ramp meters may contribute to increased rear-end accidents due to cars stopped on the ramp. Local agencies tend to perceive the ramp meters will back up traffic and degrade traffic flow on their crossing arterial roadway.

Agencies operating ramp meters have altered these perceptions through focused public communications and involvement. By proactively disseminating information to the public, these agencies are demonstrating the benefits ramp metering can offer: lower and more reliable trip times, reduced congestion, and increased peak period speeds. A marketing and outreach plan must be tailored to address the concerns of the following constituent groups that have respective interests in the proposed project:

- Technical staff – Engineers, planners, transit agency staff, and related management,
- Law enforcement/emergency responders – Principally, the NC State Highway Patrol, city police, county sheriffs, local fire and rescue personnel,
- Public officials – Appointed and elected citizens on the NCDOT Board of Transportation, Metropolitan Planning Organization officials and local government elected officials,
- General public – End users of the ramp meters, community leaders, and
- Media

It is important to reach out to constituents who may be both proponents and opponents of ramp meters. Many concerns can be addressed in the implementation of ramp meter

strategies—often these concerns are products of misinformation or misunderstanding and can be resolved.

The marketing and outreach report described the appropriate materials and techniques for such a campaign with the understanding there are different target audiences with different interests and concerns. The recommended approach included the following:

- Brochures, flyers, and/or newsletters,
- Website,
- Videos and simulations,
- Open house meetings
- Inter-agency and public officials’ meetings,
- Media releases,
- Automated messages,
- Signs, and
- Social Media (e.g. Facebook, Twitter, Pinterest, Instagram).

From the above marketing and outreach resources, certain materials can be designed to serve each constituent group. The table below depicts the recommended and appropriate resources for each group. For each constituent group, there are particular marketing and outreach materials that are more effective and more appropriate. As an example, it is more effective to use brochures, flyers, and newsletters, and websites for the general public than it is for public officials, local transportation agency law enforcement and emergency responder staff. A “P” indicates a primary communications media for that constituent group. An “S” indicates a secondary communications media for that constituent group.

Constituent Group Recommendations

Resource	Local Transportation Agencies	Law Enforcement and Emergency Responders	General Public	Public Officials
Brochures, Flyers, and Newsletters	S	S	P	S
Websites	S	S	P	S
Videos and Simulations	P	P	P	S
Open House Meetings			P	S
Inter-Agency and Public Officials’ Meetings	P	P		P
Media Releases	S	S	P	S
Automated Messages			P	
Social Media			P	S

The process of marketing and outreach should begin before funding is secured for the first project. For local transportation agencies, law enforcement and emergency responders, and public officials, marketing and outreach should begin prior to the approval of funding, when the projects are being reviewed for inclusion in state and MPO TIPs.

Ideally, the marketing and outreach program for the general public should begin one year prior to implementation. It should continue through design and after implementation, and until first installations can be evaluated.

RAMP METERING FEASIBILITY STUDY

N.C. Project No. M-0446 Durham and Wake Counties



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