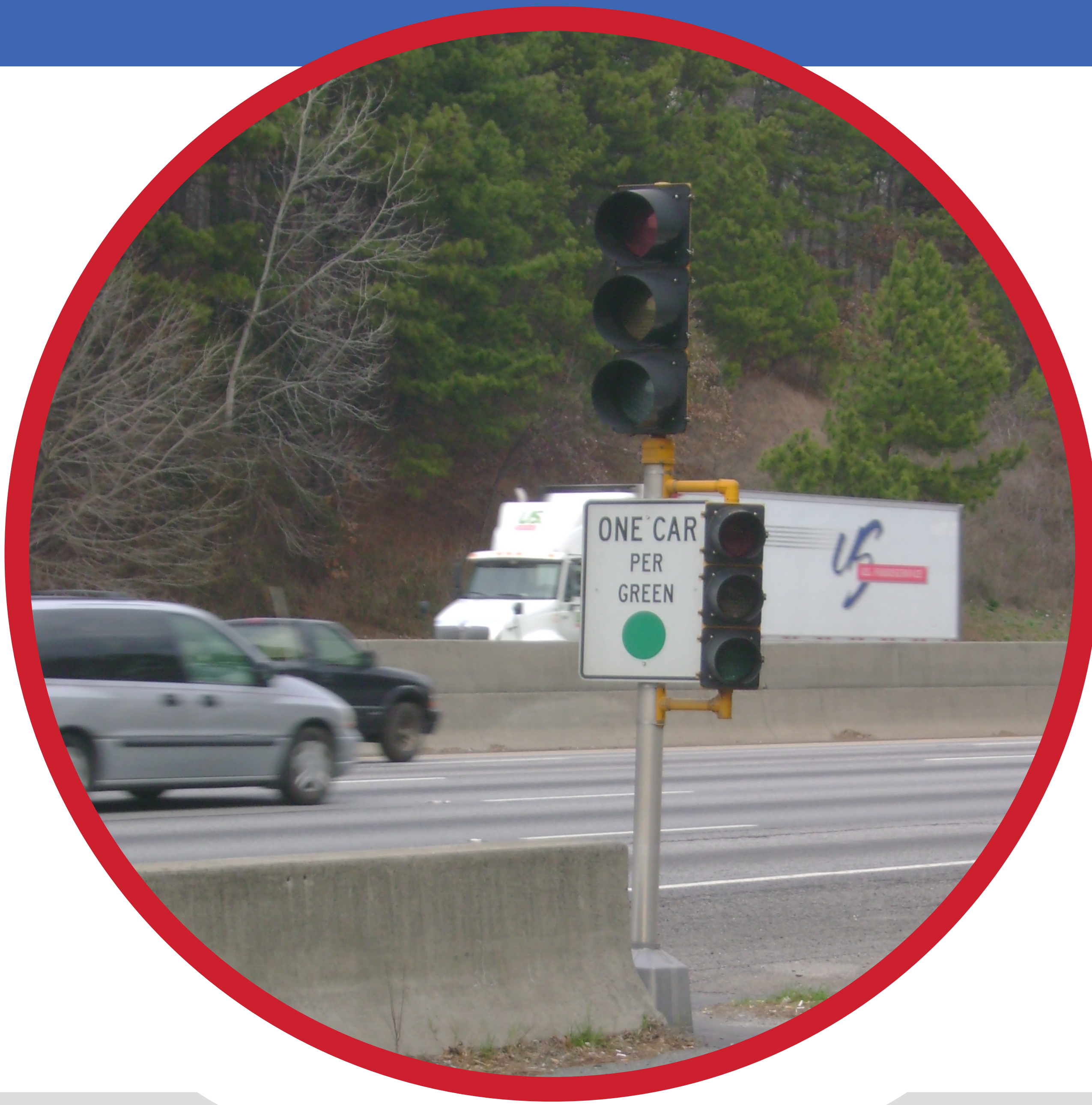
Performance Measures



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

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1. Introduction

This report outlines the process which established the likely performance of those sites that were identified as either “feasible for the introduction of ramp metering” or “to be reviewed in future” during the Detailed Analysis Task of the NCDOT Ramp Metering Feasibility Study.

The sites selected during the Detailed Analysis Task are those where ramp metering is expected to operate effectively, based on an analysis of traffic volumes and the sites’ geometric characteristics. Establishing the performance of these sites is part of the next stage of the process, to determine whether ramp metering would provide sufficient benefits to make installation financially viable. This work is accomplished in the following tasks:

- Task 9, Performances Measures (this report), identifies the performance measures to be used and calculates the estimated benefits;
- Task 10, Implementation Plan, will summarize the relative benefit-cost ratios of each site for prioritizing sites for the “Implementation Plan”.

Table 1 shows performance measures which are often used to justify transportation projects, and the reasons for including them or not in this analysis.

Table 1. Justification for Performance Measures

Measure	Used in Analysis?	Reasons
Reduction In Delay (Vehicle Hours)	Yes	This is the most significant benefit provided by ramp metering. Delays can be estimated from existing traffic data and clear proof for reduction in delay is available from the evaluation of previous ramp metering projects.
Trip Reliability	No	Ramp metering is likely to reduce congestion, which should improve travel time reliability (i.e. reduce the variability or range of travel speeds and travel time). Trip reliability is frequently measured mathematically as the change in the standard deviation of travel speed or travel time. However, it is difficult to predict what this impact will be. The economic benefits will be relatively small compared to delay reductions. There is less evidence from previous projects of the possible impact.
Crash Reduction	No	From before and after evaluations, there is evidence from other implementations that ramp metering does significantly reduce crashes. However, crash reduction is not typically used as a justification for implementing ramp metering without a detailed study of the crash history.
Air Emissions	No	Air emissions consist of carbon dioxide (CO^2), carbon monoxide (CO), methane (CH^4), nitrous oxide (N^2O), and hydro fluorocarbon (HFC).

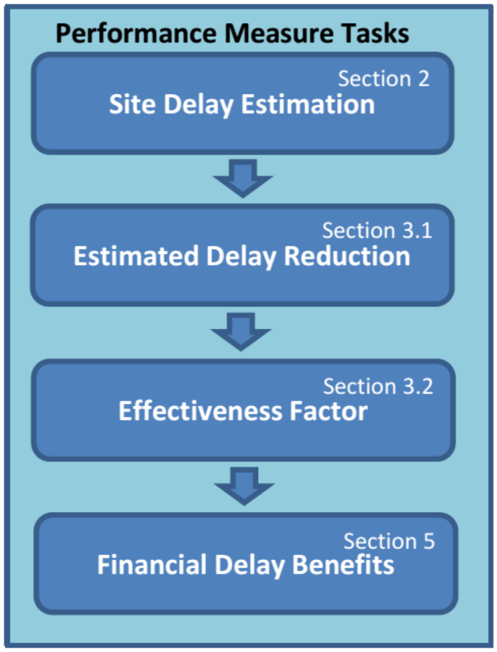
Measure	Used in Analysis?	Reasons
		Carbon dioxide is the major source of air emission and is approximately 95-99% of the total air emissions from vehicles. Carbon monoxide, methane, and nitrous oxide emissions are low relative to the carbon dioxide emissions but they are more potent than carbon dioxide. Hydro fluorocarbon emissions occur largely from leaking air conditioners. Carbon dioxide emission rates are based upon gallons of fuel consumed. The Environmental Protection Agency estimates carbon dioxide emissions rates of 8,887 grams/gallon of fuel. An improvement such as a ramp meter can improve the average travel speed and as result reduces the fuel consumption rate. This in turn reduces the carbon dioxide emissions. Emission rates of methane and nitrous oxide are based upon vehicles miles travelled and not fuel consumption. Similar to travel time reliability, reducing congestion should lead to improved emissions. Estimating carbon dioxide emissions or vehicle miles travelled for the other emissions with and without improvements requires a modelling process.

While all the benefits listed in Table 1 are likely to be achieved from the installation of Ramp Metering, reduction in delay and crash reduction are the critical measures in the justification of ramp metering. For the purposes of this project, only financial benefits due to reduced delays will be quantified for each site. The benefits of crash reduction will be discussed in terms of the expected decrease in accidents for the project as a whole.

As shown in Figure 1 below, this report covers the following:

- Method used to estimate delay at each site;
- Method used to estimate reduction in delay due to the installation of ramp metering;
- Method used to estimate secondary benefits due to crash reduction;
- Effectiveness Factor;
- Calculation of financial benefits due to delay;
- Summary results; and
- Conclusions.

Figure 1. Flowchart of Performance Measure Methodology



2. Delay Estimation per Site

The Task 4 - Screening and Data Analysis report estimated delay using the congestion data from the VPP Suite administered by the University of Maryland CATT Lab. The VPP suite consists of a number of congestion analysis tools based on probe vehicle data. The Bottleneck Ranking Application was used to identify congestion in the study area.

Delay was estimated by analyzing data from the bottleneck ranking tool. The bottleneck ranking tool was used in Task 2.1 to identify significant regular congestion. For each site, the following data was calculated:

- Average duration of congestion;
- Average maximum queue length; and
- Number of occurrences per year.

Hourly traffic volumes for each site were collected during the Screening and Data Analysis task.

Using these values in combination, it is possible to estimate the annual delay caused by congestion at each site, see Figure 2.

Figure 2. Calculation of Total Annual Delay

$$\begin{matrix} Total\ Annual\ Delay \\ (VHD) \end{matrix} =$$

$$= \underbrace{\begin{matrix} Delay\ per\ vehicle \\ per\ mile\ (1) \end{matrix} \times \begin{matrix} Average\ max \\ queue\ length \end{matrix}}_{Delay\ per\ vehicle\ (2)} \times \underbrace{\begin{matrix} Flow \\ rate \end{matrix} \times \begin{matrix} Average \\ duration \end{matrix}}_{\begin{matrix} Number\ of \\ vehicles\ affected\ (3) \end{matrix}} \times \begin{matrix} Number\ of\ occurrences \\ per\ year\ (4) \end{matrix}$$

1. The delay for each vehicle traveling through congestion is equal to the time it would take at free flow speed minus the time it would take at congested speed; the free flow speed is assumed to be the speed limit at each site (varying between 55 mph and 70 mph) and the congested speed is 30 mph.
2. The delay per vehicle per mile is multiplied by the average maximum queue length to obtain the delay per vehicle.
3. The delay per vehicle is multiplied by the number of vehicles affected (which is based on average duration and the volumes during the hours of congestion) to obtain the total delay.
4. The resulting delay per congested period is then multiplied by the number of occurrences, to obtain the total annual delay, in vehicle hours.

Automated traffic counts over a long period were not available for this project. Therefore counts were collected manually at each potential site over a period of two days. This is less robust than having long term averaged traffic data. However, the traffic data collection effort needed to be proportionate to the scale and stage of the analysis being performed, obtaining sufficient information at a reasonable cost. The fact that the volumes from the two days were relatively similar for all sites provides the confidence that the data are sufficiently robust for use in this analysis.

3. Estimate of the Reduction in Delay

The estimate of reduction in delay which might be achieved by ramp metering was based on two factors:

1. An "Expected Delay Reduction" value which was determined based on the results from evaluations of previous ramp metering installations.
2. An 'Effectiveness Factor" for each site which makes allowance for sites where the benefits achieved might be lower than previous evaluation averages due to site-specific characteristics.

The "Expected Delay Reduction" is discussed in section 3.1 and the "Effectiveness Factor" is discussed in section 3.2.

3.1. Expected Delay Reduction

In the National Research task, evaluation results of various ramp metering installations were obtained and these have been reviewed to determine an expected delay reduction value due to the use of ramp metering at a site. Not all of the evaluation results were in a useful format for this purpose, but the following assumptions have been made:

Table 2. Evaluation Results for Delay Reductions

<table>
<tr><th>Evaluation Result</th><th>Assumptions</th><th>Delay Reduction Value Assumed for this Study</th></tr>
<tr><td>Atlanta, GA – 10% decrease in travel time</td><td rowspan="3">Travel time = free flow travel time + delay time
Travel time reductions cannot be directly related to delay times but an approximation is that, if times are measured along the congested stretch:
Delay time reduction ≈ 2x travel time reduction.</td><td>20%</td></tr>
<tr><td>Houston, TX – 22% decrease in travel time</td><td>44%</td></tr>
<tr><td>Arlington, Va. – 10% decrease in travel time</td><td>20%</td></tr>
<tr><td>Minneapolis, MN – 22% decrease in delay time</td><td></td><td>22%</td></tr>
<tr><td>Madison, WI – 21% decrease in delay time</td><td></td><td>21%</td></tr>
<tr><td>Sacramento, CA – 50% decrease in driver hours</td><td>Driver hours is the same as travel time. Using above assumptions, a 50% decrease in travel time equates to 100% decrease in delay time, i.e. delay time is reduced to zero.
This approximation is too high so this result has been ignored for this study.</td><td>N/A</td></tr>
<tr><td>Los Angeles, CA – 8,470 hours saved per day</td><td>This is not a percentage reduction so cannot be related to our study.</td><td>N/A</td></tr>
</table>

Based on the data shown above, the delay reductions of previous ramp metering alternatives range between approximately 20 and 44%. The modal (most common) and median (50th percentile) averages of these results are 20% and 21% respectively, while the mean is 25%.

For the previous Ramp Metering Feasibility Study for Durham and Wake Counties, conservative figures for the reduction in delay of 20% were used in calculating the performance measures. The Metrolina Ramp Metering Steering Committee agreed that these figures should be used again for this study to maintain consistency.

We have therefore calculated the performance measures assuming delay reductions of approximately 20% could be obtained, but we have also performed sensitivity analysis using low, medium, and high projections of “Expected Delay Reduction”; these are 10%, 15%, and 20% respectively.

3.2. Effectiveness Factor

There are some sites which, although identified as suitable, might achieve lower than average benefits, for example some secondary sites and some sites with awkward geometry. All sites have been reviewed to identify an “Effectiveness Factor,” which is the percentage of the “Expected Delay Reduction” they would be expected to achieve.

Sites where no significant issues have been identified have an Effectiveness Factor of 100%, or 1 as a fraction. The sites with a lower Effectiveness Factor are shown in Table 3, with an explanation.

For each site, the expected delay reductions have been calculated by multiplying the Expected Delay Reduction and the Effectiveness Factor.

Table 3. Justification for Lower Effectiveness Factors

Log	Freeway	Cross Street	Exit	Direction	Effectiveness Factor	Reason	Detailed Analysis Category
030	I-85	Cox Rd	21	NB	0.50	This site is a secondary site to congestion problem M005. The downstream primary site for M005, site 034, is only partially effective due to low ramp volumes and this is expected to reduce the effectiveness of this site to manage the congestion problem. Combined with low ramp volumes reducing the benefits, the effective factor has been reduced by 50%.	Review in Future
032	I-85	S Main St	22	NB	0.75	This site is a secondary site to congestion problem M005. The downstream primary site for M005, site 034, is only partially effective due to low ramp volumes and this is expected to reduce the effectiveness of this site to manage the congestion problem. Therefore the effectiveness factor has been reduced by 25%.	Feasible
034	I-85	McAdenville Rd	23	NB	0.50	This site is a primary site to congestion problem M005. Ramp volumes are only acceptable during 1 of the 2 hours of congestion, significantly reducing the expected benefits of this site. Therefore the effectiveness factor has been reduced by 50%.	Feasible
035	I-85	Belmont-Mt. Holly Rd	26	SB	0.75	This site is a primary site to congestion problem M006 and a secondary site to congestion problem M004. The downstream primary site for M004 is not suitable for ramp metering. Whilst this site would be effective for M006, it would only be effective during the latter part of M004. Therefore the effectiveness factor has been reduced by 25%.	Feasible
037	I-85	Beatty Dr / Park St	27	SB	0.50	This site is a secondary site to congestion problems M004 and M006. The downstream primary site for M004 is not suitable for ramp metering. This site would only be effective during the latter part of M004. Combined with low ramp volumes reducing the benefits, the effective factor has been reduced by 50%.	Review in Future
064	I-85	Graham St	40	SB	0.50	This site is a primary site to congestion problem M009 and a secondary site to congestion problem M008. The downstream primary site for M008 is not suitable for ramp metering. This site would only be effective during the latter part of M008. Additionally, the ramp is short and curved with storage for approx. 27 vehicles. Therefore the benefits are expected to be reduced and the effectiveness factor has been reduced by 50%.	Feasible

Log	Freeway	Cross Street	Exit	Direction	Effectiveness Factor	Reason	Detailed Analysis Category
072	I-85	Harris Blvd	45	SB	0.50	This site is a secondary site to congestion problem M012. The three sites downstream within the extents of M012 are not suitable for ramp metering. This site would only be effective during the latter part of congestion problem M012. Therefore the effectiveness factor has been reduced by 50%.	Feasible
097	I-77	I-485	1B	SB	0.25	This F2F site was categorized as “not feasible” during the Detailed Analysis Task, but has been included at the request of the Steering Committee. This site is a secondary site to congestion problem M020. Ramp volumes are too high for 1½ hours of the 2 hours of congestion, considerably reducing the expected benefits of this site. Therefore the effectiveness factor has been reduced by 75%.	Not Feasible
101	I-77	Arrowood Rd	3	NB	0.75	This site is a primary site to congestion problem M024 and a secondary site to congestion problems M028, M026 and M025. There are no suitable ramp metering sites downstream. Whilst this site would be effective for M024, it would only be effective during the latter part of M028, M026 and M025. Therefore the effectiveness factor has been reduced by 25%.	Feasible
103	I-77	Nations Ford Rd	4	NB	0.75	This site is a primary site to congestion problem M022 and a secondary site to congestion problems M028, M025 and M024. There are no suitable ramp metering sites downstream within the extents of M028 or M025. Whilst this site would be effective for M024 and M022, it would only be effective during the latter part of M028 and M025. Therefore the effectiveness factor has been reduced by 25%.	Feasible
105	I-77	Tyvola Rd	5	NB	0.75	This site is a secondary site to congestion problems M028, M025, M024 and M022. There are no suitable ramp metering sites downstream within the extents of M028 or M025. Whilst this site would be effective for M024 and M022, it would only be effective during the latter part of M028 and M025. Therefore the effectiveness factor has been reduced by 25%.	Feasible
140	I-77	Gilead Rd	23	NB	0.75	This site is a primary site to congestion problem M033 and a secondary site to congestion problems M038 and M035. Since the times of congestion vary on a daily basis the system will be difficult to calibrate effectively. Therefore the effectiveness factor has been reduced by 25%.	Feasible

Log	Freeway	Cross Street	Exit	Direction	Effectiveness Factor	Reason	Detailed Analysis Category
143	I-77	NC 73 (Sam Furr Rd)	25	NB	0.75	This site is a primary site to congestion problem M035 and a secondary site to congestion problems M038 and M036. Since the times of congestion vary on a daily basis the system will be difficult to calibrate effectively. Therefore the effectiveness factor has been reduced by 25%.	Feasible
145	I-77	US 21 (Catawba Ave)	28	NB	0.75	This site is a primary site to congestion problem M036 and a secondary site to congestion problem M038. Since the times of congestion vary on a daily basis the system will be difficult to calibrate effectively. Therefore the effectiveness factor has been reduced by 25%.	Feasible
147	I-77	Goodrum Rd / Griffith St	30	NB	0.25	This site is a primary site to congestion problem M038. Ramp volumes are only acceptable during 2 of the 9.5 hours of congestion, considerably reducing the expected benefits of this site. Therefore the effectiveness factor has been reduced by 75%.	Feasible
175	I-485	Arrowood Rd	3	Inner	0.75	This site is a secondary site to congestion problem M049. The downstream sites (sites 179 and 177) are not fully effective, and this is likely to slightly reduce the benefits expected at this site. Therefore the effectiveness factor has been reduced by 25%.	Review in Future
177	I-485	Steele Creek Rd	4	Inner	0.75	This site is a secondary site to congestion problem M049. The ramp is short and curved with storage for approx. 41 vehicles. Therefore the benefits are expected to be slightly reduced. Due to this slight reduction in the site's ability to process entrance ramp traffic the effectiveness factor has been reduced by 25%.	Feasible
179	I-485	Steele Creek Rd	4	Inner	0.75	This site is a primary site to congestion problem M049. Ramp volumes are only acceptable during the first 1½ hours of congestion (out of 2 hours total). Consequently, this site would only be effective during the first part of M049. Therefore the effectiveness factor has been reduced by 25%.	Feasible
229	I-485	E John St	52	Inner	0.75	This site is a secondary site to congestion problem M052. Low ramp volumes are likely to reduce the benefits expected at this site. Therefore the effectiveness factor has been reduced by 25%.	Review in Future
231	I-485	NC 16 (Providence Rd)	57	Inner	0.75	This site is a secondary site to congestion problems M054 and M052. The ramp is short and curved with storage for approx. 24 vehicles. Therefore the benefits are expected to be slightly reduced. Due to this slight reduction in the site's ability to process entrance ramp traffic the effectiveness factor has been reduced by 25%.	Feasible

Log	Freeway	Cross Street	Exit	Direction	Effectiveness Factor	Reason	Detailed Analysis Category
232	I-485	NC 16 (Providence Rd)	57	Outer	0.75	This site is a secondary site to congestion problem M051. The ramp is short and curved with storage for approx. 25 vehicles. Therefore, the benefits are expected to be slightly reduced. Due to this slight reduction in the site's ability to process entrance ramp traffic the effectiveness factor has been reduced by 25%.	Feasible
236	I-485	Rea Rd	59	Inner	0.75	This site is a secondary site to congestion problem M054. The ramp is short and curved with storage for approx. 30 vehicles. Therefore the benefits are expected to be slightly reduced. Due to this slight reduction in the site's ability to process entrance ramp traffic the effectiveness factor has been reduced by 25%.	Feasible
237	I-485	Rea Rd	59	Inner	0.75	This site is a primary site to congestion problem M054. Ramp volumes are only acceptable during the first 2 hours of congestion (out of 3 hours total). Consequently, this site would only be effective during the first part of M054. Therefore the effectiveness factor has been reduced by 25%.	Feasible
239	I-485	US 521 (Johnston Rd)	61	Outer	0.50	This site is a secondary site to congestion problems M051, M053 and M055. The downstream primary site for M055 is not suitable for ramp metering. This site would only be effective during the latter part of M055. Additionally, the ramp is short and curved with storage for approx. 28 vehicles. Therefore, the benefits are expected to be reduced and the effectiveness factor has been reduced by 50%.	Feasible
250	US-74	Briar Creek Road/ Television Lane	244	WB	0.00	This site does not meet the typical design criteria for ramp metering sites but it has been included at the request of the Steering Committee. This site is a primary site to congestion problem M058. Ramp volumes are too low for metering to provide any benefits. Therefore the effectiveness factor has been reduced to 0 to reflect that this site is not expected to provide any benefits.	Review in Future

4. Secondary Benefits due to Crash Reduction

NCDOT provided crash data by accident type, time of day and severity that was narrowly defined as either on the ramp or on the mainline, 0.03 miles downstream or 0.02 miles upstream of the ramp gore. Two accident types are potentially correctable based upon evaluations of other ramp metering deployments: rear end (Type 21) and sideswipe, same direction (Type 28).

Based upon the national evaluation studies shown in Table 4 below, there is an expected national average crash reduction of 31% for rear end and sideswipe crashes. An equivalent level of crash reduction can therefore be expected on this project.

Table 4. Evaluation Results for Secondary Crash Benefits

Evaluation Result	Crash Reduction
Detroit, MI	50%
Kansas City KS/MO Scout	26% to 50%
Los Angeles, CA	20%
Minneapolis, MN	26%
Milwaukee, WI	16%
New York INFORM	15%
Portland, OR	43%
Seattle, WA	38%

5. Financial Benefits

The value of time due to delay is based upon the Texas A&M Transportation Institute (TTI) 2015 Urban Mobility Report. In this report, the monetary delay per person was calculated as $17.67 per hour. This rate can be converted to a value of time per passenger vehicle by applying an average vehicle occupancy rate of 1.25, giving a value of $22.09 per hour. This value converts the expected reduction in passenger vehicle delay into financial terms. The same TTI report estimated the average cost of delay per truck for all types of commercial vehicles to be $94.04 per hour.

From historical traffic classification counts, one can weight the delay based upon the distribution of passenger and commercial vehicles.

$$\begin{matrix} Weighted \\ Delay\ per\ Vehicle \end{matrix} = (\$22.09 \times Passenger\ Vehicle\ \%) + (\$94.04 \times Truck\ \%)$$

As an example, if the count data shows that 90% of the traffic volume is passenger vehicles then the weighted delay per vehicle would be:

$$Weighted\ Delay\ per\ Vehicle\ =\ \$22.09\ x\ 0.9 +\ \$94.04\ x\ 0.1 =\ \$29.28\ per\ hour$$

The results are presented per site showing reduction in delay and the monetary benefit for the low, medium, and high projections.

The reduction in delay at each of the sites, sorted by log number, can be seen in Table 5. The monetary value of the reduction in delay at each of the sites, sorted by log number, is shown in Table 6 using the following equation.

$$\begin{matrix} Reduction \\ in\ Delay \end{matrix} = \begin{matrix} Annual\ Reduction \\ in\ Delay \end{matrix} \times \begin{matrix} Expected\ Annual \\ Delay \end{matrix} \times \begin{matrix} Effectiveness \\ Factor \end{matrix}$$

$$\begin{matrix} Cost \\ Benefit\ (\$) \end{matrix} = \begin{matrix} Weighted \\ Delay\ per\ Vehicle \end{matrix} \times \begin{matrix} Reduction \\ In\ Delay \end{matrix}$$

Notes to Table 5 and Table 6:

1. Site 97: this site is an F2F site that was categorized as “not feasible” during the Detailed Analysis Task but has been included at the request of the Steering Committee.
2. Site 182: the traffic volumes for this site still need to be ascertained, but it has been assumed that this site meets the acceptable flow criteria for ramp metering sites.
3. Site 250: this site does not meet the typical design criteria for ramp metering sites but it has been included at the request of the Steering Committee.

Table 5. Reduction in Vehicle Hours Delayed

Log	Freeway	Cross Street	Exit	Direction	County	Expected Annual Delay (VHD) (See Section 2)	Effectiveness Factor (See Section 3.2)	Annual Reduction in Delay (VHD) (See Section 3)			Detailed Analysis Category
								10% Delay Reduction	15% Delay Reduction	20% Delay Reduction	
030	I-85	Cox Rd	21	NB	Gaston	3,125	0.50	156	234	313	Review in Future
032	I-85	S Main St	22	NB	Gaston	35,097	0.75	2,632	3,948	5,265	Feasible
034	I-85	McAdenville Rd	23	NB	Gaston	63,635	0.50	3,182	4,773	6,363	Feasible
035	I-85	Belmont-Mt. Holly Rd	26	SB	Gaston	151,056	0.75	11,329	16,994	22,658	Feasible
037	I-85	Beatty Dr / Park St	27	SB	Gaston	84,862	0.50	4,243	6,365	8,486	Review in Future
064	I-85	Graham St	40	SB	Mecklenburg	69,672	0.50	3,484	5,225	6,967	Feasible
067	I-85	Sugar Creek Rd	41	NB	Mecklenburg	167,752	1.00	16,775	25,163	33,550	Feasible
072	I-85	Harris Blvd	45	SB	Mecklenburg	6,231	0.50	312	467	623	Feasible
075	I-85	Mallard Creek Rd	46	NB	Mecklenburg	13,029	1.00	1,303	1,954	2,606	Feasible
093	I-77	Westinghouse Blvd	1A	SB	Mecklenburg	731,276	1.00	73,128	109,691	146,255	Feasible
097	I-77	I-485	1B	SB	Mecklenburg	417,672	0.25	10,442	15,663	20,884	Not feasible
101	I-77	Arrowood Rd	3	NB	Mecklenburg	62,216	0.75	4,666	6,999	9,332	Feasible
102	I-77	Nations Ford Rd	4	SB	Mecklenburg	375,406	1.00	37,541	56,311	75,081	Feasible
103	I-77	Nations Ford Rd	4	NB	Mecklenburg	110,865	0.75	8,315	12,472	16,630	Feasible
104	I-77	Tyvola Rd	5	SB	Mecklenburg	280,916	1.00	28,092	42,137	56,183	Review in Future
105	I-77	Tyvola Rd	5	NB	Mecklenburg	408,032	0.75	30,602	45,904	61,205	Feasible
111	I-77	Remount Rd	8	SB	Mecklenburg	239,312	1.00	23,931	35,897	47,862	Feasible
129	I-77	I-85 SB	13	NB	Mecklenburg	931,565	1.00	93,157	139,735	186,313	Feasible
140	I-77	Gilead Rd	23	NB	Mecklenburg	44,511	0.75	3,338	5,008	6,677	Feasible
143	I-77	NC 73 (Sam Furr Rd)	25	NB	Mecklenburg	231,937	0.75	17,395	26,093	34,791	Feasible

Log	Freeway	Cross Street	Exit	Direction	County	Expected Annual Delay (VHD) (See Section 2)	Effectiveness Factor (See Section 3.2)	Annual Reduction in Delay (VHD) (See Section 3)			Detailed Analysis Category
								10% Delay Reduction	15% Delay Reduction	20% Delay Reduction	
145	I-77	US 21 (Catawba Ave)	28	NB	Mecklenburg	557,052	0.75	41,779	62,668	83,558	Feasible
146	I-77	Goodrum Rd / Griffith St	30	SB	Mecklenburg	29,146	1.00	2,915	4,372	5,829	Feasible
147	I-77	Goodrum Rd / Griffith St	30	NB	Mecklenburg	971,611	0.25	24,290	36,435	48,581	Feasible
175	I-485	Arrowood Rd	3	Inner	Mecklenburg	16,835	0.75	1,263	1,894	2,525	Review in Future
177	I-485	Steele Creek Rd	4	Inner	Mecklenburg	55,819	0.75	4,186	6,280	8,373	Feasible
179	I-485	Steele Creek Rd	4	Inner	Mecklenburg	83,547	0.75	6,266	9,399	12,532	Feasible
181	I-485	West Blvd	6	Inner	Mecklenburg	12,571	1.00	1,257	1,886	2,514	Feasible
182	I-485	US 74 / US 29 (Wilkinson Blvd)	9	Outer	Mecklenburg	17,784	1.00	1,778	2,668	3,557	Review in Future
229	I-485	E John St	52	Inner	Mecklenburg	10,009	0.75	751	1,126	1,501	Review in Future
230	I-485	NC 16 (Providence Rd)	57	Outer	Mecklenburg	168,910	1.00	16,891	25,337	33,782	Feasible
231	I-485	NC 16 (Providence Rd)	57	Inner	Mecklenburg	144,674	0.75	10,851	16,276	21,701	Feasible
232	I-485	NC 16 (Providence Rd)	57	Outer	Mecklenburg	141,693	0.75	10,627	15,940	21,254	Feasible
233	I-485	NC 16 (Providence Rd)	57	Inner	Mecklenburg	189,988	1.00	18,999	28,498	37,998	Feasible
234	I-485	Rea Rd	59	Outer	Mecklenburg	154,499	1.00	15,450	23,175	30,900	Feasible
236	I-485	Rea Rd	59	Inner	Mecklenburg	118,345	0.75	8,876	13,314	17,752	Feasible
237	I-485	Rea Rd	59	Inner	Mecklenburg	95,152	0.75	7,136	10,705	14,273	Feasible
239	I-485	US 521 (Johnston Rd)	61	Outer	Mecklenburg	46,948	0.50	2,347	3,521	4,695	Feasible
250	US-74	Briar Creek Road/Television Lane	244	WB	Mecklenburg	75,605	0.00	0	0	0	Review in Future

Table 6. Financial Benefits Due to Delay Reduction

Log	Freeway	Cross Street	Exit	Direction	County	Effectiveness Factor (See Section 3.2)	Percent Trucks (See Section 5)	Annual Financial Benefit (See Section 5)			Detailed Analysis Category
								10% Delay Reduction	15% Delay Reduction	20% Delay Reduction	
030	I-85	Cox Rd	21	NB	Gaston	0.50	11%	$4,714	$7,072	$9,429	Review in Future
032	I-85	S Main St	22	NB	Gaston	0.75	13%	$83,321	$124,982	$166,642	Feasible
034	I-85	McAdenville Rd	23	NB	Gaston	0.50	24%	$124,763	$187,145	$249,527	Feasible
035	I-85	Belmont-Mt. Holly Rd	26	SB	Gaston	0.75	14%	$368,419	$552,628	$736,837	Feasible
037	I-85	Beatty Dr / Park St	27	SB	Gaston	0.50	16%	$141,516	$212,274	$283,032	Review in Future
064	I-85	Graham St	40	SB	Mecklenburg	0.50	9%	$99,353	$149,029	$198,706	Feasible
067	I-85	Sugar Creek Rd	41	NB	Mecklenburg	1.00	10%	$485,800	$728,700	$971,600	Feasible
072	I-85	Harris Blvd	45	SB	Mecklenburg	0.50	7%	$8,395	$12,593	$16,791	Feasible
075	I-85	Mallard Creek Rd	46	NB	Mecklenburg	1.00	10%	$38,000	$57,000	$76,001	Feasible
093	I-77	Westinghouse Blvd	1A	SB	Mecklenburg	1.00	10%	$2,119,960	$3,179,941	$4,239,921	Feasible
097	I-77	I-485	1B	SB	Mecklenburg	0.25	6%	$276,861	$415,292	$553,722	Not feasible
101	I-77	Arrowood Rd	3	NB	Mecklenburg	0.75	14%	$151,190	$226,785	$302,380	Feasible
102	I-77	Nations Ford Rd	4	SB	Mecklenburg	1.00	18%	$1,313,006	$1,969,509	$2,626,012	Feasible
103	I-77	Nations Ford Rd	4	NB	Mecklenburg	0.75	13%	$262,429	$393,643	$524,857	Feasible
104	I-77	Tyvola Rd	5	SB	Mecklenburg	1.00	11%	$837,355	$1,256,033	$1,674,711	Review in Future
105	I-77	Tyvola Rd	5	NB	Mecklenburg	0.75	23%	$1,182,071	$1,773,107	$2,364,142	Feasible
111	I-77	Remount Rd	8	SB	Mecklenburg	1.00	23%	$925,237	$1,387,855	$1,850,473	Feasible
129	I-77	I-85 SB	13	NB	Mecklenburg	1.00	5%	$2,375,113	$3,562,670	$4,750,227	Feasible
140	I-77	Gilead Rd	23	NB	Mecklenburg	0.75	20%	$121,952	$182,929	$243,905	Feasible

Log	Freeway	Cross Street	Exit	Direction	County	Effectiveness Factor (See Section 3.2)	Percent Trucks (See Section 5)	Annual Financial Benefit (See Section 5)			Detailed Analysis Category
								10% Delay Reduction	15% Delay Reduction	20% Delay Reduction	
143	I-77	NC 73 (Sam Furr Rd)	25	NB	Mecklenburg	0.75	11%	$519,278	$778,917	$1,038,556	Feasible
145	I-77	US 21 (Catawba Ave)	28	NB	Mecklenburg	0.75	13%	$1,302,305	$1,953,457	$2,604,610	Feasible
146	I-77	Goodrum Rd / Griffith St	30	SB	Mecklenburg	1.00	8%	$80,914	$121,371	$161,828	Feasible
147	I-77	Goodrum Rd / Griffith St	30	NB	Mecklenburg	0.25	9%	$701,433	$1,052,150	$1,402,867	Feasible
175	I-485	Arrowood Rd	3	Inner	Mecklenburg	0.75	6%	$33,671	$50,507	$67,343	Review in Future
177	I-485	Steele Creek Rd	4	Inner	Mecklenburg	0.75	9%	$119,276	$178,915	$238,553	Feasible
179	I-485	Steele Creek Rd	4	Inner	Mecklenburg	0.75	19%	$223,420	$335,130	$446,840	Feasible
181	I-485	West Blvd	6	Inner	Mecklenburg	1.00	6%	$32,803	$49,204	$65,606	Feasible
182	I-485	US 74 / US 29 (Wilkinson Blvd)	9	Outer	Mecklenburg	1.00	4%	$44,773	$67,160	$89,546	Review in Future
229	I-485	E John St	52	Inner	Mecklenburg	0.75	10%	$21,856	$32,784	$43,712	Review in Future
230	I-485	NC 16 (Providence Rd)	57	Outer	Mecklenburg	1.00	5%	$433,446	$650,169	$866,893	Feasible
231	I-485	NC 16 (Providence Rd)	57	Inner	Mecklenburg	0.75	11%	$322,338	$483,506	$644,675	Feasible
232	I-485	NC 16 (Providence Rd)	57	Outer	Mecklenburg	0.75	5%	$272,702	$409,053	$545,403	Feasible
233	I-485	NC 16 (Providence Rd)	57	Inner	Mecklenburg	1.00	3%	$465,945	$698,918	$931,891	Feasible
234	I-485	Rea Rd	59	Outer	Mecklenburg	1.00	7%	$416,939	$625,408	$833,878	Feasible
236	I-485	Rea Rd	59	Inner	Mecklenburg	0.75	8%	$249,653	$374,480	$499,306	Feasible
237	I-485	Rea Rd	59	Inner	Mecklenburg	0.75	6%	$190,070	$285,105	$380,141	Feasible
239	I-485	US 521 (Johnston Rd)	61	Outer	Mecklenburg	0.50	6%	$61,699	$92,548	$123,397	Feasible
250	US-74	Briar Creek Road/Television Lane	244	WB	Mecklenburg	0.00	25%	$0	$0	$0	Review in Future

6. Conclusions

The results of this analysis show a wide range of estimated annual financial savings due to delay reduction across the sites, from $9,429 to $4,750,227 per year for the 20% reduction scenario (excluding Site 250 that has no benefits – see Table 6). This demonstrates the importance of focusing on congestion and the potential benefits of reducing it when selecting ramp metering sites.

While the analysis has focused on reduction in delays (vehicles hours) and crashes, there will be other subjective and more minor quantitative benefits as a result of ramp metering installation, including more reliable trips, reduction in fuel consumption, and reduction in emissions.

These results indicate that a number of sites could have the ability to gain significant monetized benefits offsetting the cost of implementing ramp metering within a relatively short period.

The results for each site will now be compared with the cost of implementing ramp metering. The costs for each individual site are being estimated in a separate task and the benefit/cost analysis will be developed in the "Implementation Plan" task to determine the financial feasibility of implementing each site.

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