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Date:	12/29/2009
To:	Marie Treazise, WisDOT Bureau of Highway Operations
From:	Amanda Ryadi, Wisconsin TOPS Lab
Subject:	Ramp Metering Evaluation – Technical Memo #5 Operational Evaluation

This memorandum summarizes the ramp meter operational evaluation results. The primary purpose of this evaluation is to evaluate the effectiveness of the ramp meters currently operating. In combination with metering warrants (refer to Technical Memo #7) this information may help determine whether the ramp meters need to continue operating.

For the analyses, 30-day data prior to installation and 30-day data post installation were observed at each location. Unfortunately, most ramp meter locations lack operational data for the period prior to installation. In some instances, data were available but operations were adversely affected by workzone and construction activity prior to meter turn-up. Due to these limitations of data availability, 27 ramp meter locations were observed.

By using WisTransPortal's volume, speed, and occupancy (V-SPOC) tool, the 60-day data was retrieved for the 27 ramp meters, including mainline loops but leaving out queue loop and exit loop data. The data retrieved are limited to only weekday data at the determined peak hour period of operations for each meter, for example, 5 AM – 9 AM and 4 PM – 7 PM. The operating times were all collected from hard copy files of meter operating parameters at the State Traffic Operations Center (STOC).

In several cases the records of dates and times were inconsistent or absent, and these locations were not included in the analysis. The remaining ramp meter data were then checked for zero and null values where locations with a majority of missing values are considered not workable and therefore shortens the list of ramp meters to work with to 16 ramp meters. The operations data for these 16 ramp meters were then entered to Stata software, in which a process is run to execute the analysis. Additional background and methodology is documented in Technical Memo #3.

The remainder of this memo is divided into three sections. The first discusses operations before and after the initial ramp meter start ups. The second section summarizes the assessment of operations observed before and after smaller changes in meter operation times. The third section covers the assessment made of four meter installations that were turned off in 2009.

Initial Startups

The remaining 16 ramp meters are evaluated for their reliability and travel time change after the ramp meters were initially activated. The following series of figures includes what is called the data confidence level. The confidence level is the level of confidence of the accuracy of the metering start-up dates and metering timing information. This is a subjective measure based on observed inconsistencies in the records.

The units on the following graphs are in minutes per vehicle along the mainline. What is sought upon a meter installation is a drop (negative value) in both the travel time and reliability/variability measures. With a meter installed, ramp delay increases. While there are no data on ramp delay, the results of this analysis define a necessary lower bound for efficacy. For example, if no improvement is observed for mainline travel and safety, the meter would not be beneficial since ramp delay necessarily increases.

To assess the aggregate value at a metering location, the minutes per vehicle are converted to an annual number of hours figure by multiplying in the number of lanes, volume per lane, and time of meter operation. This value is then used for comparison in an economic context. A brief discussion of this comes after the following two figures.

For AM data, as shown in Figure 1, RM-67-069 I-94 EB at CTH T shows the most positive improvement for both reliability and travel time changes after the ramp meter was activated. RM-40-075 I-94 EB at 25th St, on the other hand, shows the most negative change for both reliability and travel time changes.

For PM data, as shown in Figure 2, RM-67-062 I-94 WB at Moorland Rd shows the most positive impact on reliability change and RM-40-077 US 41 NB at the Stadium Interchange N-E Ramp shows the most positive impact on travel time changes. RM-40-075 I-94 EB at 25th St also shows the most negative improvement for both reliability and travel time changes in the PM.

Figure 1. Reliability and Travel Time vs. Confidence (AM)

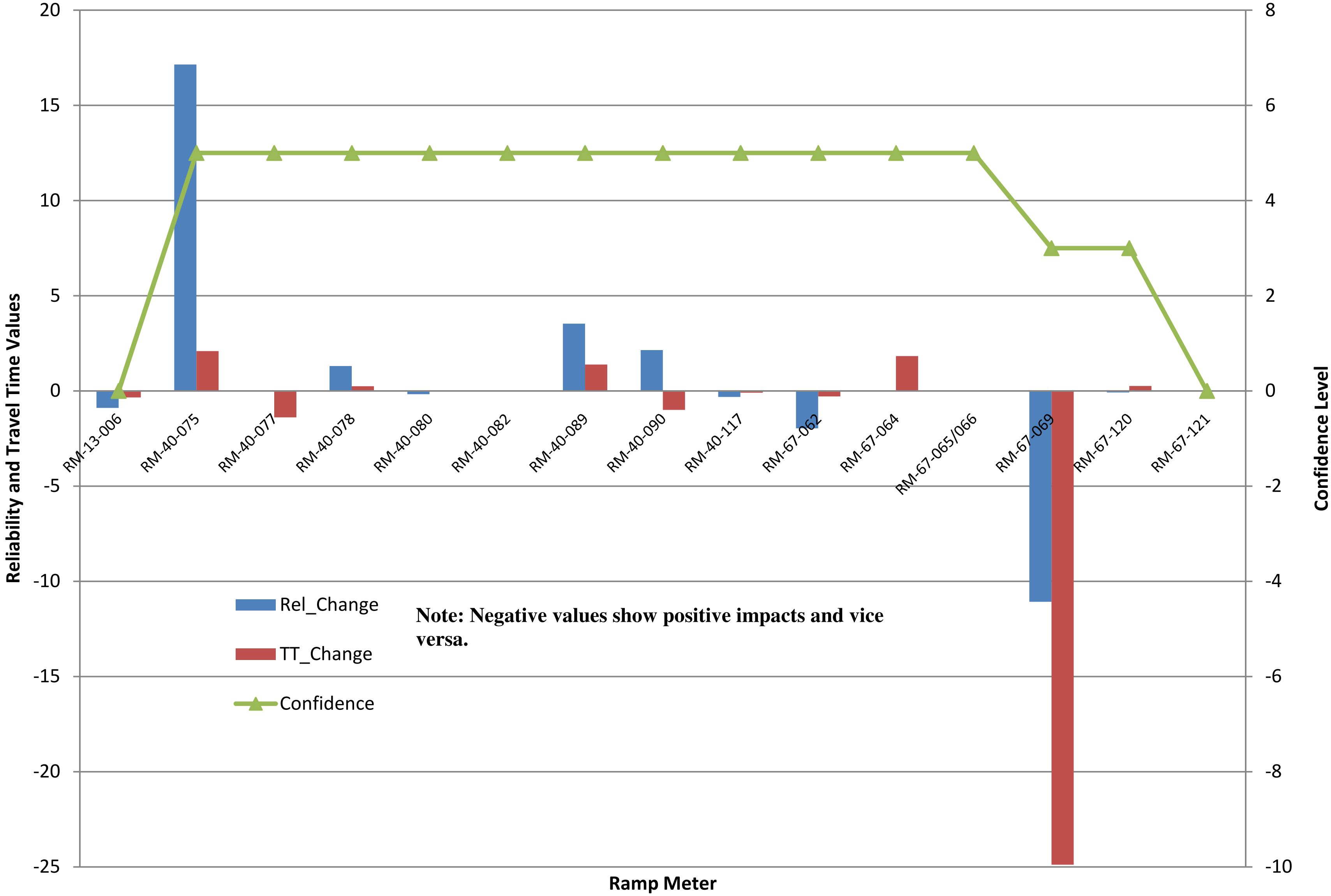
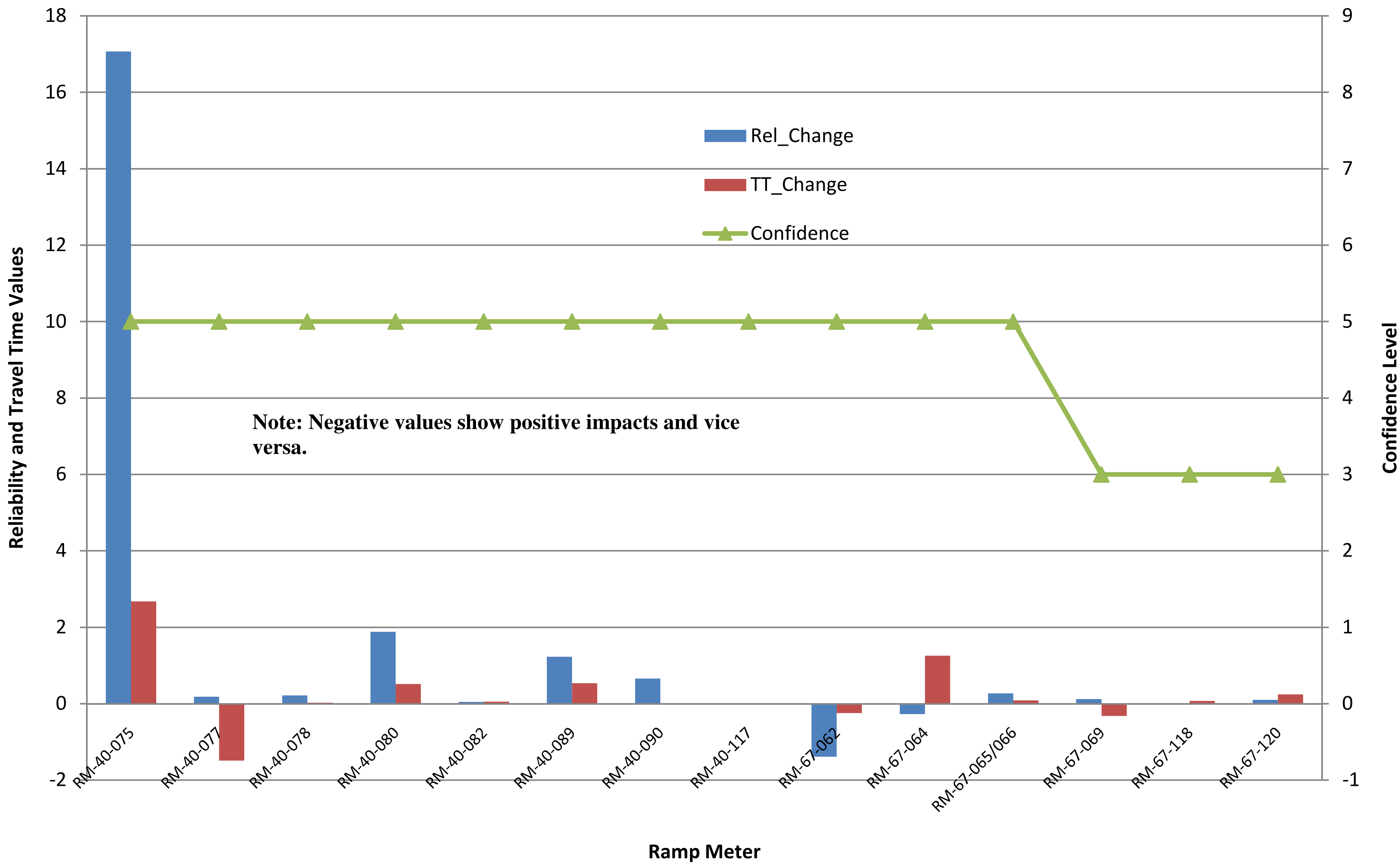


Figure 2. Reliability and Travel Time vs. Confidence (PM)



To illustrate the magnitude of the values on the previous two graphs, the minutes per vehicle values are converted to an annual hourly total using traffic volumes, as described above.

Annual Hourly Sum of Travel Time and Variability Change

Location	Meter	AM	PM	Total
US 12 WB @ Todd Dr	RM-13-006	-63,933		**-63,933**
I-94 EB @ 25th St	RM-40-075	345,179	382,313	727,493
US41 NB @ Stadium Int S-E Ramp	RM-40-077	-15,532	-19,125	**-34,657**
US41 NB @ Stadium Int S-W Ramp	RM-40-078	45,405	8,903	54,308
US41 SB @ Stadium Int N-E Ramp	RM-40-080	-3,100	41,479	38,380
I-94 EB @ Mitchell Blvd	RM-40-082	-58	2,848	2,790
US45 SB @ Good Hope Rd WB (loop)	RM-40-089	60,075	27,459	87,534
US45 SB @ Good Hope Rd (slip)	RM-40-090	23,347	17,774	41,122
US41/45 SB @ Hwy 145	RM-40-117	-9,777	-147	**-9,924**
I-94 WB @ Moorland Rd	RM-67-062	-23,912	-19,989	**-43,900**
I-94 EB @ Hwy 18	RM-67-064	16,277	11,628	27,905
I-94 WB @ CTH JJ (Bluemound)	RM-67-065/066	284	11,399	11,683
I-94 EB @ CTH T	RM-67-069	-402,850	-2,852	**-405,702**
US45 NB @ Main St	RM-67-118		1,913	1,913
I-94 WB @ Hwy G	RM-67-120	3,711	12,311	16,023
I-94 EB @ Hwy G	RM-67-121	453	-681	-227

Next, the economic values for the cost of the meter and values of time described in Tech Memo #3 can be applied to find a breakeven point for comparative purposes. Take the life cycle of a meter to be 10 years and a discount rate of 5%. With the typical cost of a meter, it equates such that the total annual savings in hours (as shown in the table above) must exceed a reduction of 1,137, at a minimum, for the benefit cost ratio to exceed one or the net present value to remain positive. In actuality it would need to be greater than this to offset the increased delay on the ramp itself, but those data are not available.

The proportion of missing or null operations data for these locations ranged from 0% to 60% with an average percent missing around 33%. The proportion of missing data may also be a confounding factor, for instance, if the third missing is all in the same busiest lane of the mainline, but this level of investigation was beyond the scope of this assessment.

Of the sixteen installations shown in the table, five show an improvement exceeding this breakeven point, while some show substantially worse conditions. In most cases these ramp meters have not demonstrated operational benefit.

The result for I-94 Eastbound at County Highway T (RM-67-069) is an extreme example of further issues with the data reliability. While the percent of missing or null data was just 6% in the morning and 10% in the afternoon, the volumes recorded before and after the installation increased by 303% in the morning and 214% in the afternoon. Meanwhile the data tells us that travel times (on the per mile basis) dropped by 85% in the morning and 22% in the afternoon. While this indicates a dramatic improvement, it is far too implausible, and attributing this to a single ramp meter installation is unrealistic.

Meter Operating Time Changes

Information on the time of operation changes are obtained through the Wisconsin Department of Transportation (WisDOT) controller configuration reports on file at the STOC. There are nine ramp meters with timing changes information obtained for the evaluation. However, only ramp meters with the at least 15 minutes difference between the old metering start time with the new one are analyzed. Since the difference between the metering start time for RM-67-062 is less than 15 minutes, RM-67-062 is excluded from the analysis leaving only eight ramp meters to evaluate. However, there were 40 timeframe changes available for evaluation at these eight locations.

The time period used for the shift in metering times represents only the time when the meter is known to operate, and it does control for the time periods when a meter has the option of operating or not. A small shift in operating time is very common, but if the total shift was not greater than this optional time, that change was not included.

The timing changes are evaluated for their reliability and travel time changes in the same manner as for the initial startup periods. The confidence level shows the level of accuracy of the timing changes information and date of the changes.

Figure 3 to 10 below show the results of the analysis. The ON and OFF denotes whether the ramp meter was turned from off to on (ON) or turned from on to off (OFF). The time on the second row shows the old start time and the time on the third row shows the new start time. Lastly, the last row shows the date of the timing changes.

The figures show how the timing changes affect the reliability and travel time change. For example, Figure 3 shows that turning on RM-40-006 at 6:45 PM rather than at 6:20 PM gives a positive impact on both the reliability and travel time change.

Because these are minor adjustments to metering times, the threshold for assessing whether a benefit exists is lower than for the initial start-ups, specifically because the costs of operating the meters are assumed unchanged. Therefore, an operating benefit is assumed if the net change to travel time and travel time reliability is improved.

Of the 40 time changes, 13 were an extension of metering time (from off to on), and 27 were a reduction (from on to off). Of the 13 extensions, five (38%) showed a positive change to mainline operations with the meter operating. Of the 27 timeframe reductions, 14 showed an improvement without the meter, or in 13 (48%) cases the mainline operated better with the meter. Overall, in 18 of 40 (45%) cases the mainline was found to operate better with the meter operating.

In most cases the mainline operates better during these shoulder periods without the metering operating. This suggests a policy that leans more toward meters operating less unless other evidence and control room operator experience suggests otherwise.

Figure 3. RM-40-006 Reliability and Travel Time vs. Confidence Level

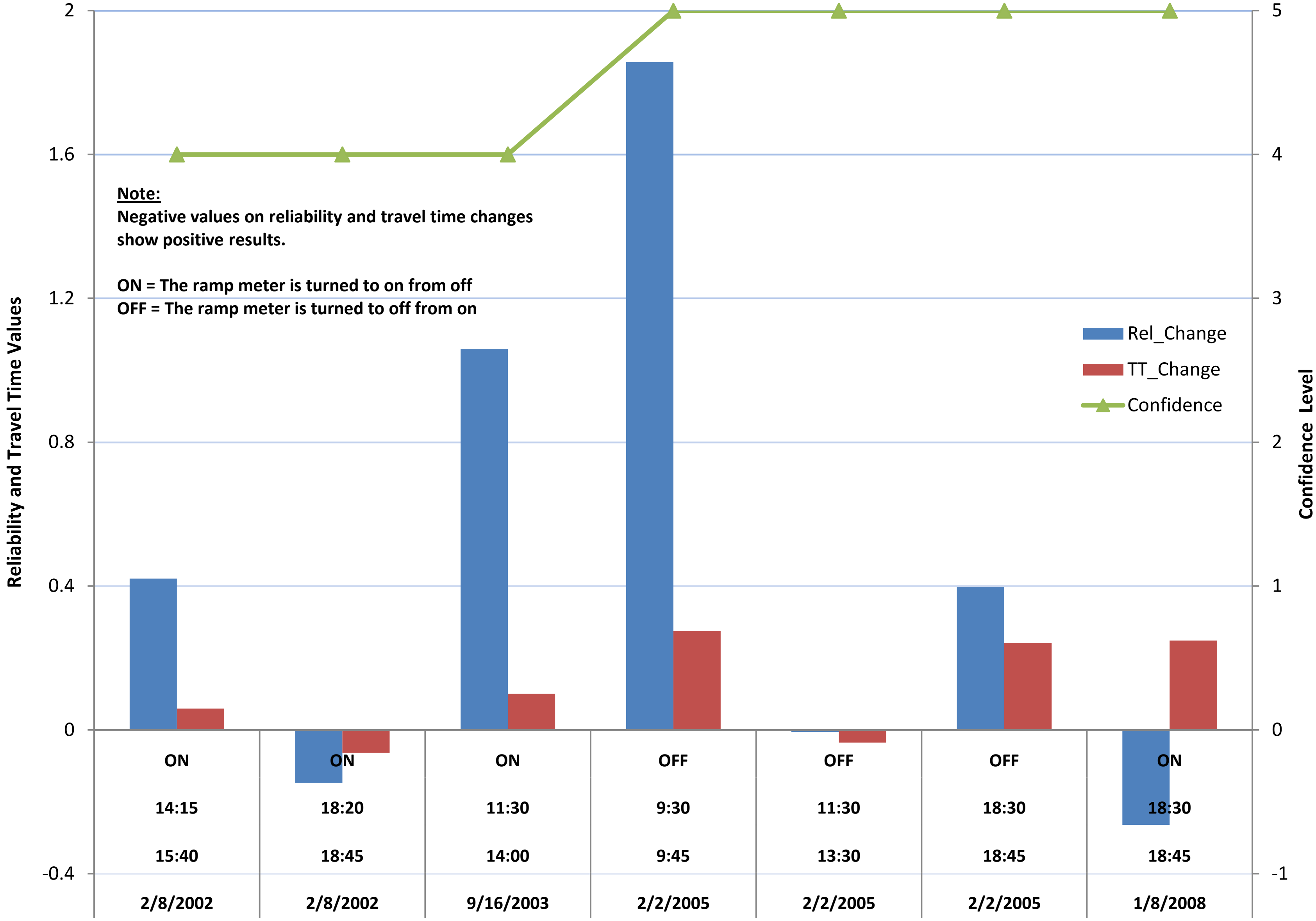


Figure 4. RM-40-124 Reliability and Travel Time vs. Confidence Level

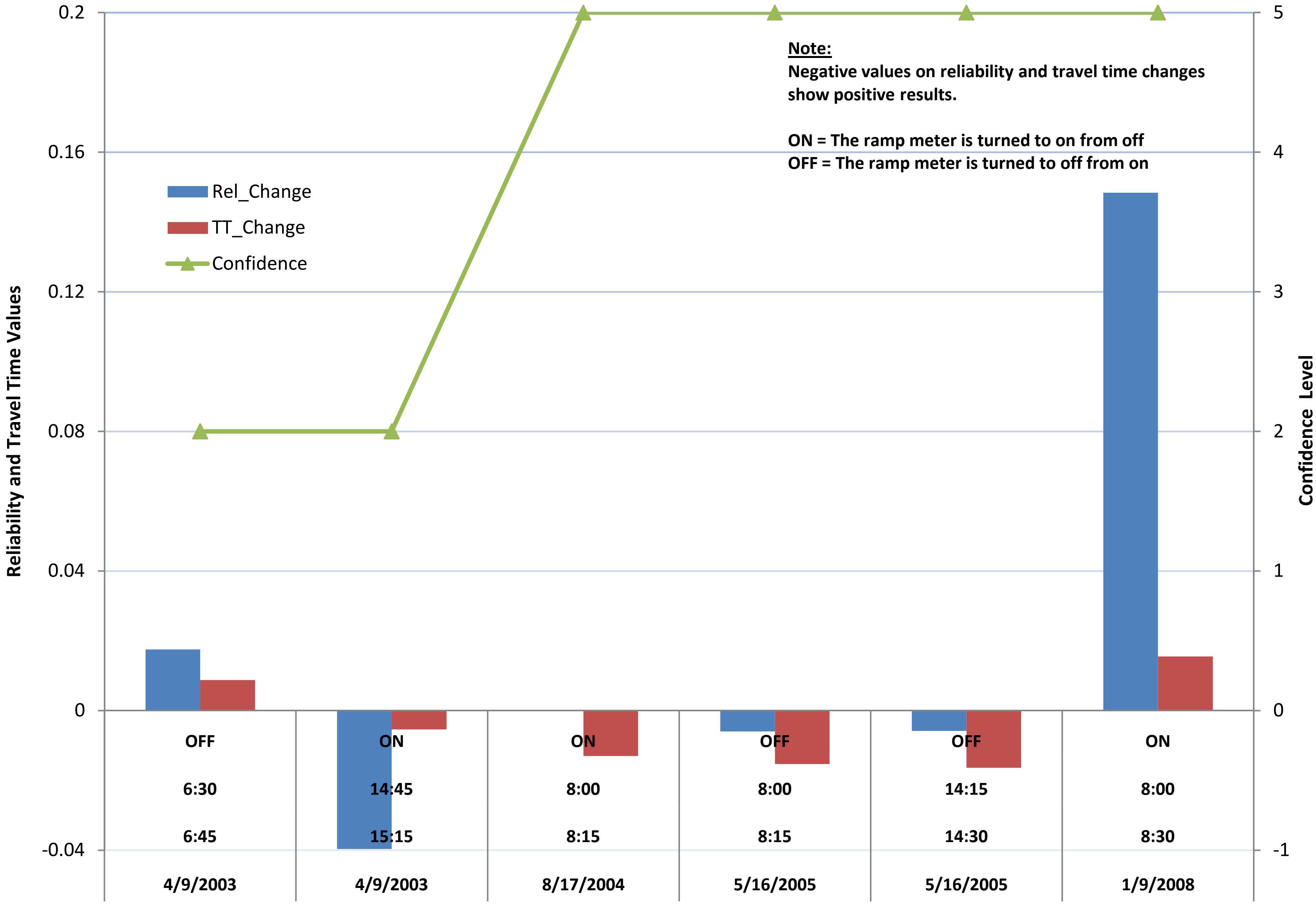


Figure 5. RM-67-043 Reliability and Travel Time vs. Confidence Level

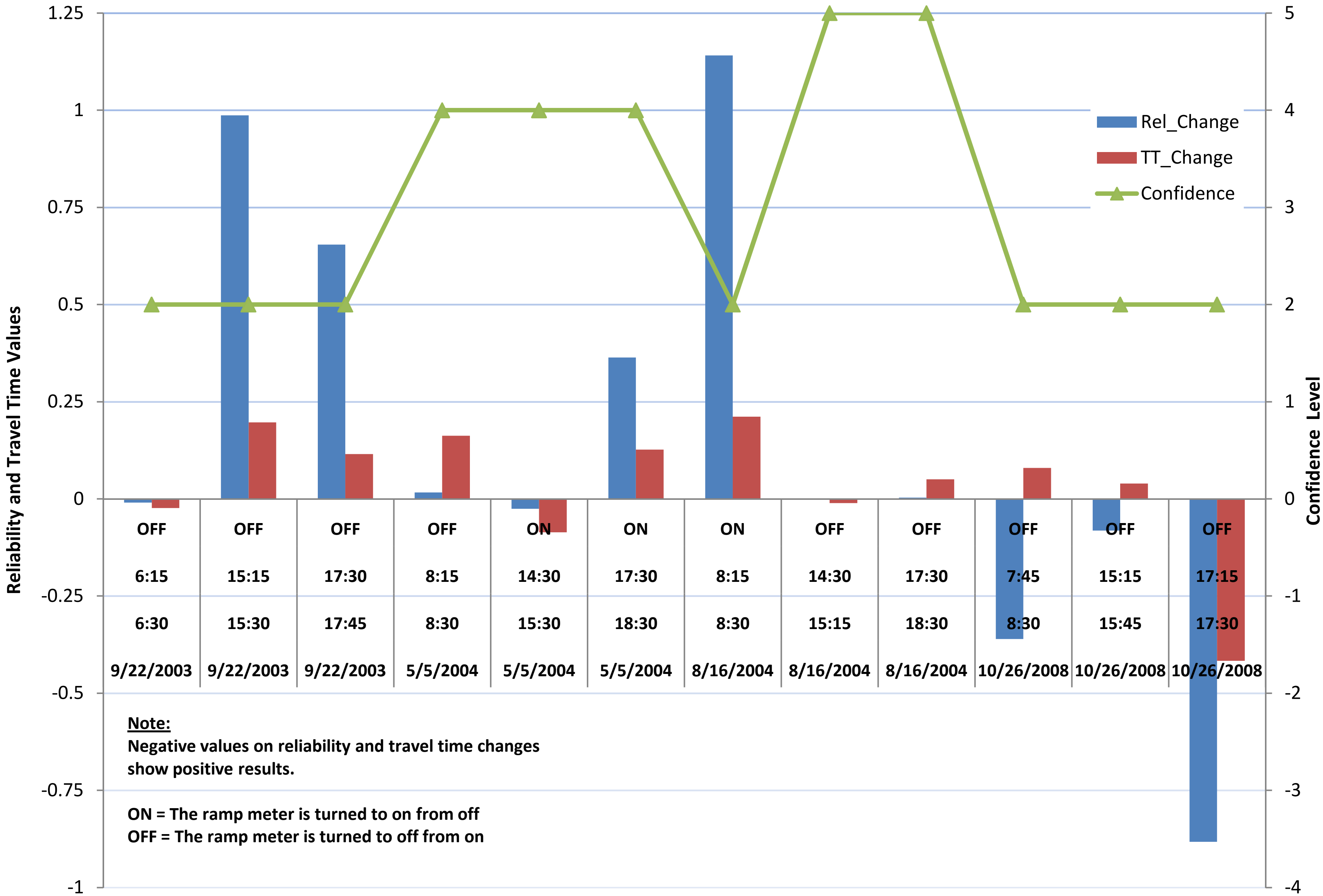


Figure 6. RM-67-063 Reliability and Travel Time vs. Confidence Level

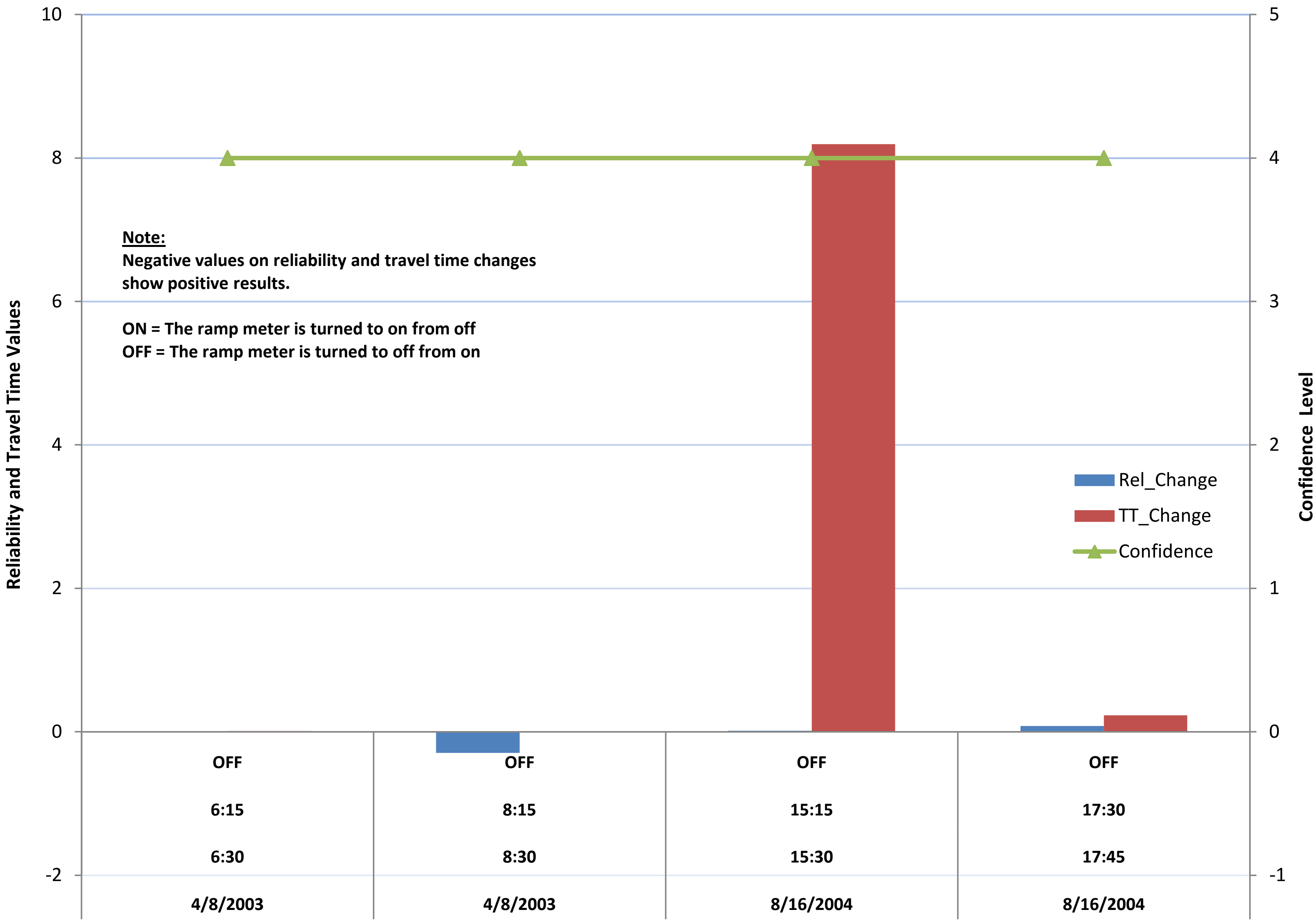


Figure 7. RM-67-065/066 Reliability and Travel Time vs. Confidence Level

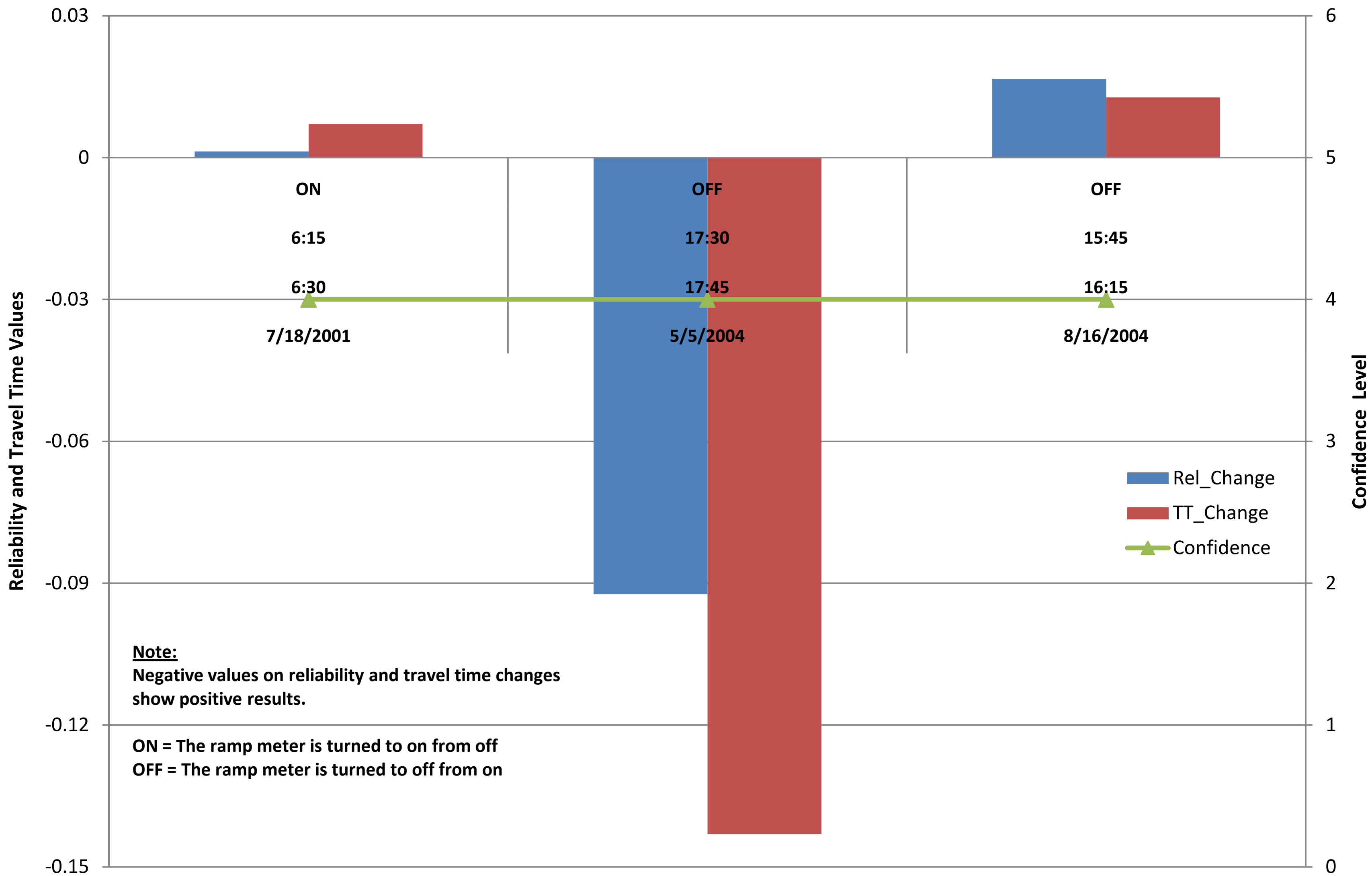


Figure 8. RM-67-069 Reliability and Travel Time vs. Confidence Level

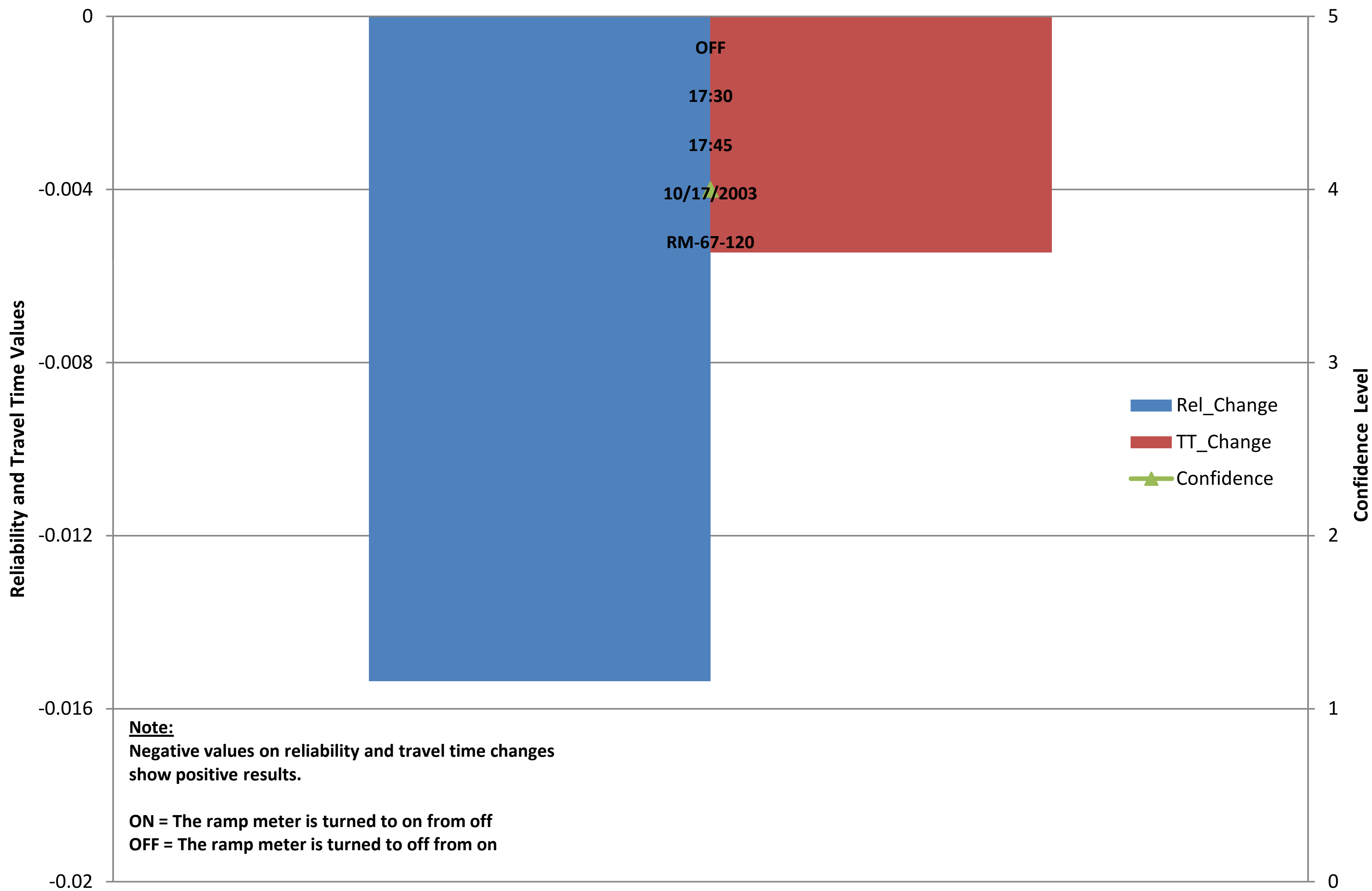


Figure 9. RM-67-118 Reliability and Travel Time vs. Confidence Level

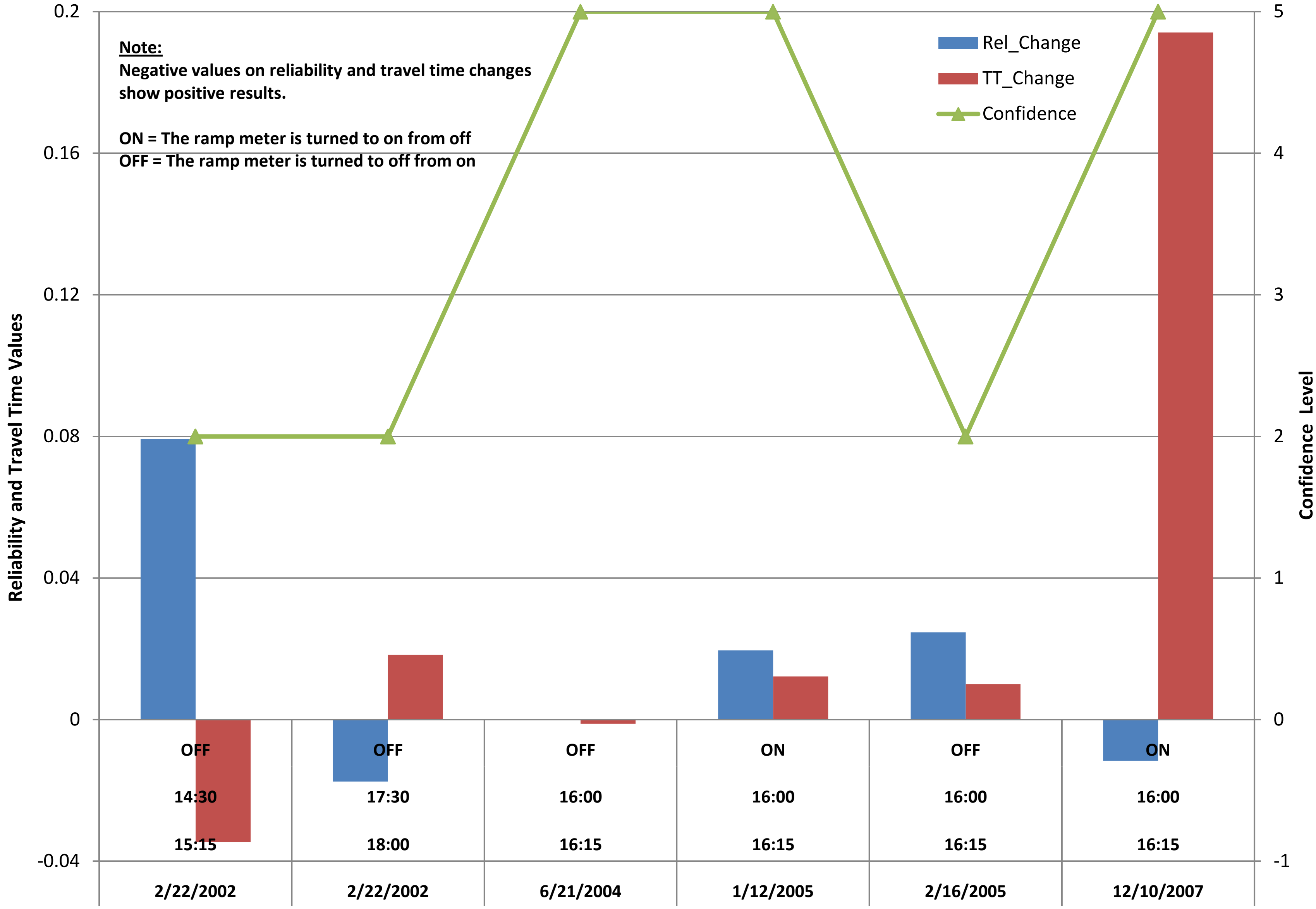
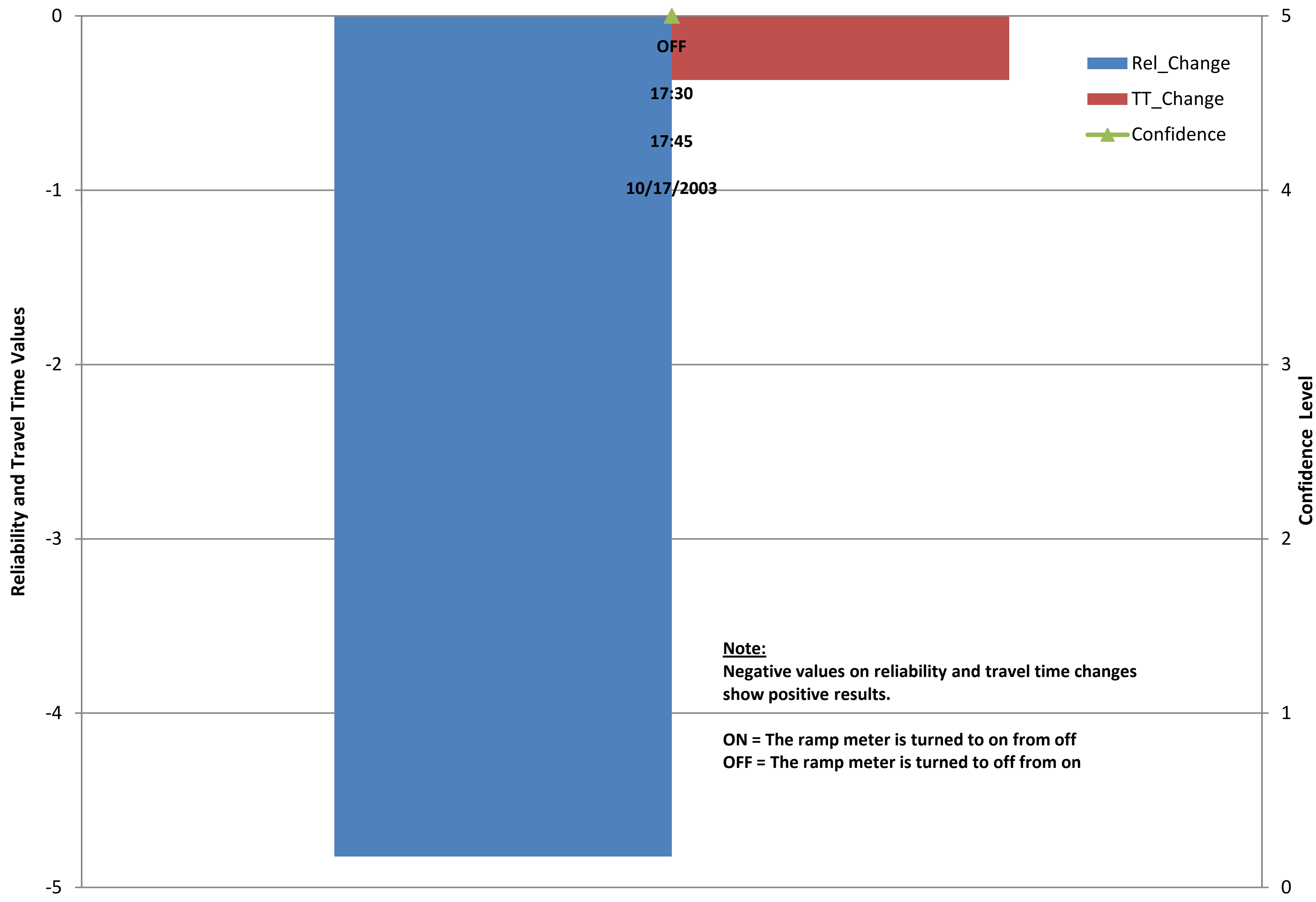


Figure 10. RM-67-120 Reliability and Travel Time vs. Confidence Level



Ramp Meter Turn-Offs

On June 11th and 12th of 2009, WisDOT turned off three ramp meters along I-94 highway and one ramp meter along US 41/45 highway. These meters are:

- RM-67-069 I-94 EB @ CTH T
- RM-67-113 I-94 WB @ CTH T
- RM-67-118 US 41/45 NB @ STH 74 (Main St.)
- RM-67-120 I-94 WB @ CTH G

Furthermore, on December 9th of 2009, WisDOT turned off ramp meter RM-67-062 located on I-94 Westbound (WB) on Moorland Road.

The purpose is to evaluate whether it is necessary for these ramp meters to stay activated. Therefore, the analyses include the comparison of the activity from before and after the ramp meters are turned off. The following pages summarize the analyses results:

The ramp meter turn-off analyses show that turning off the ramp meters show improvements on both the ramp and the mainline, especially for RM-67-120 and RM-67-069.

The ramp meter turn-off analysis for RM-67-062 indicates that turning off the ramp meter shows improvements, especially for the ramp. Only in the case of RM-67-062 (Moorland Road) did the mainline show a statistically significant decrease in speed. In this case there are very high ramp volumes and other considerations for leaving the meter turned off.

The evidence from these turn-offs suggests in is appropriate keep these ramp meters turned off.

RM-67-069
The data used are from May 14, 2009 to July 31, 2009. The ramp meter was inactive starting from June 11, 2009. The ramp meter is being analyzed during metering time between 7 and 8 AM from Monday to Friday. The result of the analysis shows that there is a significant improvement on the ramp. The mainline speed and occupancy also improve.

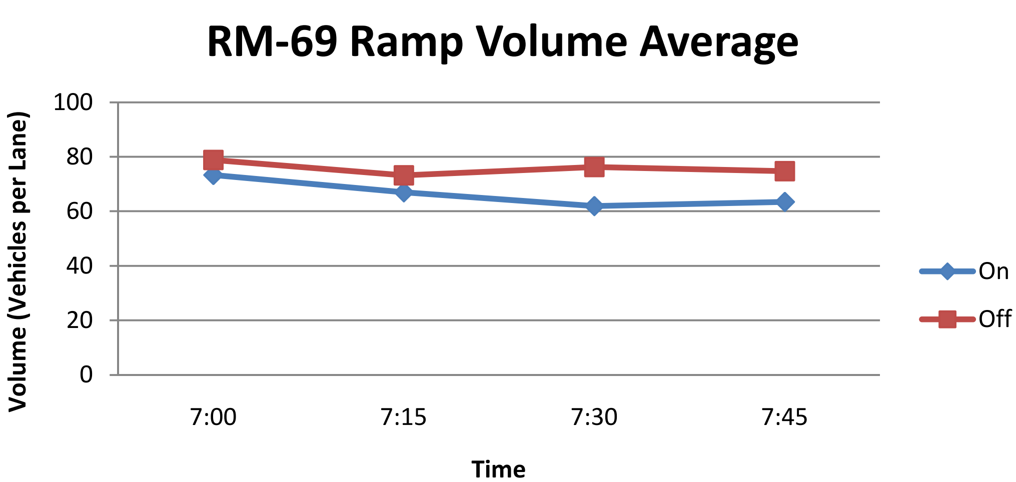
Volume (avg vpl every 1 hour)	Meter		
	Active	Inactive	Change
Mainline	1174.1	1142.9	-31.3
Ramp	265.6	303.0	37.4*

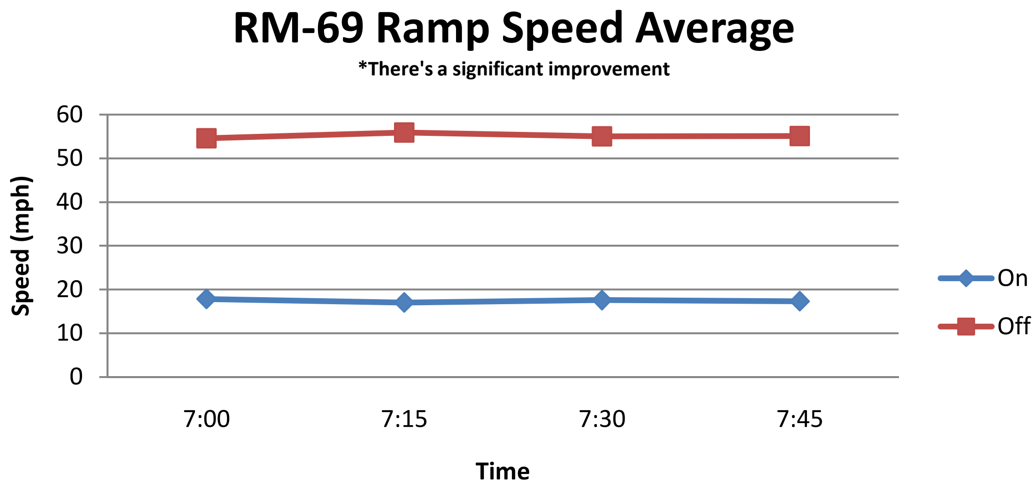
Speed (avg mph)	Meter		
	Active	Inactive	Change
Mainline	65.4	66.1	0.7
Ramp	17.4	55.2	37.8*

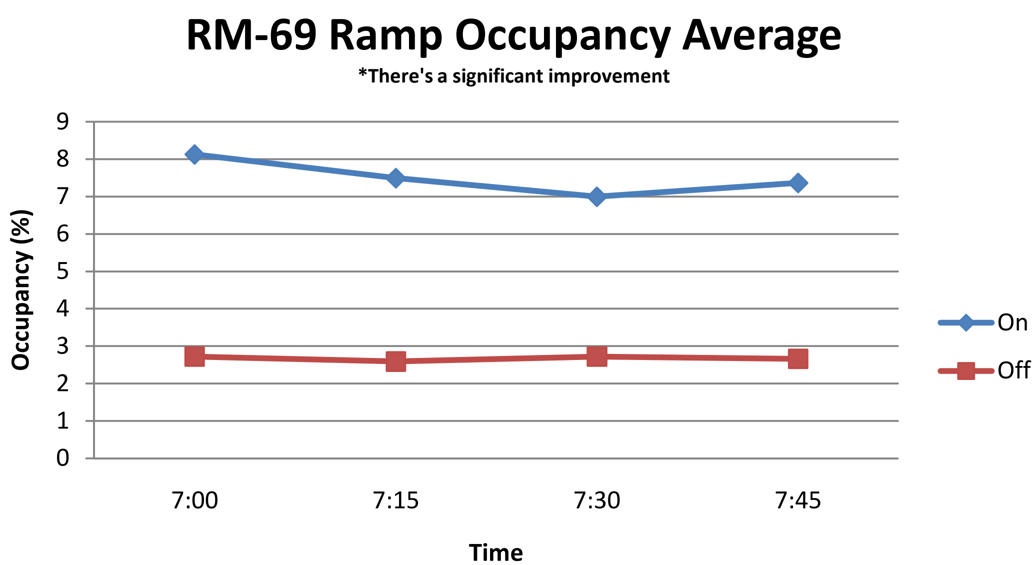
Occupancy (avg % per lane)	Meter		
	Active	Inactive	Change
Mainline	7.4	7.2	-0.3
Ramp	7.5	2.7	-4.8*

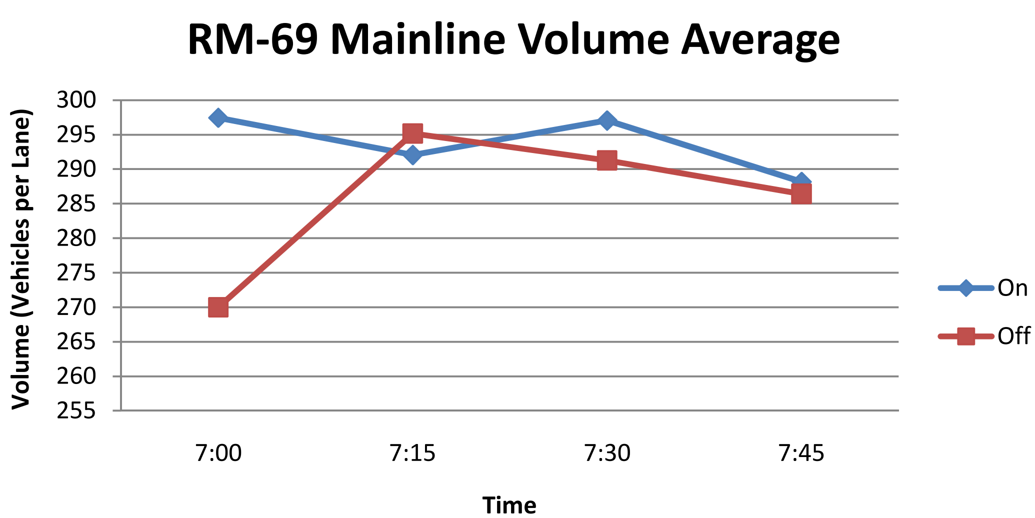
Note: * = The change is statistically significant

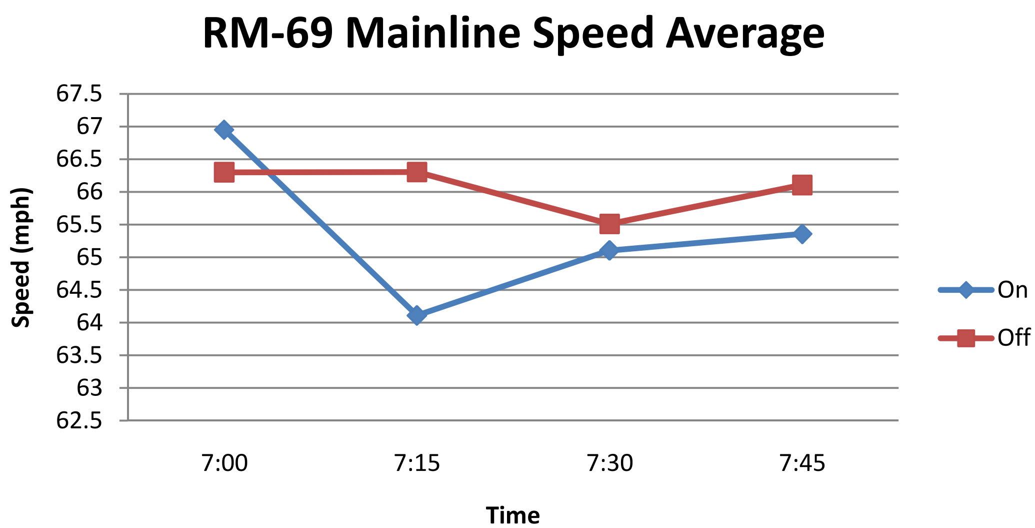
Improvement
Non-improvement

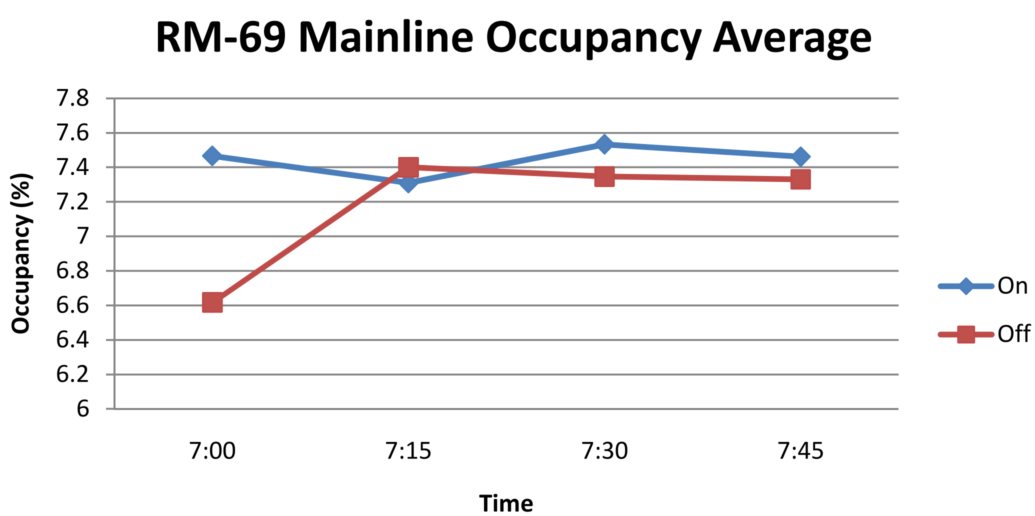



RM-69 Ramp Speed Average
*There's a significant improvement
Speed (mph)
60
50
40
30
20
10
0
7:00
7:15
7:30
7:45
Time
On
Off


RM-69 Ramp Occupancy Average
*There's a significant improvement
Occupancy (%)
9
8
7
6
5
4
3
2
1
0
7:00
7:15
7:30
7:45
Time
On
Off


RM-69 Mainline Volume Average
Volume (Vehicles per Lane)
300
295
290
285
280
275
270
265
260
255
7:00
7:15
7:30
7:45
Time
On
Off


RM-69 Mainline Speed Average
Speed (mph)
67.5
67
66.5
66
65.5
65
64.5
64
63.5
63
62.5
7:00
7:15
7:30
7:45
Time
On
Off


RM-69 Mainline Occupancy Average
Occupancy (%)
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
7:00
7:15
7:30
7:45
Time
On
Off

RM-67-113

The data used are from May 8, 2009 to July 31, 2009. The ramp meter was inactive starting from June 12, 2009. The ramp meter is being analyzed during metering time which is between 3:30 and 5:45 PM on Fridays. The result of the analysis shows that there is a significant improvement on the ramp occupancy and speed after the ramp meter is turned off.

Volume (avg vpl every 1 hour)	Meter		
	Active	Inactive	Change
Mainline	1283.6	1267.4	-16.2
Ramp	199.4	199.0	-0.5

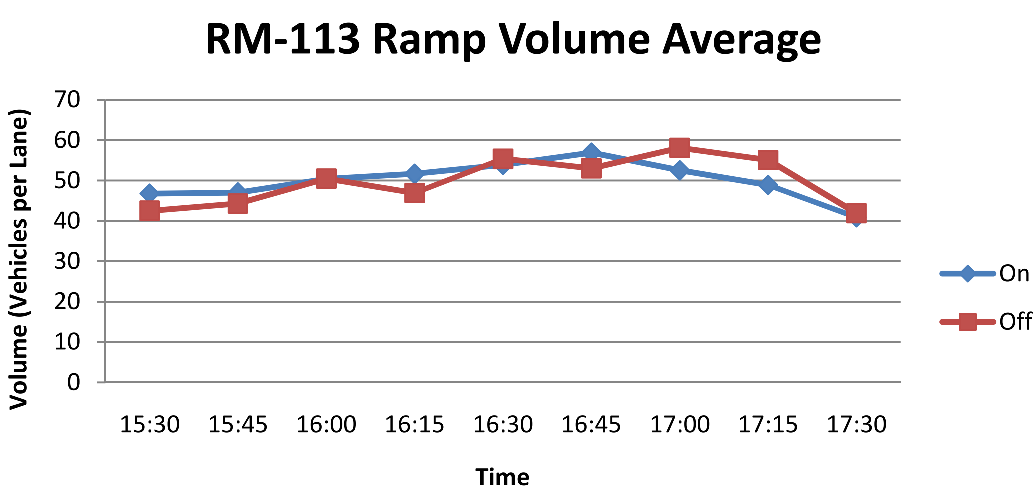
Speed (avg mph)	Meter		
	Active	Inactive	Change
Mainline	65.2	63.2	-2.0
Ramp	17.8	56.5	38.7*

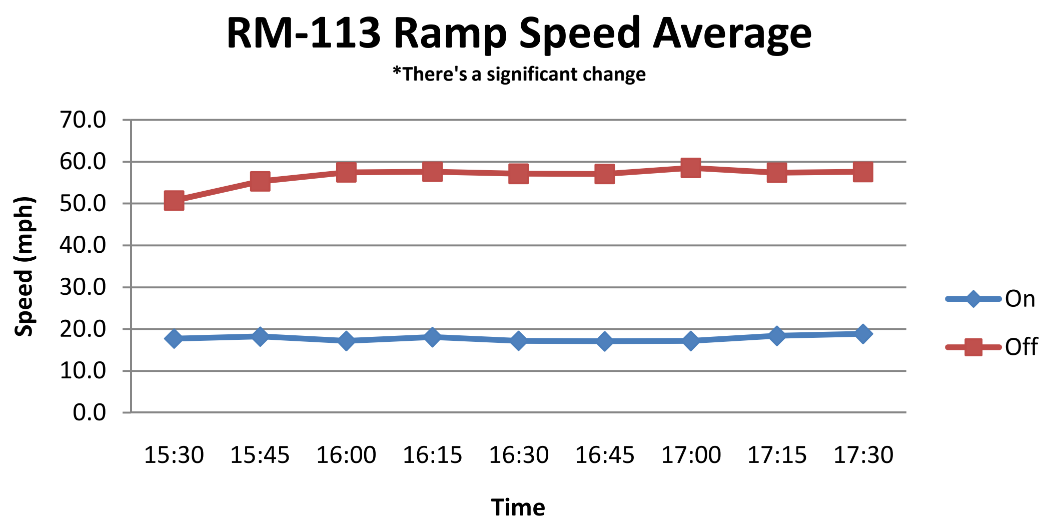
Occupancy (avg % per lane)	Meter		
	Active	Inactive	Change
Mainline	8.5	8.6	0.1
Ramp	5.8	1.7	-4.1*

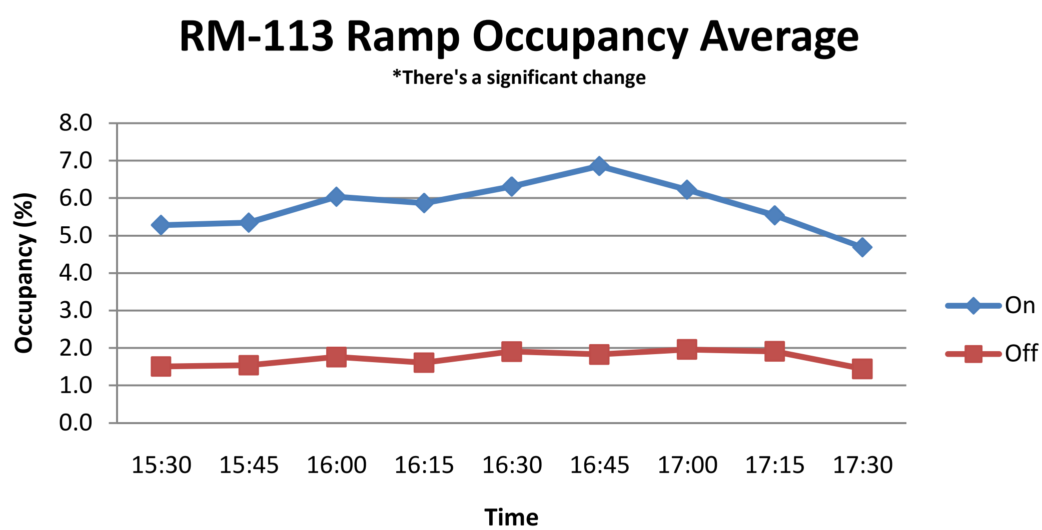
Note: *= The change is statistically significant

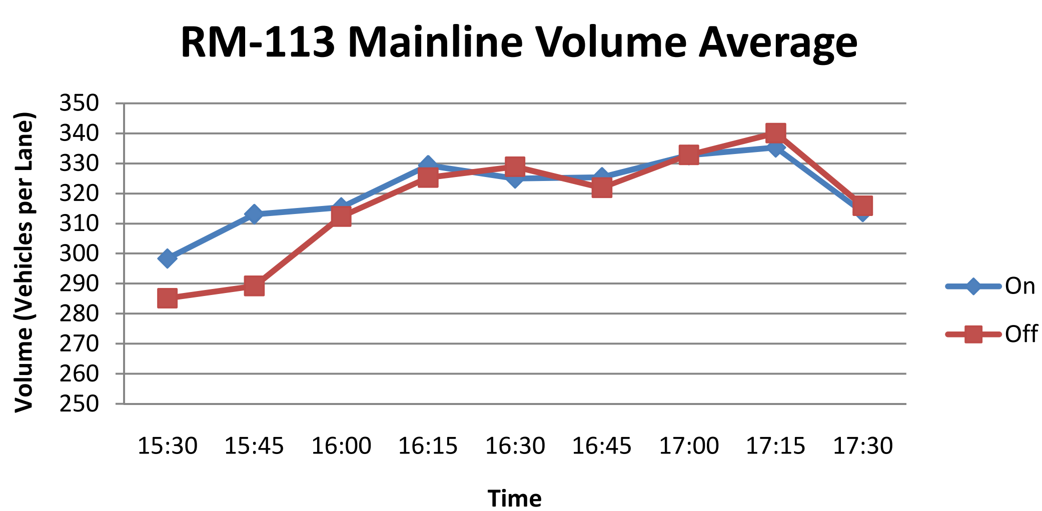
Improvement

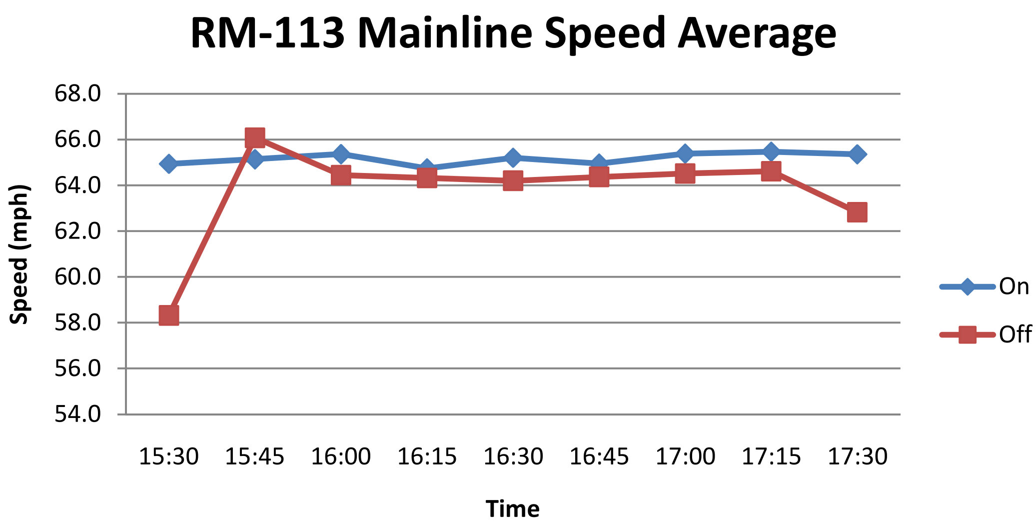
Non-improvement

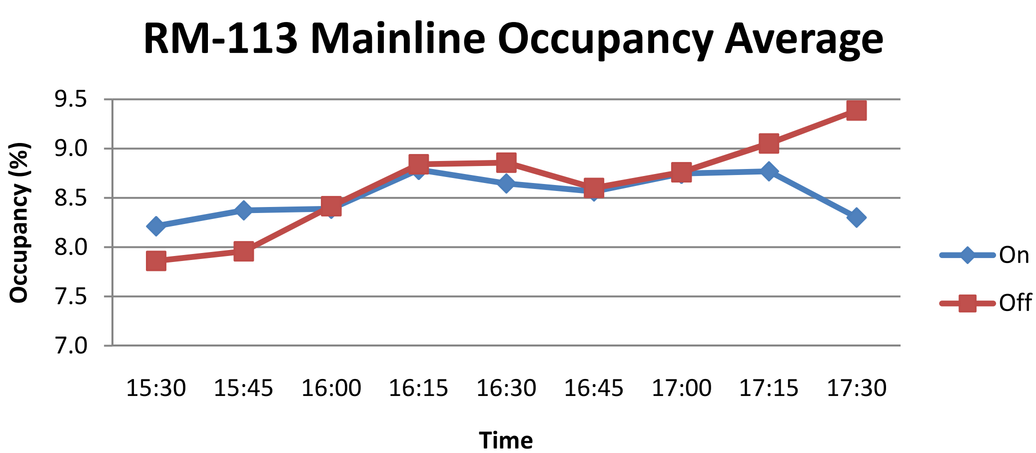



RM-113 Ramp Speed Average
*There's a significant change
Speed (mph)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
15:30
15:45
16:00
16:15
16:30
16:45
17:00
17:15
17:30
Time
On
Off


RM-113 Ramp Occupancy Average
*There's a significant change
Occupancy (%)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
15:30
15:45
16:00
16:15
16:30
16:45
17:00
17:15
17:30
Time
On
Off


RM-113 Mainline Volume Average
Volume (Vehicles per Lane)
350
340
330
320
310
300
290
280
270
260
250
15:30
15:45
16:00
16:15
16:30
16:45
17:00
17:15
17:30
Time
On
Off


RM-113 Mainline Speed Average
Speed (mph)
68.0
66.0
64.0
62.0
60.0
58.0
56.0
54.0
15:30
15:45
16:00
16:15
16:30
16:45
17:00
17:15
17:30
Time
On
Off


RM-113 Mainline Occupancy Average
Occupancy (%)
9.5
9.0
8.5
8.0
7.5
7.0
15:30
15:45
16:00
16:15
16:30
16:45
17:00
17:15
17:30
Time
On
Off

RM-67-118
The data used are from May 14, 2009 to July 31, 2009. The ramp meter was inactive starting from June 11, 2009. The ramp meter is being analyzed during metering time which is between 4:00 and 5:15 PM from Monday to Friday. The result of the analysis shows that there is an improvement on the occupancy after the ramp meter is turned off but there are no significant changes. Nevertheless, note that the ramp speed when the ramp meter is active is above 70 mph, which indicates that there might be discrepancies or errors in the data.

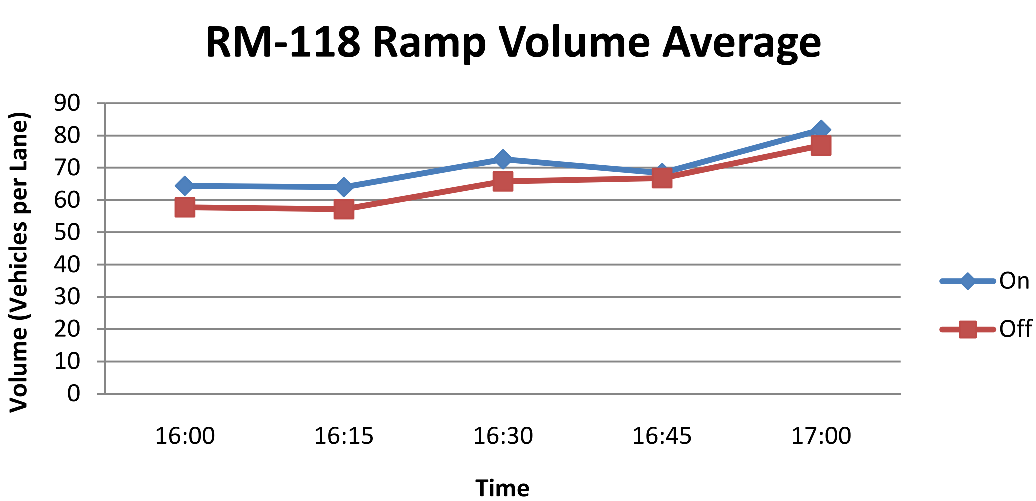
Volume (avg vpl every 1 hour)	Meter		
	Active	Inactive	Change
Mainline	1508.3	1477.0	-31.3
Ramp	280.9	258.9	-22.0

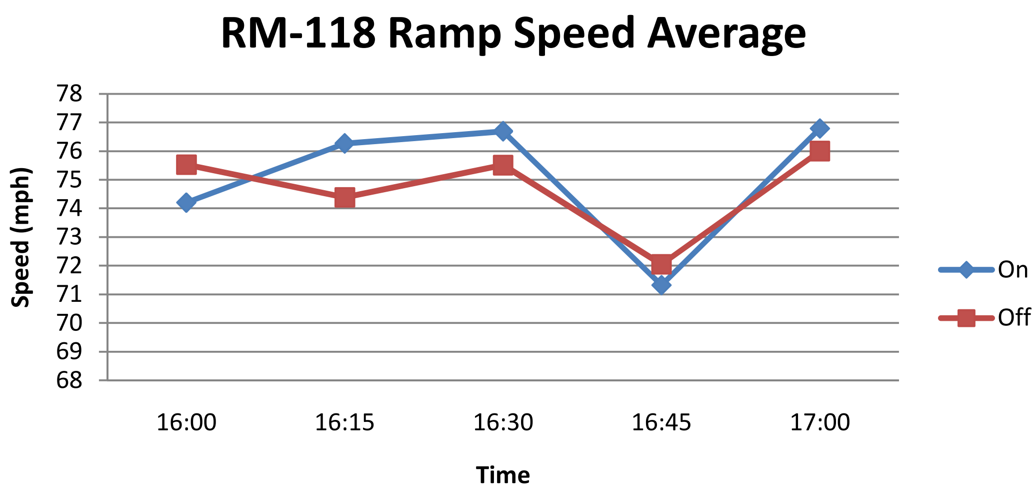
Speed (avg mph)	Meter		
	Active	Inactive	Change
Mainline	62.4	61.9	-0.5
Ramp	75.1	74.7	-0.4

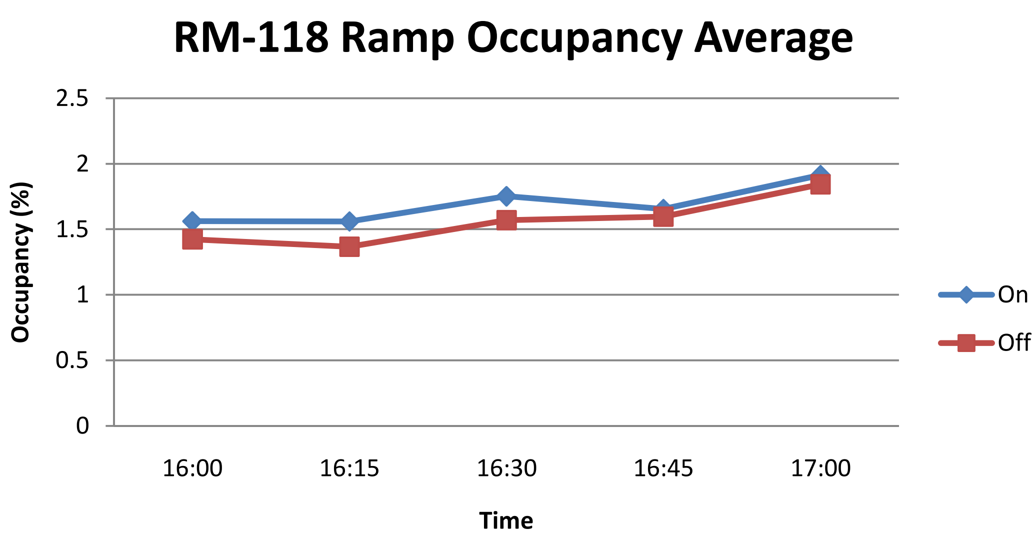
Occupancy (avg % per lane)	Meter		
	Active	Inactive	Change
Mainline	13.5	12.4	-1.04
Ramp	1.7	1.6	-0.1

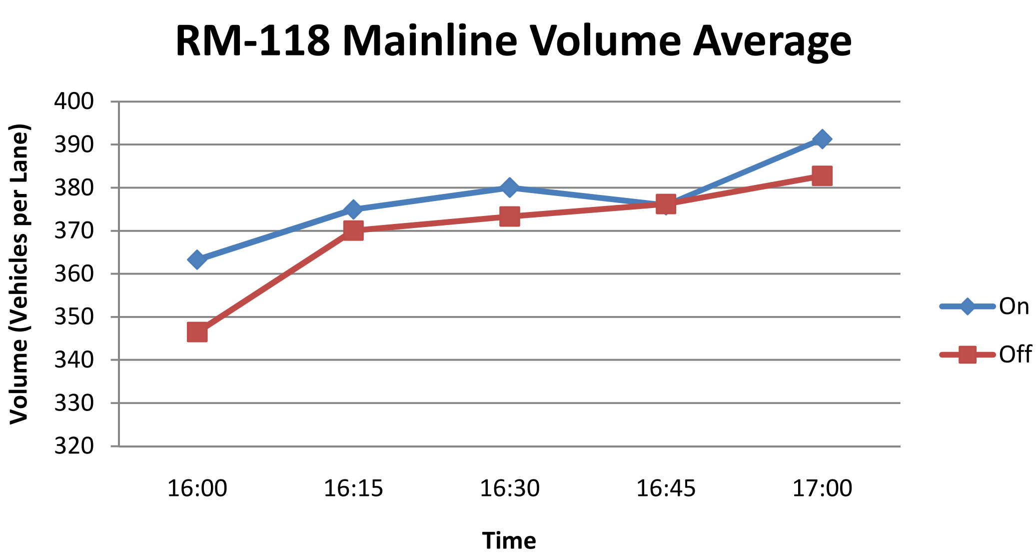
Note: * = The change is statistically significant

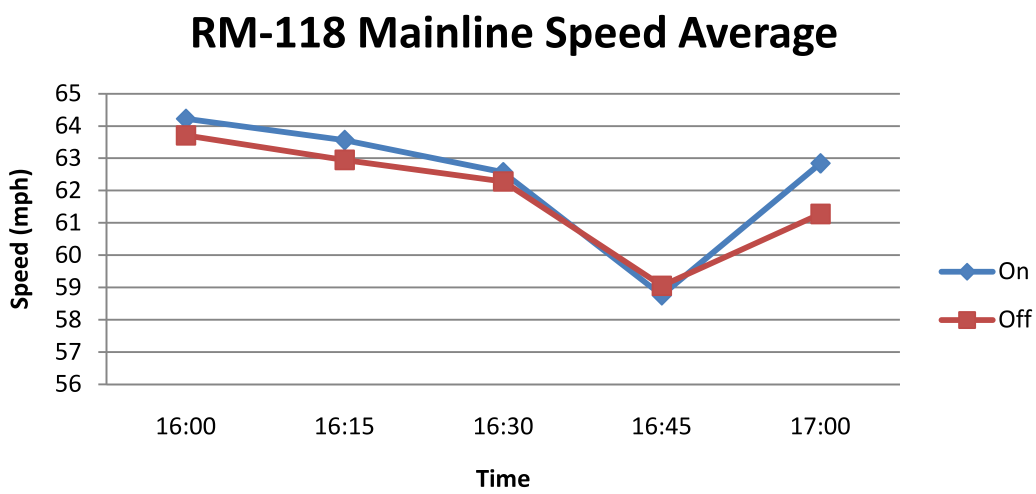
Improvement
Non-improvement

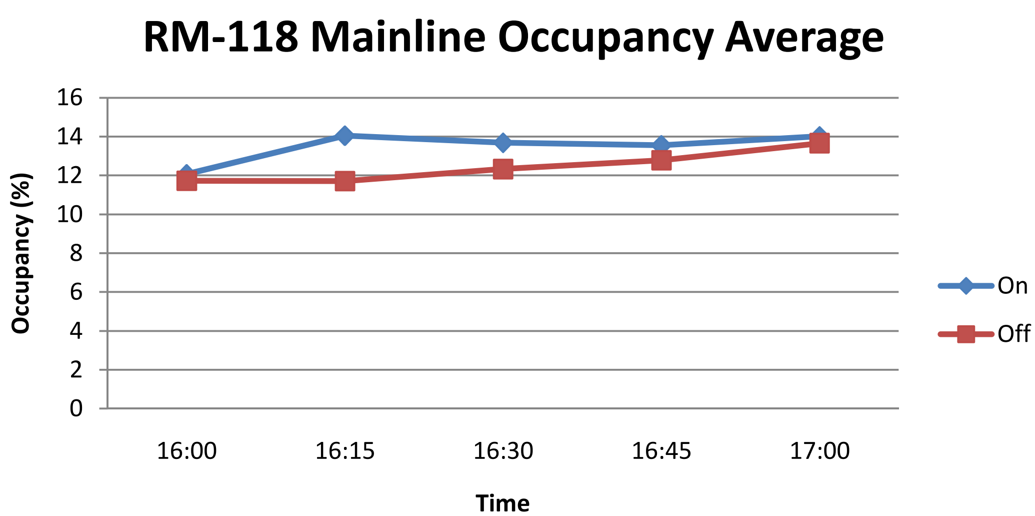



RM-118 Ramp Speed Average
Speed (mph)
78
77
76
75
74
73
72
71
70
69
68
16:00
16:15
16:30
16:45
17:00
Time
On
Off


RM-118 Ramp Occupancy Average
Occupancy (%)
2.5
2
1.5
1
0.5
0
16:00
16:15
16:30
16:45
17:00
Time
On
Off


RM-118 Mainline Volume Average
Volume (Vehicles per Lane)
400
390
380
370
360
350
340
330
320
16:00
16:15
16:30
16:45
17:00
Time
On
Off


RM-118 Mainline Speed Average
Speed (mph)
65
64
63
62
61
60
59
58
57
56
16:00
16:15
16:30
16:45
17:00
Time
On
Off


RM-118 Mainline Occupancy Average
Occupancy (%)
16
14
12
10
8
6
4
2
0
16:00
16:15
16:30
16:45
17:00
Time
On
Off

RM-67-120

The data used are from May 8, 2009 to July 31, 2009. The ramp meter was inactive starting from June 12, 2009. The ramp meter is being analyzed during metering time which is between 3:30 and 5:45 PM on Friday. The result of the analysis shows that there is an improvement for both the ramp and mainline. The improvement is especially significant on the ramp speed as shown in the table and graphs below.

Volume (avg vpl every 1 hour)	Meter		
	Active	Inactive	Change
Mainline	1319.7	1369.8	50.1
Ramp	138.4	142.8	4.4

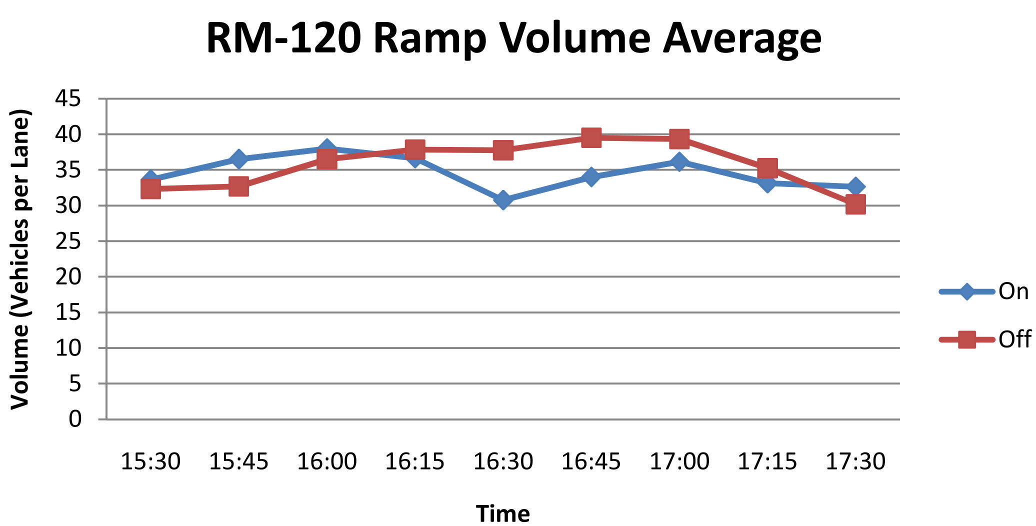
Speed (avg mph)	Meter		
	Active	Inactive	Change
Mainline	27.5	31.2	3.7
Ramp	29.3	71.2	41.9*

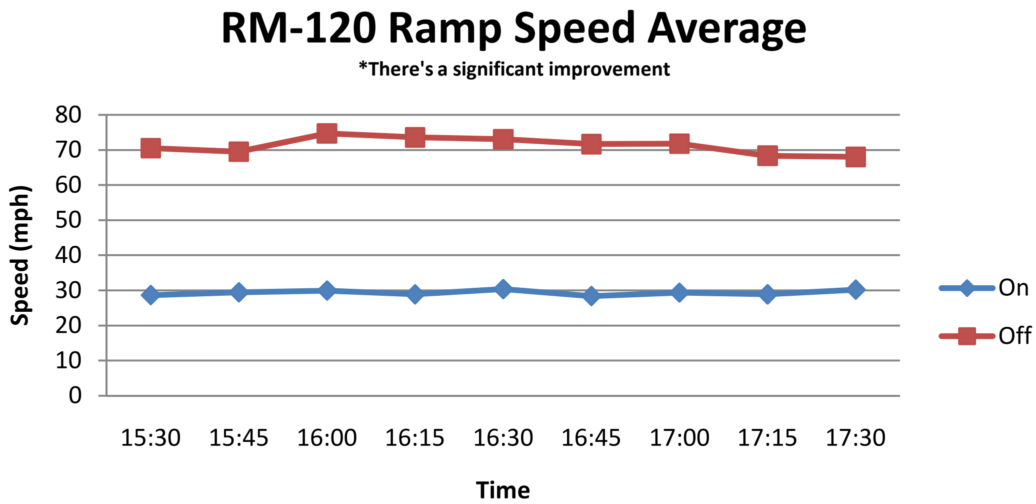
Occupancy (avg % per lane)	Meter		
	Active	Inactive	Change
Mainline	29.6	22.6	-7.0
Ramp	2.6	1.0	-1.6

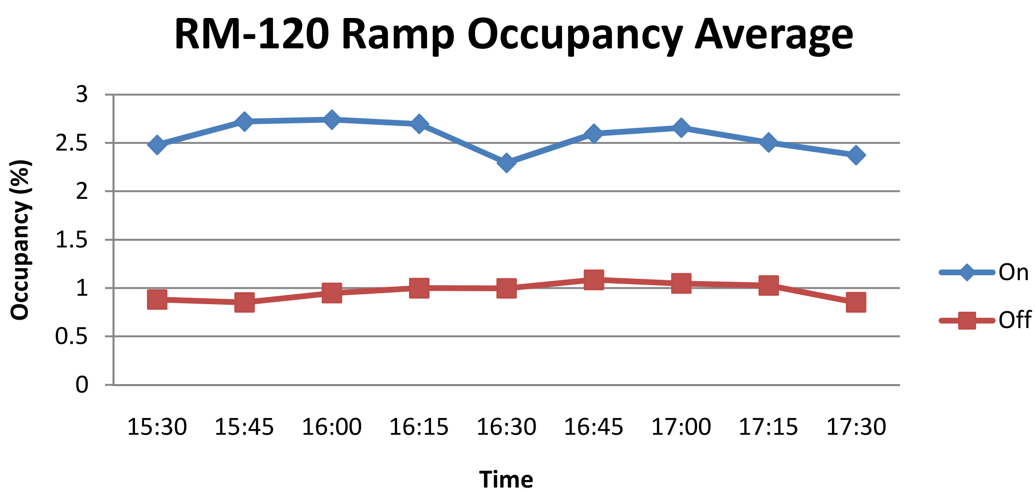
Note: * = The change is statistically significant

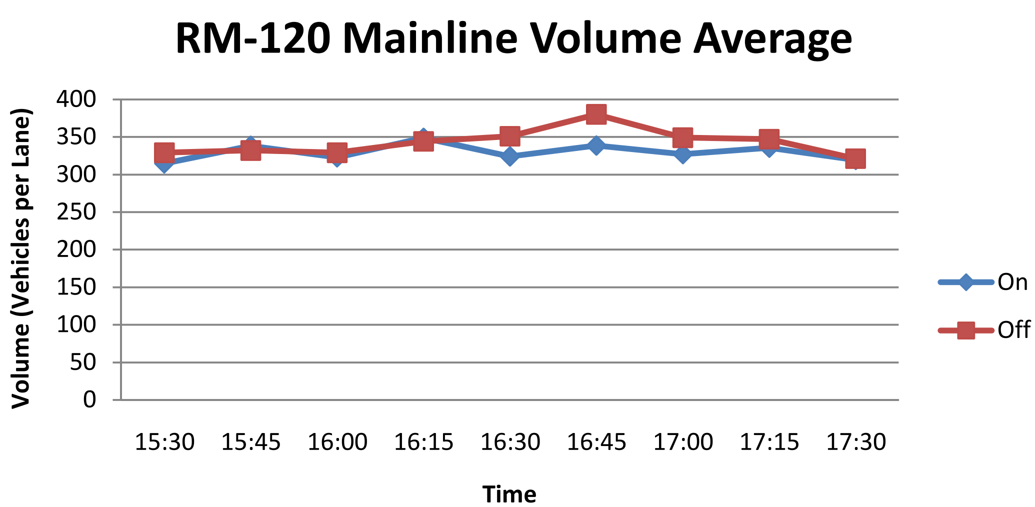
Improvement

Non-Improvement

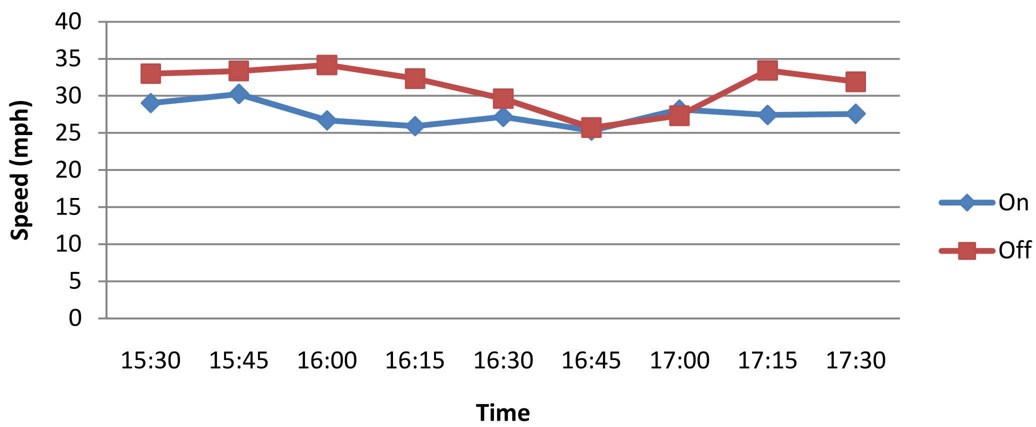



RM-120 Ramp Speed Average
*There's a significant improvement
Speed (mph)
80
70
60
50
40
30
20
10
0
15:30
15:45
16:00
16:15
16:30
16:45
17:00
17:15
17:30
Time
On
Off

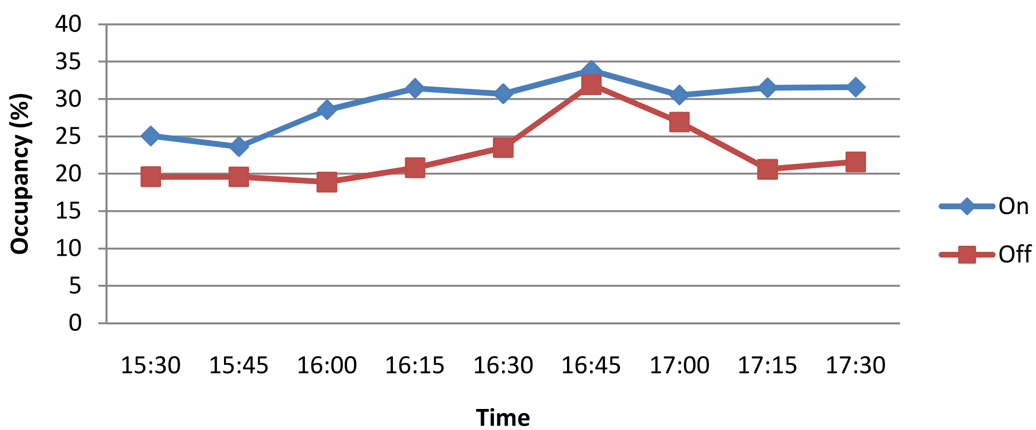

RM-120 Ramp Occupancy Average
Occupancy (%)
3
2.5
2
1.5
1
0.5
0
15:30
15:45
16:00
16:15
16:30
16:45
17:00
17:15
17:30
Time
On
Off


RM-120 Mainline Volume Average
Volume (Vehicles per Lane)
400
350
300
250
200
150
100
50
0
15:30
15:45
16:00
16:15
16:30
16:45
17:00
17:15
17:30
Time
On
Off

RM-120 Mainline Speed Average



RM-120 Mainline Occupancy Average



RM-67-062

The data used are from November 9th of 2009 to January 9th of 2010. The ramp meter was inactive starting from December 9th, 2009. The metering periods are 7:00-8:30 AM and 3:30-5:30 PM from Monday to Friday. The result shows that there is an improvement on the ramp with significant improvement on both the ramp speed and occupancy for both AM and PM. There is also a statistical significant declination on the mainline speed for both AM and PM. The mainline speed decreased by approximately 6 mph for both AM and PM.

AM

Volume (avg vplph)	Meter		
	Active	Inactive	Change
Mainline	1289.7	1142.0	-147.7
Ramp	348.5	330.5	-18.0

Speed (avg mph)	Meter		
	Active	Inactive	Change
Mainline	44.9	39.0	-5.9*
Ramp	17.5	56.3	38.8*

Occupancy (avg % plph)	Meter		
	Active	Inactive	Change
Mainline	10.7	9.8	-0.9
Ramp	10.8	2.9	-7.9*

Note: * = The change is statistically significant

Improvement
Declination

PM

Volume (avg vplph)	Meter		
	Active	Inactive	Change
Mainline	1390.1	1330.1	-60.0
Ramp	421.8	425.1	3.3

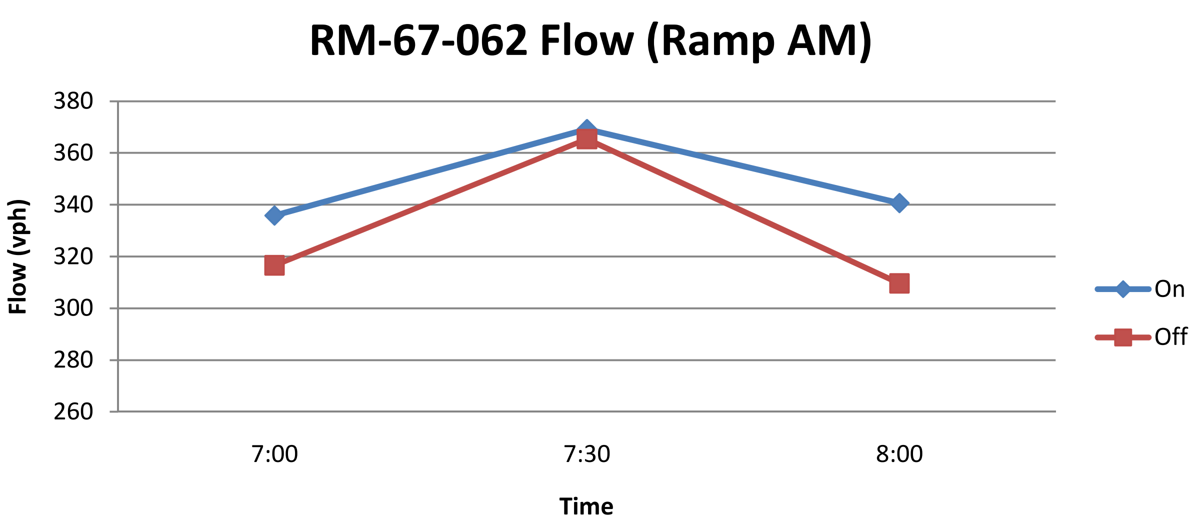
Speed (avg mph)	Meter		
	Active	Inactive	Change
Mainline	44.6	39.3	-5.3*
Ramp	20.1	58.8	38.7*

Occupancy (avg % plph)	Meter		
	Active	Inactive	Change
Mainline	11.9	11.3	-0.6
Ramp	12.6	3.5	-9.1*

Note: * = The change is statistically significant

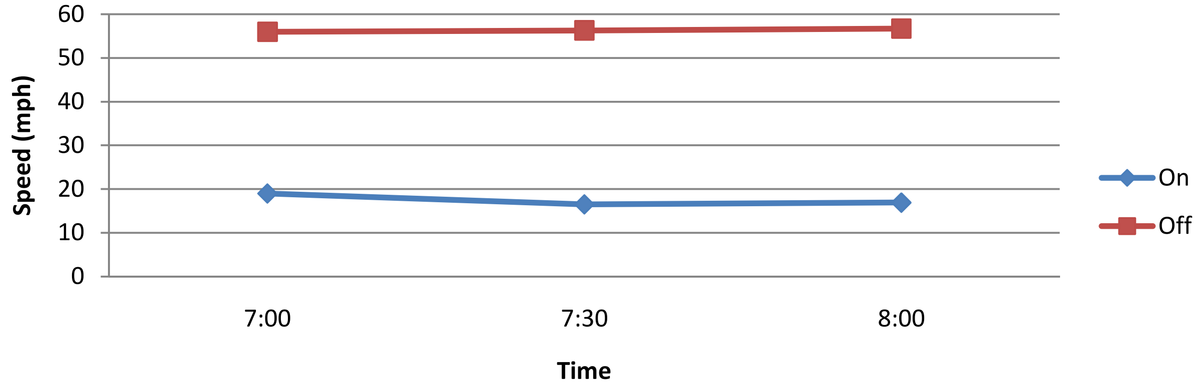
Improvement

Declination



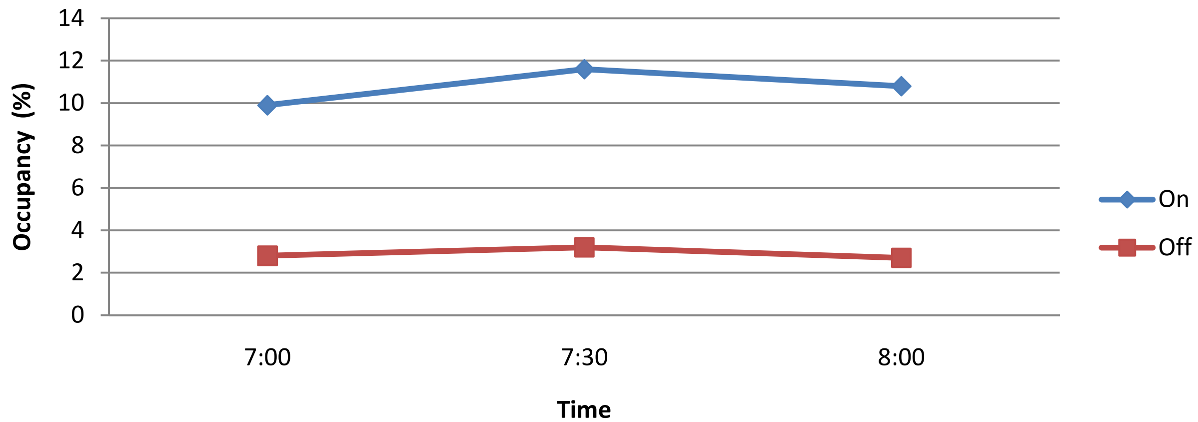
RM-67-062 Speed (Ramp AM)

* There is a significant improvement

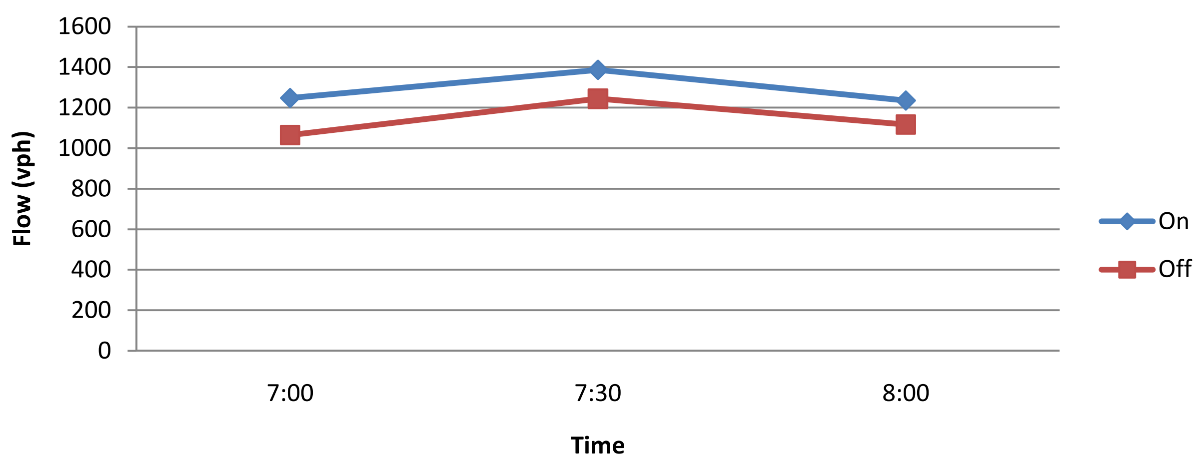


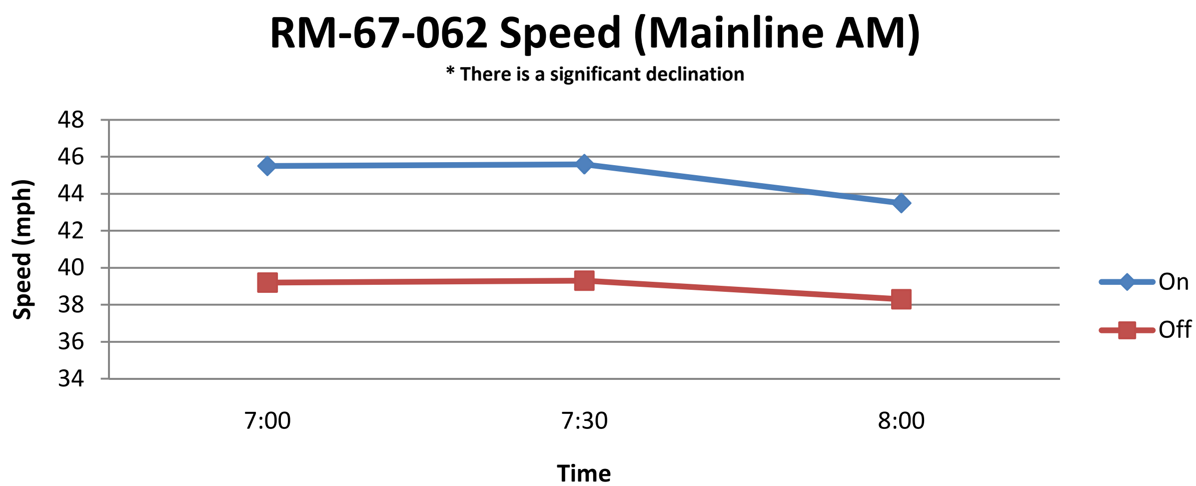
RM-67-062 Occupancy (Ramp AM)

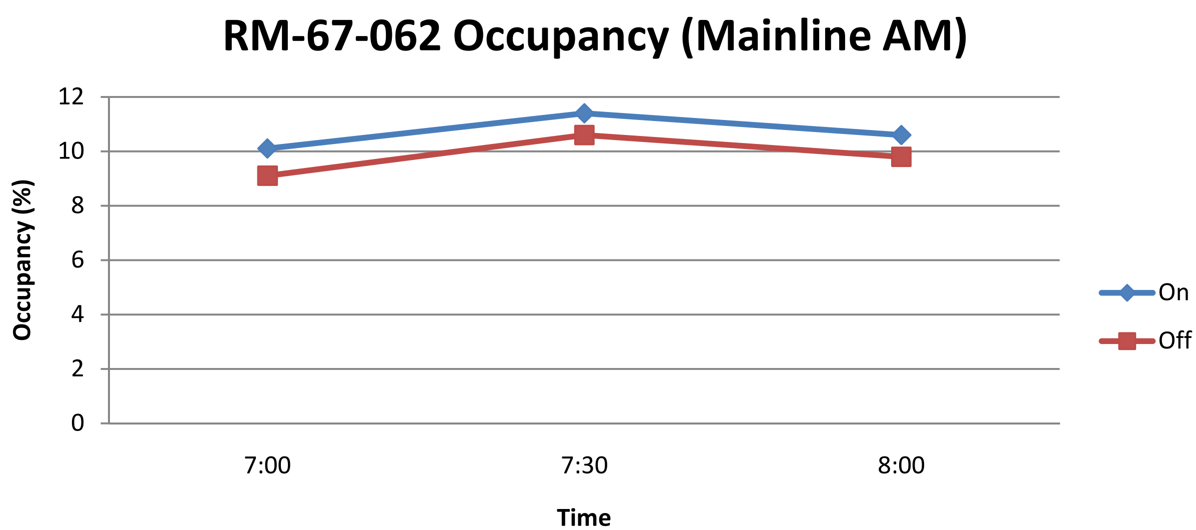
* There is a significant improvement

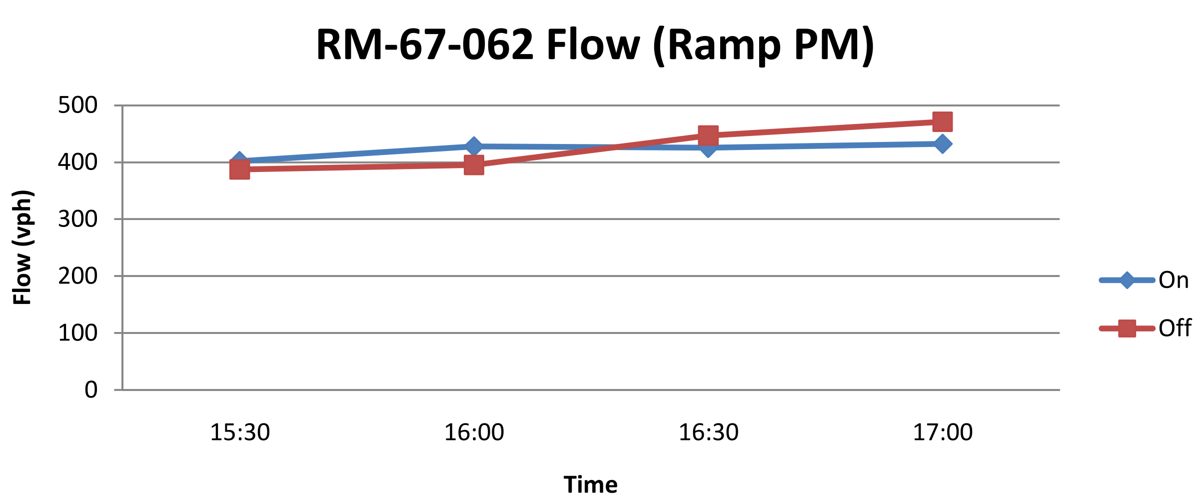


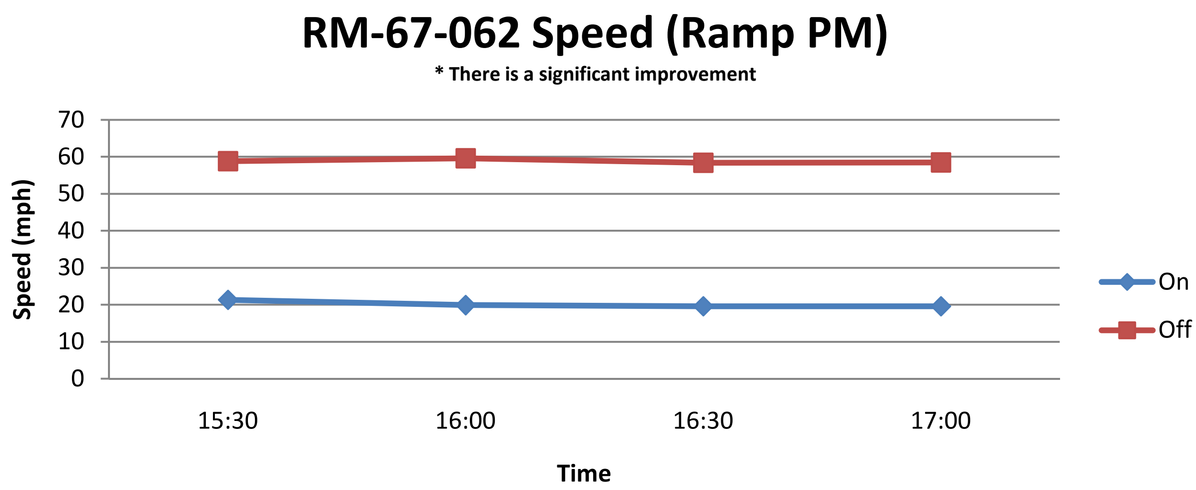
RM-67-062 Flow (Mainline AM)

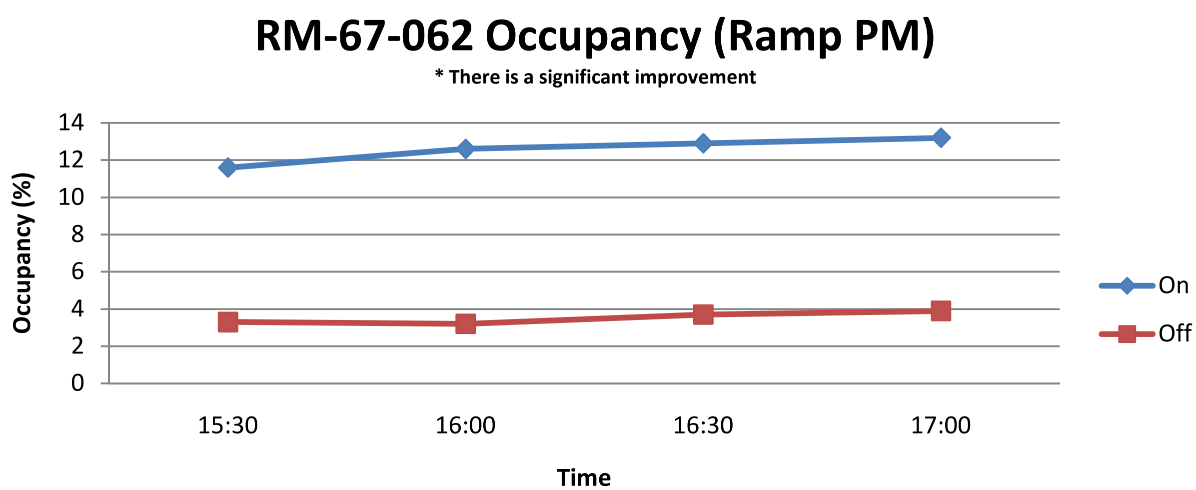


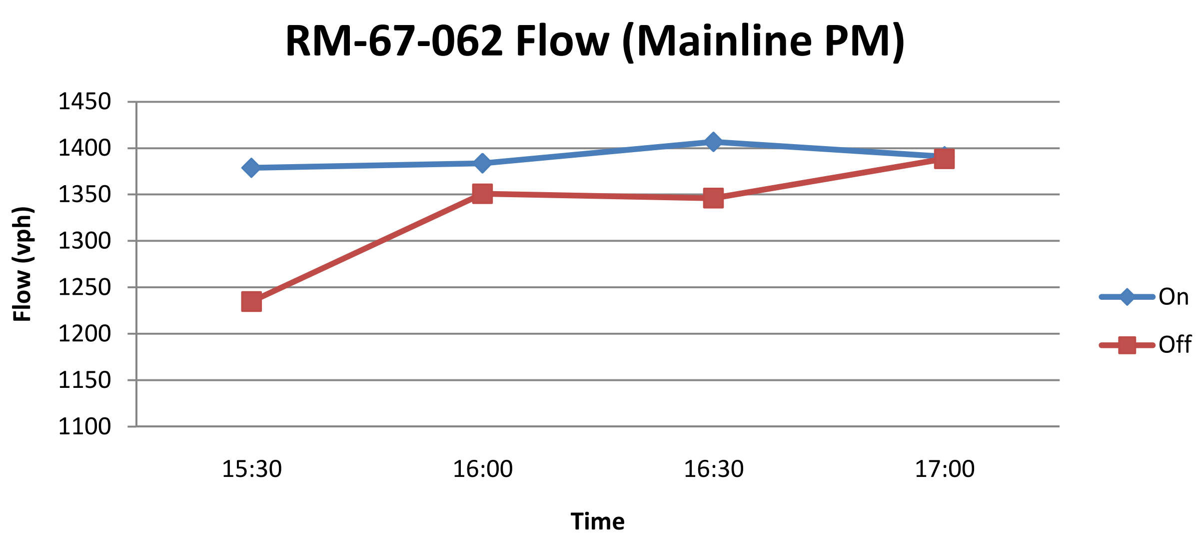

RM-67-062 Speed (Mainline AM)
* There is a significant declination
Speed (mph)
48
46
44
42
40
38
36
34
7:00
7:30
8:00
Time
On
Off

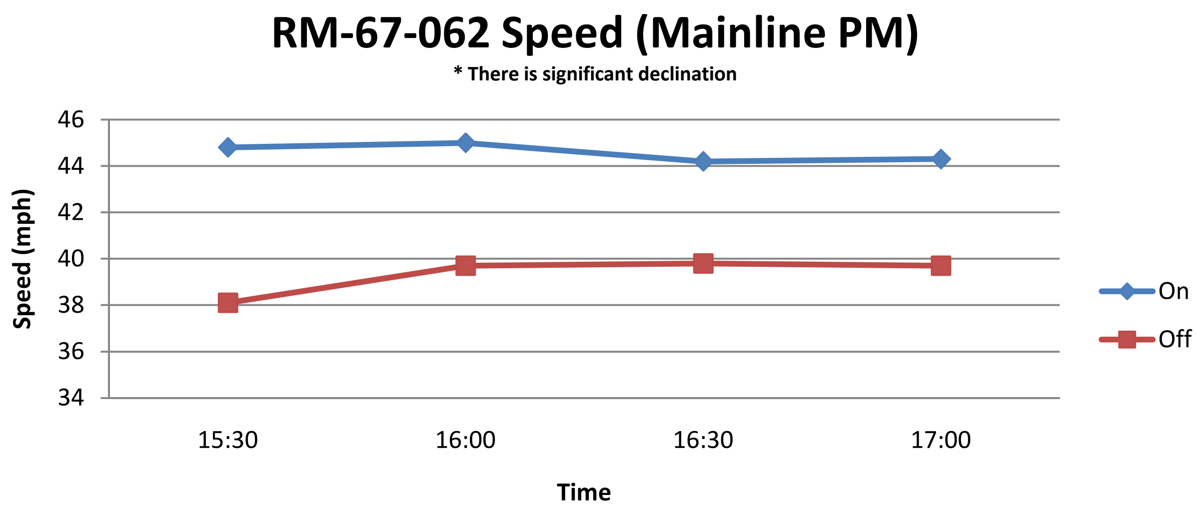

RM-67-062 Occupancy (Mainline AM)
Occupancy (%)
12
10
8
6
4
2
0
7:00
7:30
8:00
Time
On
Off

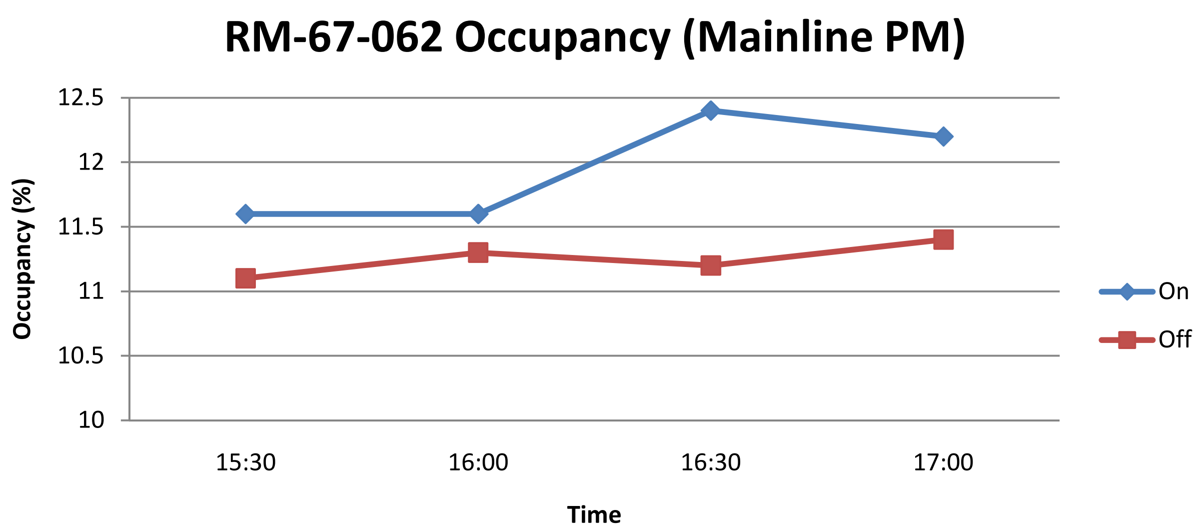

RM-67-062 Flow (Ramp PM)
Flow (vph)
500
400
300
200
100
0
15:30
16:00
16:30
17:00
Time
On
Off


RM-67-062 Speed (Ramp PM)
* There is a significant improvement
Speed (mph)
70
60
50
40
30
20
10
0
15:30
16:00
16:30
17:00
Time
On
Off


RM-67-062 Occupancy (Ramp PM)
* There is a significant improvement
Occupancy (%)
14
12
10
8
6
4
2
0
15:30
16:00
16:30
17:00
Time
On
Off


RM-67-062 Flow (Mainline PM)
Flow (vph)
1450
1400
1350
1300
1250
1200
1150
1100
15:30
16:00
16:30
17:00
Time
On
Off


RM-67-062 Speed (Mainline PM)
* There is significant declination
Speed (mph)
46
44
42
40
38
36
34
15:30
16:00
16:30
17:00
Time
On
Off


RM-67-062 Occupancy (Mainline PM)
Occupancy (%)
12.5
12
11.5
11
10.5
10
15:30
16:00
16:30
17:00
Time
On
Off