

OPEARTION OF RAMP SIGNALING SYSTEM – FDOT’S EXPERIENCES

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ABSTRACT. Ramp signaling, a relatively low-cost traffic management technique, that has been used to alleviate congestion due to bottlenecks and mainline traffic flow being disrupted by entering platoons in the past two decades. As part of an overall long-term strategy of integrated initiatives to improve the safety, throughput and reliability of mobility within South Florida, the Florida Department of Transportation (FDOT) implemented the first Ramp Signaling (RS) system along the I-95 corridor in this region. This RS system is operated by FDOT District VI Transportation Management Center (TMC) located in Miami-Dade County, FL. This paper presents the start-up and the initial operation of the RS system. It provides practical experiences in RM system implementation and operation from a TMC perspective.

Keywords: Ramp Signaling, ITS

INTRODUCTION

Traffic congestion is one of the most severe problems in metropolitan areas throughout the world. In many of these metro areas, existing roadway infrastructures cannot accommodate increasing traffic demand, while construction or expansion of roadway facilities is not feasible due to Right-of-way constraints, financial difficulties, and/or political pressure. This has given rise to the use of low-cost traffic management techniques such as Ramp Signaling (RS) system, which uses traffic signals at freeway on-ramps to control the rate of vehicles entering the freeway. By metering the ramp, the signals can be set for different entering rates generated by a ramp metering algorithm (or a fix rate) to optimize freeway flow and reduce congestion. The primary goal of RS system is to alleviate congestion due to bottlenecks and mainline traffic flow being disrupted by entering platoons.

While RS has been in use in the United States for more than half a century, the first such project in Florida did not go into operation until February 4, 2009, when ramp signals on the northbound section of I-95 in Miami-Dade County were first turned on for South Florida's traveling public by FDOT.

PROJECT OVERVIEW

FDOT's Ramp Signaling System is being deployed in multiple phases. Phase 1a of the system includes eight (8) ramp signals along northbound of I-95 from NW 62nd Street to the Golden Glades Interchange (GGI) (Figure 1), which was activated on February 4, 2009. Before-and-after studies based on both travel time runs and detector data on the corridor have shown that the ramp signals significantly improved both the travel speeds and flow rates on the corridor. Building on this success, Phase 1b of the system is scheduled to commence operation on April 14, 2010. This will add another 14 Ramp Signals on both southbound and northbound directions along I-95 corridor. This RS system is operated and maintained by FDOT District VI Transportation Management Center (TMC) located in Miami-Dade County, Florida.

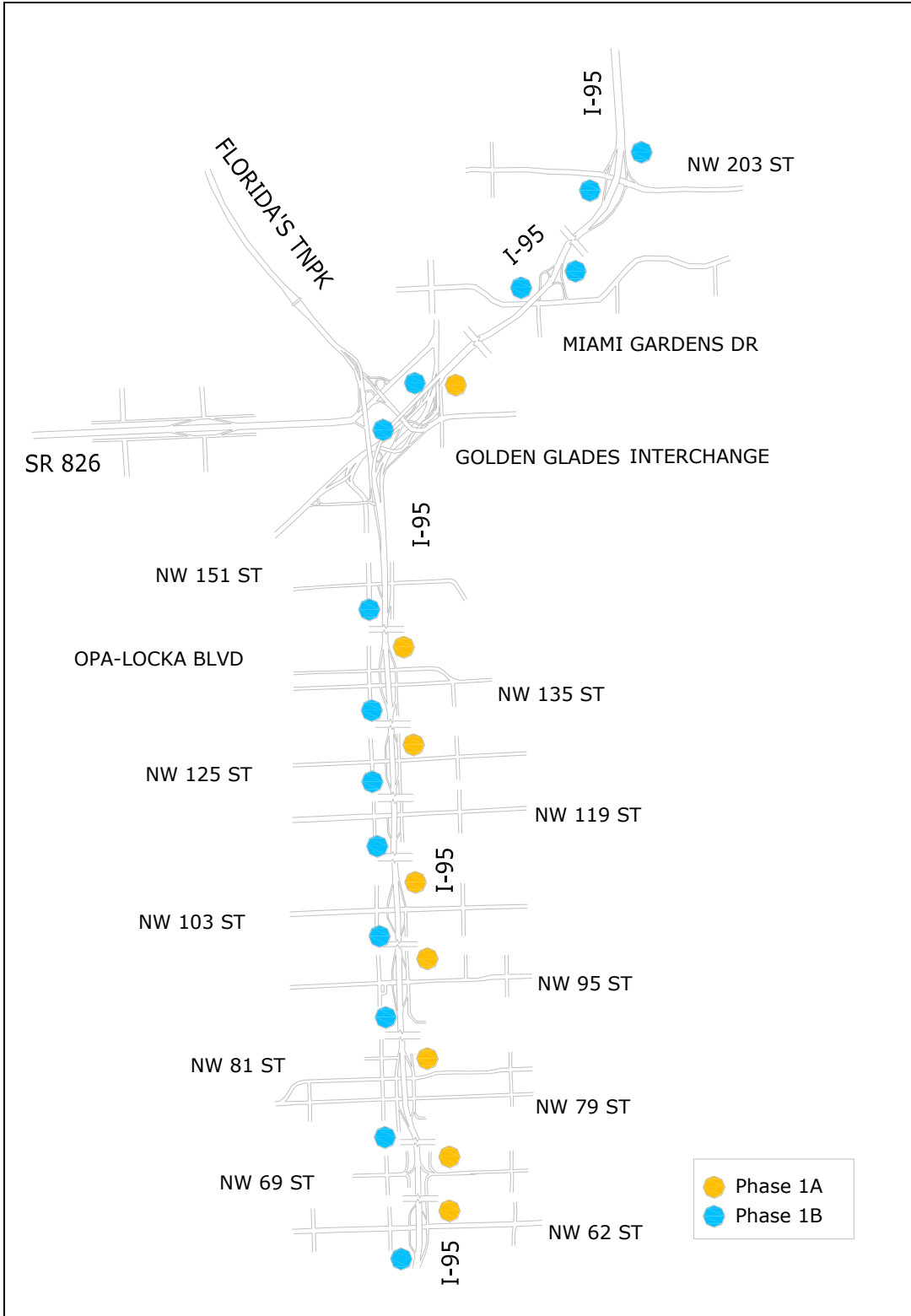


Figure 1 I-95 Ramp Signal Deployment Phase 1

OPERATION SETUP

Successful implementation of Ramp Signaling System requires considerable effort and delicate planning prior to the activation of the system. These efforts include scheduling/staffing plan, inter-agency coordination, system readiness, CCTV installation and Public Information and Outreach (PIO).

Scheduling and Staffing

Three weeks before the activation of the system, FDOT developed a detailed pre-launch, launch, after-launch three-week scheduling/staffing plan. This plan specified all the actions/efforts need to be conducted and the responsible parties for each action. The actions that are generally included in this plan are:

- Pre and Post data collection for Measures of Effectiveness (MOE) study. These include:
 - Travel time data collection (mostly through a floating car study),
 - Turning movement count at the adjacent intersection,
 - On ramp traffic data collection,
 - Freeway/intersection/alternative route traffic operation observation
- System integration and live field test
- Field device inspection
- Filed observer training
- Enforcement training
- TMC operation staff training
- Supply/Equipment coordination
- Meetings/Debriefing

This plan also determined the number and type of staff need to deploy the RS system. The resources that need to be identified include:

- Management Team
- Field Engineers/Ramp Signal Experts
- Maintenance Staff
- TMC Operation Staff
- Field Observers
- System/Software Support
- Administrative Support

The past experiences showed that the three-week scheduling/staffing plan has effectively facilitated the activation of FDOT's RS system.

Inter-Agency Coordination

The implementation of RS system requires coordination among agencies to establish region-wide polices/protocols that guide how the system can be activated and how emerging issues can be solved. FDOT worked closely with local agency responsible for arterial signal management and traffic enforcement agencies in the activation of the system, which significantly contributed to the success of the system.

One major issue associated with the implementation of the RS system is the impact of the ramp queue on the adjacent arterial intersection. In this project, FDOT constantly coordinated with Miami-Dade County Traffic Signals and Signs Division, the local agency that are responsible for the arterial traffic signal operations within Miami-Dade County. The following efforts were performed:

- Meetings were held before implementation to achieve good understanding of how the system was implemented and what issues could arise (e.g., ramp queue blocks the arterial),
- Protocol/Procedure were established between the two agencies to address operation issues that may be caused by Ramp Signals, and
- Inter-agency communication (via a weekly debriefing or direct communication to one designated pointed of contact) after RS system was activated for overall feedback.

To maintain the effectiveness of the RS system, it is important to enforce and achieve compliance of the ramp signal indications in the early operation. At the same time, the motorists should be given an opportunity to learn how to use the system legally and safely. During the implementation of I-95 RS system, FDOT has been working closely with Florida Highway Patrol (FHP) to achieve motorist compliance of the system and reduce the number of violators. The following efforts have been undertaken to achieve enforcement and compliance

- Prior to the turn-on, the executive management of FHP and FDOT met and discussed the implementation of the RM System,
- Elaborate enforcement plan was established to guide the staffing and scheduling, and
- The FHP officers assigned to this program were trained in regards to the operation of the RS System.

Public Information and Outreach

Public support and understanding of RM system is critical to ensure the successful deployment of any RM system. The goal of the public information campaign is to lay the foundation needed to build consensus and understanding of the RM system to be implemented within a corridor. FDOT Public Information Office (PIO) has undertaken various activities during the deployment to keep the public aware of project progress. The targeted audience and the PIO activities include:

- Motorist
 - E-mail Blasts sent through various means
 - Ramp Signaling Brochure created for public distribution
 - Variable Message Signs (VMS) informing of launch date along each ramp signal site two weeks before launch to increase the awareness of the motorists (Figure 2)
 - Static Signs informing of Ramp Signaling at each on ramp (Figure 3)
 - News posted on websites (www.SunGuide.org and www.95express.com)
 - Call Center was established to answer public calls regarding RS system
- Media
 - Press Releases pre and post the implementation
 - Media availability event held at TMC prior to implementation and turn-on
 - News covered by most local TV stations in Miami, both in Spanish and English

- Advertisements in local paper
- Radio commercials through Radio stations both in English and Spanish
- Local Leaders /Local community
 - Public Mail-out to Local leaders including city officials of impacted municipalities as well as other interested members of the community
 - Public meetings were held to achieve buy-in on the project



Figure 2 VMS Informing Launch Date



Figure 3 Static Sign Informing of Ramp Signaling

System Readiness

Implementation of the RM system requires that all the system components including field devices, software/hardware, and system settings be installed and tested in advance of when they are first operated. This reduces the likelihood that motorists will be confused and/or frustrated. The following tasks have been accomplished prior to the system launch:

- Software/hardware were thoroughly tested and troubleshot
- Field devices were properly installed and tested, these include:
 - Detectors – should properly collect and report data to central system
 - Signals – should have proper green/red indication
 - Flashing beacon – flash when signal is on
 - Static signs (e.g., X vehicles(s) per green sign, Ramp Metering when flashing) – should be carefully placed and orientated to be fully visible to motorists
 - Controller– should be able to perform data collection and metering functions
- Parameters that affect the operation of the system were carefully analyzed and proper values were recommended, including:
 - Releasing Rate (one or two vehicle per green) – determined based on analyzing historical on-ramp volume
 - Time of Day Scheduling (timeframes of signal operation)– recommended via examining freeway mainline occupancy distribution over time of day

CCTV Installation and Preset

The utilization of closed-circuit television (CCTV) in RS operation was recognized by FDOT as one of the most important efforts that led to the successful implementation and operation of a RS system. In addition to the existing CCTVs, dedicated Ramp Signaling CCTVs were installed at each Ramp Signaling site. The ideal location and orientation of a Ramp Signaling CCTV should provide full views of the ramp, signal head, adjacent intersection and mainline freeway. This has served as a guideline for FDOT in identifying proper location for the installation of Ramp CCTV. These CCTVs make constant monitoring of each Ramp Signaling Site possible.

To make the monitoring more efficient, a series of “views” were preset for each CCTV. These views were numerically coded and easy for the operation staff to navigate. During operation, the operation staff constantly cycle through the live images of each ramp using these preset views. This smoothed the operation and effectively improved the identification of issues associated with RS system. Figures 4 through 9 depict these preset “views” at one Ramp Signaling site.



Figure 4 CCTV Preset View- Signal Head



Figure 5 CCTV Preset View- Ramp



Figure 6 CCTV Preset View- Intersection



Figure 7 CCTV Preset View- Flashing Beacon



Figure 8 CCTV Preset View- Arterial



Figure 9 CCTV Preset View- Freeway

INITIAL OPERATION

The initial turning-on phase is defined as the time period from the activation of the system to the full steadiness of the system in terms of operation. The initial turning-on is critical in determining the success of a newly implemented RS system because a great number of issues need to be identified and solved in this stage, the system needs to be adjusted for optimal performance, and the public learns how to use the system during the initial turn-on. Hence, immediately after the launch, the system should be monitored and managed and the operation should be analyzed on a continuous basis. The following issues are discussed: (1) field observation deployment, (2) enforcement, and (3) system adjustments.

Field Observation

Performing field observations during initial operation is one of the most effective initiatives that contributed to the success of RS system implementation. Field observers played important roles in (1) educating public and increase the acceptance level of the system, (2) reviewing the effectiveness of RS system, 3) monitoring traffic operation on both arterial and freeway, 4) identification of erratic behavior and failure of the system, and 5) ease motorists frustration. Field observers were trained on the following aspects:

- Understanding Ramp Signaling
- Field Components
- Signaling Operations
- Signal Release Rates
- Whats need to be Observed and Reported
- Usage of Two-Way Radio Communications
- Dealing with the Public
- Materials Needed in Field

The following items were assigned to each observer:

- Safety Vest
- Cell Phone / Two-way radio
- Contact List
- Observation Report
- Location Map
- Brochures / Flyers
- FDOT PIO Contact
- Clipboard
- Flashlight
- Bottled Water

During the observation, the observers communicate via the TMC radio system with each other, as well as TMC operational staff, maintenance crew, and field engineers. System operation are observed in the field and confirmed in the TMC. If problems are observed or reported, adjustments of the parameters via the software, maintenance, or another responsive action are performed. This ensures problems can be fixed in a timely manner without significantly affecting the operation. The resources (i.e., the number of staff) are progressively reduced with the stabilization of the system operation. The followings have been closely monitored and reported by the observers:

- Motorist Behavior in Queue
 - Length of the Queue
 - Observed Queue Jumpers
- Vehicles backing (spillover) into arterials and through the off ramps
- Signal Operation
 - Detector Operation (Passage, Demand, and Queue)
 - Signal Head Operation
 - Flashing Beacon
- Violations

Enforcement

FDOT worked closely with Florida Highway Patrol (FHP) during the initial operation to enforce the newly launched RS system and it significantly contributed to the success of the implementation. To achieve this success, FDOT modified an existing Hireback Contract to include off duty FHP Trooper to be allowed to provide RS enforcement. This contract allowed for the staffing of additional Troopers for RS enforcement but also is utilized for any incident management or incident response within the I-95 Facility. The enforcement level was progressively reduced with the increasing of system stability and motorist compliance. Full coverage enforcement (a trooper was assigned at each ramp site) was deployed in the first two weeks of launch. Specifically, the procedures of the enforcement are listed as the following:

- Week 1 and week 2 - Full coverage enforcement (a trooper at each location during the entire metering period)

- Week 3 and week 4 -50 percent coverage enforcement
- Week 5 through week 12 - 25 percent coverage enforcement
- After Week 13 to present- Targeted coverage, intermittent enforcement

The following strategies are established for the enforcement of the RS system operation:

- In the first 10 working days, the officers should be present and highly visible at each ramp signal site to gain immediate compliance by nearly all motorists,
- A two-week grace period (weeks 1 and 2) is established for motorists. During the grace period, the violators only receive warnings citations. Starting from the third week, the violator will be issued a citation,
- FHP officers should distribute RM informational brochure to the violators to inform them how to properly use the ramp signals, and
- Follow-up Enforcement meetings between FHP and FDOT to improve the enforcement process

System Adjustments

Monitoring and operating the RS system during the initial operational period also included documenting issues of software and hardware, errors from the various devices (e.g., detectors, ramp signal, ramp controllers), as well as fine-tuning of the parameter settings used to control the system. During initial activation, the system errors, the methods to resolve the errors, and any system updates/parameters change that have been incorporated to prevent the errors from occurring in the future were documented. The operational procedures, optimum parameter settings and troubleshooting procedures that were standardized and established from the documentation were included in Standard Operating Guidelines (SOG) of the TMC. This effort will be carried beyond the initial operation of the system and will be continually conducted as a life cycle activity.

OPERATION

The system reaches a day-to-day operational period once the system stabilizes after several month of operation. FDOT integrated Ramp Signal operation into the daily operation of TMC by establishing Standard Operating Guidelines (SOG) for Ramp Signals and utilizing various existing Intelligent Transportation System (ITS) devices (e.g., traffic detectors and CCTVs) in RS operation. The following issues are discussed: (1) operation timeframes, (2) daily operation procedure, and (3) data collection via observation.

Operation Timeframes

FDOT's RS system includes 22 ramp signals along both northbound and southbound of I-95 in Miami-Dade County. Given the nature of traffic variation on this freeway segment, southbound signals (12 signals) are being operational during morning peak period and northbound signals (10 signals) during afternoon peak period. The peak period was identified through analyzing

traffic data (volume and occupancy) from potential downstream detectors adjacent to each Ramp Metering Site. The detailed ramp singling operations schedule is described herein:

- The AM peak period – 6:00 AM to 10:30AM
- The PM peak period – 3:00 PM to 7:00 PM

The turning-on and turning-off of each ramp signal is also subject to the traffic conditions and the signals are not necessarily turned on at the same time. For example, the signal may be turned on earlier than 3 PM or turned off later than 7PM if needed when mainline I-95 is highly congested. The Ramp Signals are also being used in traffic management when non-recurring congestion is caused by incidents, meaning that the signals may be turned on or turned off when needed to alleviate the congestion in response to an incident. This is introduced in next section.

Daily Operation Procedure

FDOT developed operation guidelines based on initial operation experiences. These guidelines, as part of TMC Standard Operating Guidelines (SOG), include both technical and human resources/procedures for RS operation and monitoring. The daily operation of FDOT’s RS system includes multi-steps that are graphically depicted in the RS System Daily Operation Flowchart (Figure 10).

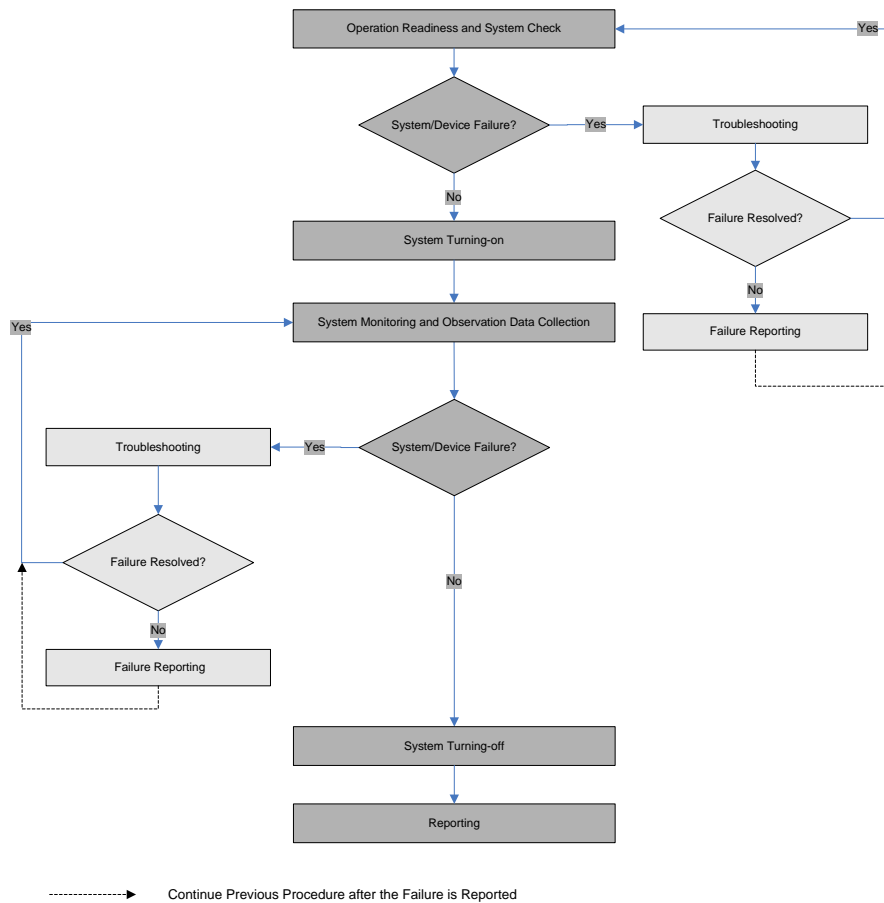


Figure 10 FDOT Ramp Signaling System Operation Procedure

The procedures are further explained below:

- Operation Readiness and System Check – This step includes Ramp Signaling Workstation readiness, software readiness, daily operation log preparation and RM system check.
- System Turning-on – During the peak period, Ramp Signals shall be turned on to help regulate flow onto the freeway. This step established the guidelines for the operation staff to determine when to turn on the RS. Generally TMC Operations Staff monitor the detector to determine when to turn the signals on. Once the average spot speeds drop below the 45 mph in a consistent five (5) minutes period, the TMC operator initiate the tuning on of adjacent RS that is upstream to the detector(s).
- System Monitoring and Observation Data Collection – After the Ramp Signals are turned on, the operation staff should use CCTVs, detector data and other sources to monitor the system operation and traffic conditions; the operation staff should also collect and document various observation data pertaining to the system operation. (See Data Collection for data obtain).
- Troubleshooting – When a failure (e.g., loss of communication, detector failure) is identified prior to or during operation, the operation staff should verify and document the failure. The operation staff should perform preliminary troubleshooting before reporting the failure into Maintenance Database.
- Failure Reporting – To maintain high system availability, the operation staff must report the failure if the failure cannot be resolved via preliminary troubleshooting.
- System Turning-off –After the peak period, Ramp Signals should be turned off. The operation staff should turn off the ramp signals following the turning-off guidelines.
- Reporting – The operation staff prepare a daily report upon completion of RS system operation. Daily reports will include information on turning-on/-off timings, ramp queues, listing of emergency or special events, etc. A weekly report will also be prepared to provide a weekly debriefing on the RS system operation.

Data Collection

During operation, the operational staff cycle through all the Ramp Signal sites periodically (currently every 15 minutes) to monitor the operation of the RM system. The frequency of cycling should be determined based on the number of Ramp Signals and the level of staffing. Observation data are being documented in the daily operation log every 15 minutes. The data documented by FDOT include:

- Signal Operation – normal or not
- Queue length (%) – the maximum percentage of the ramp being occupied by the vehicles within the 15 minutes
- Number of Vehicles on ramp – the maximum number of vehicles queuing on the ramp within the 15 minutes
- Number of Vehicle spilled back – the maximum number of vehicles spilled back onto the arterial within the 15 minutes
- Other Issues –
 - Recurring Congestion

- Mainline Traffic Stopped
- Incident on Ramp
- Incident on Mainline
- Mainline Traffic Moving Slowly
- Recurring Congestion- Mainline Traffic Moving Slowly
- Short Stop
- Significant Red Light Violations
- Mainline Free Flow
- Incident – document the event number of the event occurring within the scope of RS implementation that has affected the operation of the RS system.

RAMP SIGNALING FOR INCIDENT MANAGEMENT

After gaining adequate experience on Ramp Signal operation, FDOT started to utilize Ramp Signaling in incident management and managing special event traffic. FDOT’s practices showed that flexible ramp signaling strategies can facilitate incident clearance and mitigate congestion caused by an incident, especially when the incident occurs near a Ramp Signaling Site. Figure 11 demonstrates the utilization of ramp signaling by FDOT during an incident.

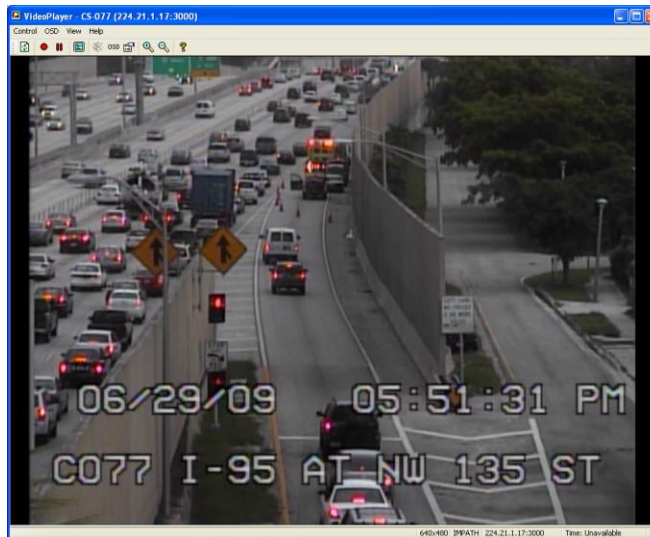


Figure 11 FDOT Ramp Signaling in Incident Management

To mitigate the impact of the event and to provide greater system efficiency, the following actions may be taken during an event:

- Metering Rate adjustment- higher
- Metering Rate adjustment- lower
- Ramp Signal turn-off
- Ramp Signal turn-on (real time traffic responsive)

The level of restriction on ramp traffic is shown in Figure 12:

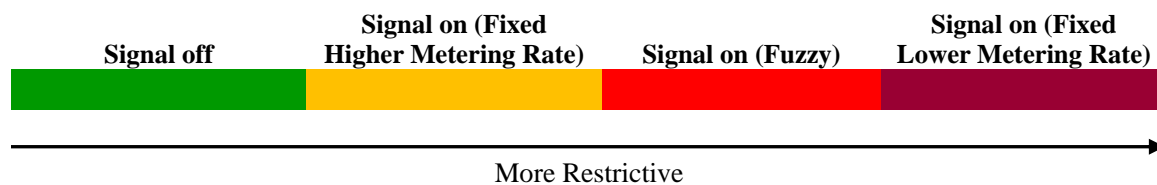


Figure 12 FDOT Ramp Signaling Strategies and Restrictive Level

The selection of the action to be taken depends on the nature of the event (e.g., severity), the event location and the assessment of Ramp Signaling operation. To mitigate the impact of the event and assist in the recovering of the roadway capacity, the following operational strategies are established by FDOT in the selection of action in an event:

- All Lane Blockage Events – all upstream Ramp Signals from the event should be turned on and the Metering Rate shall be lowered. The minimum Metering Rate should be used. TMC operations staff should monitor the queues both for the ramps and the mainline freeway. The downstream Ramp Signals from the event shall be turned off temporarily to allow the arterial adjacent to the on-ramp to recover and provide an easy alternate route during the event. The Ramp Signal should be turned on immediately after the lane blockage is cleared.
- Events with More than Two Lane Blockage –all upstream Ramp Signals from the event should be turned on and the Metering Rate shall be lowered. The minimum Metering Rate should be generally used; however the level of congestion on mainline and the queue on the ramp should be monitored and an appropriate Metering Rate should be determined. The first adjacent downstream Ramps Signals should be turned off or temporarily turned off during peak period. Depending on the level of congestion, the other downstream Ramp Signals from the event can be turned off or use a higher Metering Rate. The Ramp Signal should be turned on immediately after the lane blockage is cleared.
- Events with Two or Less Lane Blockage – the first adjacent upstream Ramp Signal should be turn on and a lower Metering Rate should be used. The minimum Metering Rate should be generally used; more upstream signals should be turned on depending on the queuing conditions. The downstream Ramp Signals should be turn on and a higher Metering Rate should be used. The first adjacent downstream Ramps Signals should be turned off or temporarily turned off during peak period. Operational staff should determine an appropriate Metering Rate based on the queuing condition on ramp. When the blocked lane is open, the Metering Rate at downstream Ramp Signals should be adjusted back to normal operation or turned off once the freeway has returned to free flow conditions.
- Events without Lane Blockage – for an event without lane blockage but causing congestion during peak hours, the first adjacent upstream Ramp Signal should be turn on and a lower Metering Rate should be used. More upstream signals should be turned on depending on the queuing conditions. The Ramp Signal Signals just upstream of the end of the queue tail should always be turned on. The downstream Ramp Signals should remain operational during peak hours and turned off during non-peak periods.

Figures 13 and 14 depict the actions to be taken during events with varying level of severity.

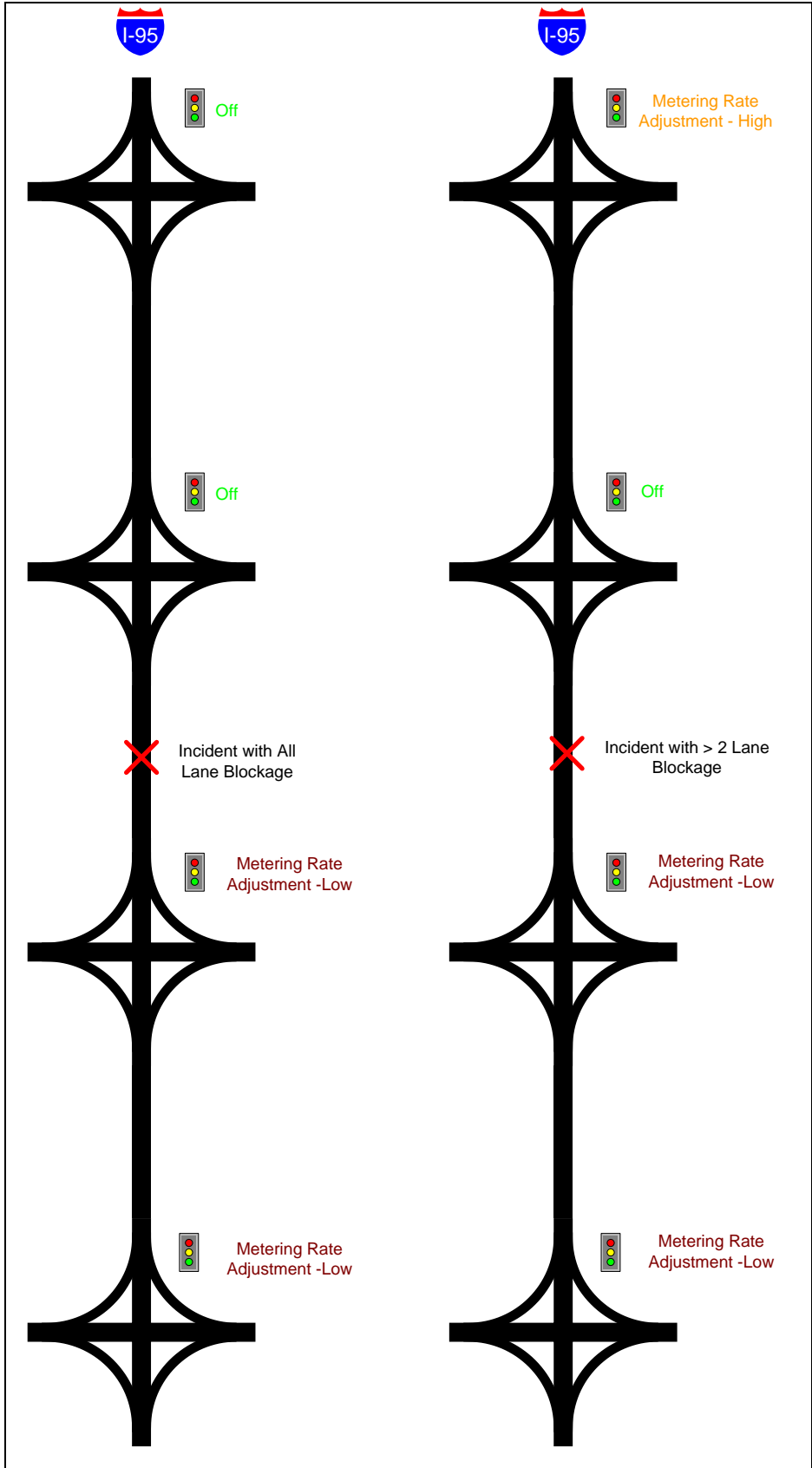


Figure 13 FDOT Ramp Signaling Strategies Applied during Incident (1)

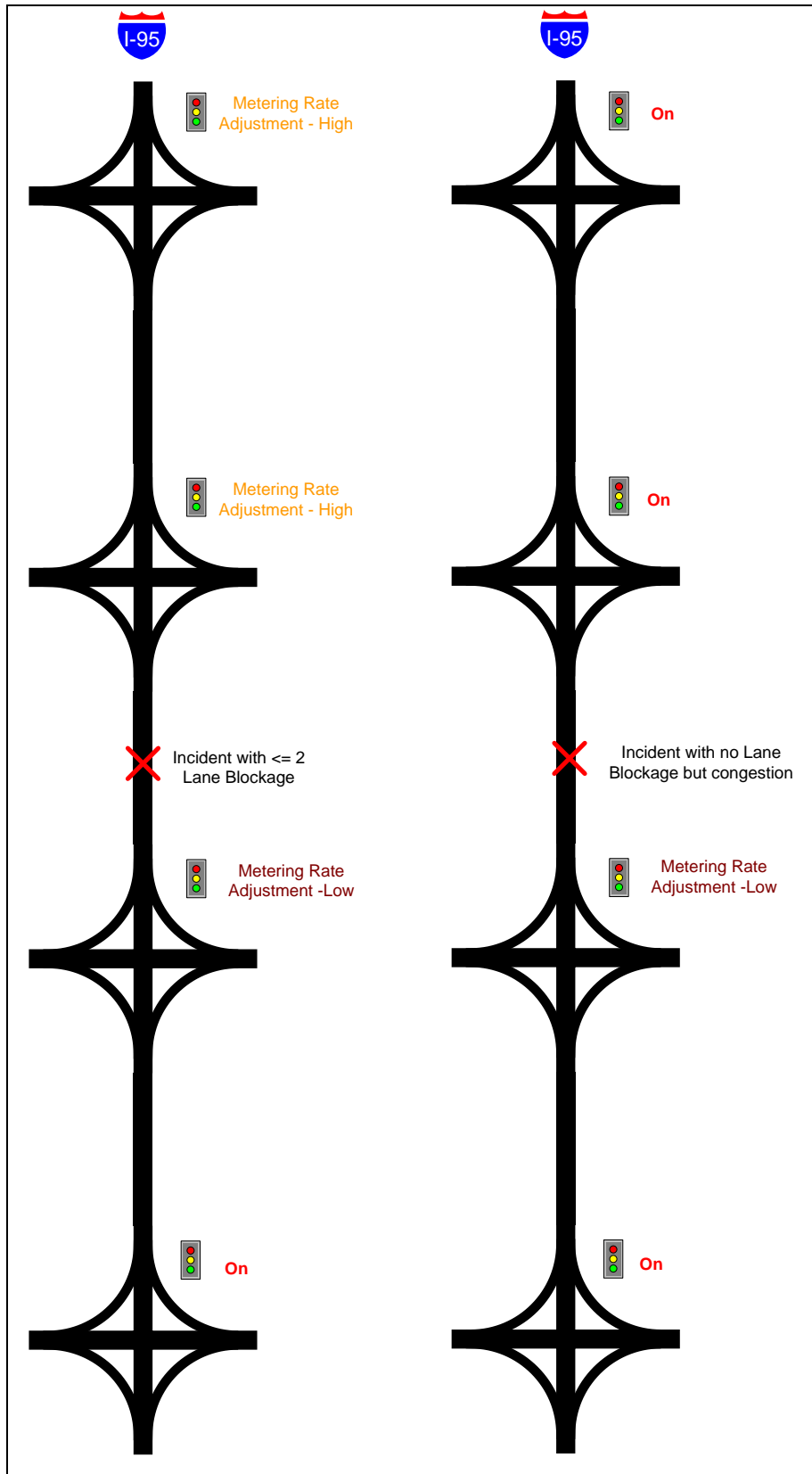


Figure 14 FDOT Ramp Signaling Strategies Applied during Incident (2)

When there is a Special Event (e.g., sports event), management team will develop a RS operation plan in preparation for the particular event. The plan includes the following:

- Nature of the event
- Time and Duration of the Event
- Travel Lane Blockage, if applicable
- Revised Minimum and Maximum Metering Rates, if applicable
- Revised Turning on and Turning off timeframes, if applicable

The 2010 Super Bowl event was hosted in Miami and the event caused an influx of traffic on major freeways in the Miami area including I-95. During the event, Ramp Signals were turned on to assist with the increased demand of traffic on I-95. Traffic conditions were affected due to the large number of police escorts shutting down the roadway. The implementations of the signals for the special event allowed the freeway to recover and improved trip reliability for motorist attending the event.

LESSONS LEARNED

FDOT has been operating Phase 1a of the RS system for more than a year and is currently implementing Phase 1b of the system. FDOT recognized a variety of experiences and lessons learned from its successful implementation and operation of RM system. These lessons learned should provide practical experiences and benefit future similar system implementation. These include:

- A detailed pre-launch, launch, after-launch scheduling/staffing plan that specified all the actions/efforts need to be conducted and the responsible parties for each action facilitated the success of RS system launch.
- Early coordination and communication with local agencies, especially the agency responsible for arterial signal management, significantly contributed to the success of the system implementation.
- Well coordinated and established enforcement plan in early operation substantially promoted and maintained the effectiveness of the RS system.
- Considerable PIO effort played critical role in promoting public support and understanding of the RS system, which extensively contributed to the successful deployment/operation of the system.
- Comprehensive system test (e.g., field devices, software/hardware, and system settings) prior to system launch ensured the stable functionality of the system, which effectively reduced motorists' confusion and frustration.
- The utilization of dedicated CCTV substantially improved the operation of a RS system. The ideal location and orientation of a Ramp Signaling CCTV should provide full views of the ramp, signal head, adjacent intersection and mainline freeway.
- The deployment of a well-trained field observation team during initial operation effectively contributed to the success of RS system implementation and operation. These field observers played important roles in educating the public, reviewing the effectiveness of RS system, and identification of erratic behavior and failure of the system.

- A well established Ramp Signal operation procedure to effectively facilitate the daily operation. The procedures were included in FDOT TMC Standard Operating Guidelines (SOG). Dedicated operation staffs were trained on SOG to closely monitor the RS system and traffic operation.
- The practice of FDOT indicated that flexible ramp signaling strategies implemented during an incident or special event can effectively facility incident clearance and mitigate congestion caused by the incident/special event.

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