# SYNCHROGREEN REAL-TIME ADAPTIVE TRAFFIC CONTROL SYSTEM
# SEMINOLE COUNTY SR 436 DEPLOYMENT

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## ABSTRACT

SR 436 (Altamonte Drive), between Westmonte Drive and Maitland Avenue, is a 1.7 mile roadway segment in Seminole County, Florida. This corridor includes 12 traffic signals and a minimum six lane roadway section within the study area. This corridor presents a number of challenges with respect to traffic signal coordination, which are not easily overcome using conventional traffic signal timing principles. Over 700 transition events due to pre-emption or pedestrian crossings have been recorded within a 24-hour period; making traffic signal coordination on SR 436 difficult. Seminole County staff has adjusted the signal timing on SR 436 in response to changing traffic conditions through routine maintenance and retiming studies. Despite these adjustments, the unpredictable nature and day-to-day fluctuation on this corridor are not conducive to actuated-coordinated operations.

SynchroGreen provides an intuitive interface and platform to implement real-time adaptive traffic control. SynchroGreen collects traffic data at intersections over time, analyzes it for changing trends and adjustments are programmed into the traffic signal controllers. SynchroGreen was deployed by Seminole County in May 2011. The goal of SynchroGreen was to improve traffic conditions on SR 436. Both vehicular traffic and pedestrians were considered on this project.

Reductions in arterial travel time and delay are given in Table A.1. Most notably, mid-day (MD) travel time runs were reduced by 27 percent eastbound and 25 percent westbound, while delay was reduced 46 percent eastbound and 37 percent westbound. On average, side-street delay reduced by 19 percent, while pedestrian delay reduced by 10 percent. Fuel consumption was reduced a minimum of 8 percent during all time periods, resulting in fewer HC, CO and NOx emissions.

**Table A.1 - Travel Time and Delay Comparison**

| SYNCHROGREEN STATUS | | AM Peak | | MD Peak | | PM Peak | |
|---|---|---|---|---|---|---|---|
| | | Travel Time (s) | Delay (s) | Travel Time (s) | Delay (s) | Travel Time (s) | Delay (s) |
| EASTBOUND | "OFF" | 266 | 113 | 369 | 216 | 393 | 239 |
| | "ON" | 253 | 100 | 271 | 117 | 331 | 177 |
| | **% Difference** | **-5%** | **-11%** | **-27%** | **-46%** | **-16%** | **-26%** |
| WESTBOUND | "OFF" | 311 | 157 | 488 | 334 | 450 | 296 |
| | "ON" | 293 | 139 | 363 | 210 | 418 | 264 |
| | **% Difference** | **-6%** | **-12%** | **-25%** | **-37%** | **-7%** | **-11%** |

## INTRODUCTION

This paper describes the results of a project in Seminole County, Florida involving Trafficware's SynchroGreen Real-time Adaptive Control System. This project demonstrates the benefits of SynchroGreen using actual field data collected while SynchroGreen was both active and inactive. A discussion of the project location, objectives, study methodology, data collection and results is included in the following sections.

### Background

SR 436 (Altamonte Drive), between Westmonte Drive and Maitland Avenue, is a 1.7 mile roadway segment in Seminole County, Florida. This corridor was selected as it provided a challenging setting to test the capabilities of a new technology. This corridor includes 12 traffic signals and a minimum six lane roadway section within the study area. Average Daily Traffic (ADT) is approximately 59,600 vehicles. Nearby development includes the Altamonte Mall, Florida Hospital-Altamonte and numerous retail, dining and entertainment establishments. I-4 intersects SR 436 forming two intersections with the eastbound and westbound exit/entrance ramps. Intersections involving I-4, as well as Douglas Avenue and Cranes Roost Boulevard are major intersections on SR 436.

This corridor presents a number of challenges with respect to traffic signal coordination, which are not easily overcome using conventional traffic signal timing principles. This corridor is in close proximity to Florida Hospital-Altamonte, a major medical facility, as well as Seminole County Fire Station 12. Due to the hospital and fire station, emergency vehicles frequently access SR 436 and utilize traffic signal pre-emption. Within a 24-hour period, over 140 pre-emption calls have been recorded on SR 436 (sum of all 12 signalized intersections). Pre-emption causes phases to extend or truncate, requiring the traffic signal controller to transition back to normal operations once the emergency vehicle exits the intersection. Multiple intersections are typically impacted by an emergency vehicle as the vehicle traverses SR 436.

Most traffic signal coordination issues on SR 436 are attributed to high pedestrian volumes. Within a 24-hour period, over 1,100 pedestrian calls have been recorded at the study intersections. Furthermore, side-street splits are less than pedestrian walk and clearance intervals across SR 436 at most intersections; this allows for maximum main-street progression in the absence of pedestrians. However, when a pedestrian call is received, large pedestrian clearance intervals are required to cross SR 436 and the corresponding side-street phases are extended beyond programmed force-off points. Pedestrian walk and clearance intervals across SR 436 are between 35 and 53 seconds. Once the pedestrian clearance interval terminates, the traffic signal controller transitions back to the normal timing plan and often requires several cycles to recover. As a result, the controller does not return to coordinated phases at assigned times and causes poor arterial progression, excessive vehicle queuing and unpredictable traffic flow on SR 436. This phenomenon is compounded during peak periods when vehicular and pedestrian volume is highest.

Transition is the process of either entering into a coordinated timing plan or changing between two plans (*1*). Transition is often necessary after an event such as pre-emption or a pedestrian crossing SR 436. Within a 24-hour period, over 700 transition events have been recorded on SR 436. Due to the number of transition events that occur on SR 436 on a daily basis, maintaining traffic signal coordination is difficult.

Seminole County staff has adjusted the signal timing on SR 436 in response to changing traffic conditions through routine maintenance and retiming studies. Despite these adjustments, the unpredictable nature and day-to-day fluctuation on this corridor make traffic signal timing difficult and not conducive to actuated-coordinated operations.

**Objective**

The goal of this project was to improve traffic conditions on SR 436 using SynchroGreen. Both vehicular traffic and pedestrians were considered, as it was desired to provide optimal service for these modes. Specific objectives are as follows:

- Reduce Arterial Travel Time
- Reduce Arterial Delay
- Reduce Number of Stops
- Reduce or Maintain Side-Street Delay
- Reduce or Maintain Pedestrian Delay
- Reduce Emissions

**SYNCHROGREEN**

SynchroGreen provides an intuitive interface and platform to implement real-time adaptive traffic control. SynchroGreen collects traffic data at intersections over time, analyzes it for changing trends and adjustments are programmed into the traffic signal controllers. SynchroGreen is National Transportation Communications for ITS Protocol (NTCIP) compliant and is compatible with standard NEMA/2070/ATC traffic controllers. SynchroGreen does not require external hardware. The SynchroGreen adaptive operation is accomplished through two major components:

1. SynchroGreen measures and makes phase allocation and period adjustments based on real-time traffic data.
2. SynchroGreen provides information to system traffic signal controllers to ensure traffic progression.

SynchroGreen does not operate using fixed cycle lengths. Instead, “periods” are used to define the length of time to service all phases. SynchroGreen uses volume or occupancy data from inductive loops, video or other detection devices to analyze green time utilization. Based on these data, SynchroGreen establishes target “phase allocation” and periods for each intersection; the goal is to minimize these values in order to minimize the time between successive green intervals for a particular phase. Target periods are compiled from each intersection, and the maximum is selected as the corridor period for that iteration. On average, the selected period is shorter than the time-of-day cycle length under a traditional actuated-coordinated system.

SynchroGreen uses a transition-less offset adjustment to improve traffic progression. “Start time” replaces the traditional offset using SynchroGreen. As the period and traffic flow changes, the greenband start time for each intersection is adjusted. The updated start time calculation promotes better progression along the main-street. A traffic signal controller may still transition for other reasons (pattern change, pre-emption, pedestrian crossing, etc.); however, it will not enter transition due to changing offset.

**Seminole County SynchroGreen Deployment**

SynchroGreen was deployed by Seminole County in May 2011. A diagram for this deployment is given in Figure 1. This deployment used a central server system to operate SynchroGreen. Seminole County utilized Naztec 900 series TS2 controllers and installed additional video detection. Seminole County utilized existing loop detection on main-street left-turn lanes and side-streets and installed new cameras for main-street stop-bar detection. Seminole County elected to create a test bed using real traffic controllers before deploying SynchroGreen in the field. This allowed for optimization of SynchroGreen settings before implementation. No proprietary hardware was installed inside the traffic signal cabinet to operate SynchroGreen.

Seminole County used the Naztec controller feature “stop-in-walk”. This allows pedestrian walk and clearance intervals to time beyond the concurrent phase force-off. This causes the traffic signal controller to transition in order to re-establish coordination. Where pedestrians cross SR 436, Seminole County staff selected minimum phase allocation to better align with the time required for pedestrian walk and clearance. Minimum phase allocation was set to 45 seconds for these phases. This number is based on the average time required for pedestrian walk and clearance across SR 436. This setting limited the transition time resulting from a pedestrian call. However, it also created longer phase allocations and periods than may have been required. Ultimately, these settings were designed to mitigate the effects of pedestrians and better maintain traffic signal coordination.

For this deployment, start time adjustments were based on period changes only and did not change based on traffic flow. This decision was made by Seminole County based on the close intersection spacing at some locations on SR 436 that limited the ability to use advanced detection.

## DATA COLLECTION/METHODOLOGY

An “On-Off” study was performed to test the effectiveness of SynchroGreen using a number of standard evaluation studies. The evaluation studies considered not only main-street measures of effectiveness (MOEs) but also those for side-streets and pedestrians. Data were collected in April 2011, as well as after SynchroGreen was deployed in May 2011. Data collection occurred on average weekdays (Tuesday, Wednesday or Thursday) while school was in session during AM, Mid-day (MD), and PM peak periods. Peak periods are defined as follows:

- AM Peak (7:00 A.M. – 9:00 A.M.)
- MD Peak (11:00 A.M. – 1:00 P.M.)
- PM Peak (4:00 P.M. – 6:00 P.M.)

**Arterial Travel Time and Delay**

Arterial travel time and delay were recorded using a global positioning system (GPS) receiver and computer software. Travel time runs were performed in each direction while SynchroGreen was active (“On”) and while it was inactive (“Off”). The “floating car technique” was used for this study, whereby the probe vehicle traveled at speeds and maneuvered in a matter that was representative of other vehicles on the roadway. The Probe vehicle began travel time runs at various time points during signal cycles or periods to avoid starting each run at the same location within a platoon. Some travel time runs were video recorded for comparison.

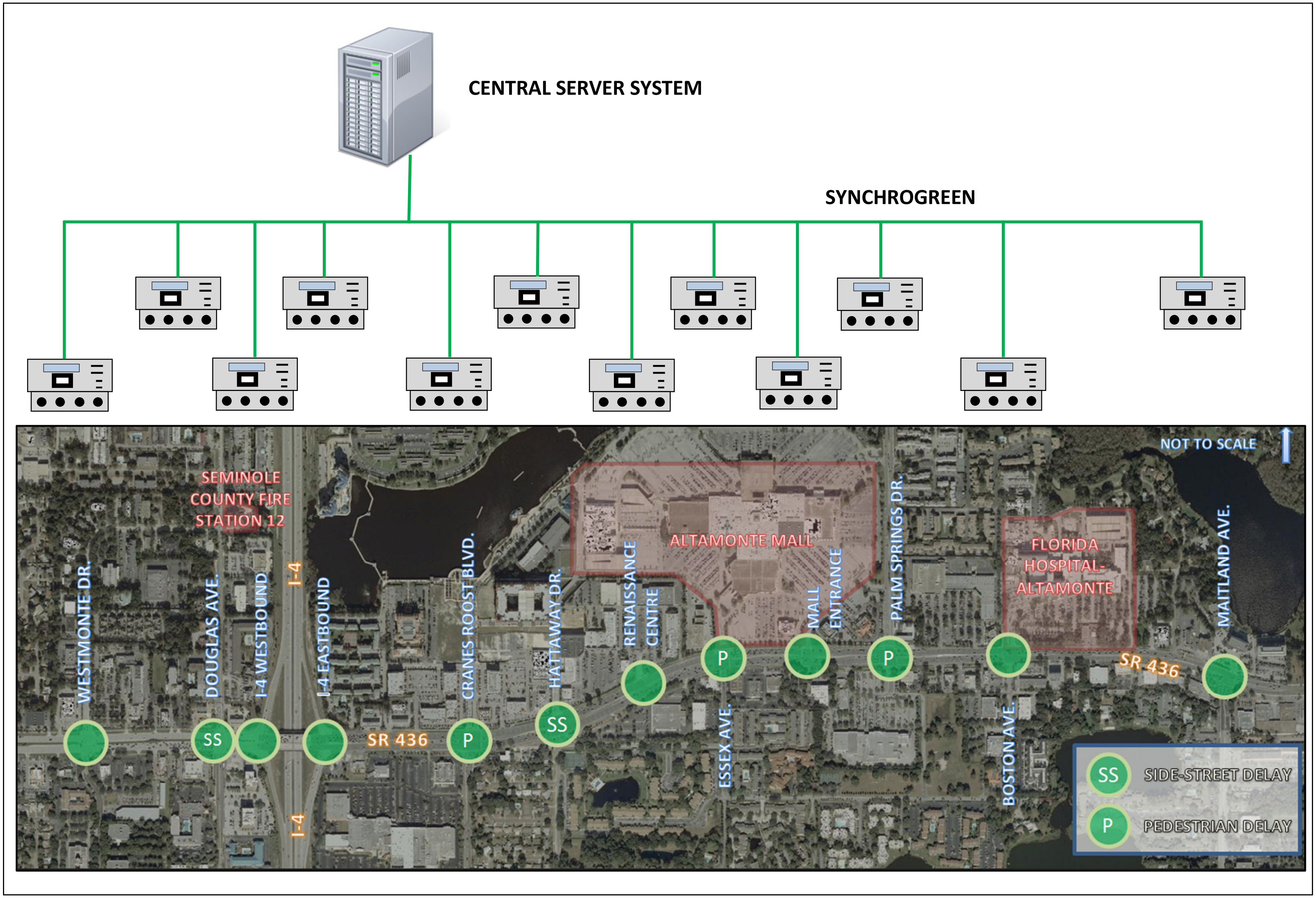


**Figure 1 - SR 436 Deployment in Seminole County, Florida**

Processing of GPS data yielded a number of MOEs, such as: travel time, delay and stops. Data were reduced by intersection and were aggregated to produce overall system results. Delay is defined as the difference between the actual travel time and the time required to traverse the corridor at free-flow speed.

**Side-Street Delay**

Side-street control delay was measured in the field using procedures outlined in the *Highway Capacity Manual (HCM 2010)* (*2*). This analysis was conducted at two intersections (Douglas Avenue and Hattaway Drive) during MD and PM peak periods (see Figure 1). These two intersections were selected based on relative balance of left, through and right-turn maneuvers. Other intersections had disproportionately high turning maneuvers, channelized right-turns, lack of volume or oversaturated conditions that were not conducive to procedures outlined in the *HCM 2010*. At each intersection, one approach was selected to be included in the side-street delay study; each approach was comprised of two lane groups.

A survey period of 30 minutes was selected for this study, while a 15 second count interval was used for all field analyses and was not a multiple of the cycle length. Surveys began at the start of the red indication for the study lane group when no vehicles were queued. Two field personnel were used during this procedure; one person was responsible for recording vehicle arrivals, while the second was responsible for recording the number of vehicles in the queue (queue-count). Vehicle arrivals were classified as "stopped" or "not-stopped". Vehicles turning right-on-red that did not significantly yield to conflicting traffic were recorded as "not-stopped".

The queue-count portion of the delay estimate was performed by counting the number of vehicles queued in the study lane group every count interval (i.e., 15 seconds). A queued vehicle was defined as those that were within one car length of a stopped vehicle and was itself about to stop. A vehicle was counted as queued until the rear axle crossed the stop line (through vehicles) or until the vehicle cleared opposing traffic (turning vehicles). Data were reduced using the worksheet provided in the *HCM 2010*. Ultimately, field estimates of control delay were produced for each lane group, and were used to calculate control delay for each approach.

**Pedestrian Delay**

Pedestrian delay was measured in the field for those crossing SR 436 using a simple stopwatch technique. Pedestrian delay was measured at three locations (Cranes Roost Boulevard, Essex Avenue and Palm Springs Drive) during the PM peak (see Figure 1). Delay was measured from the moment a pedestrian arrived at the intersection until they entered the roadway. An arrival was recorded once the pedestrian pushed the pushbutton. If a pedestrian did not press the pushbutton upon arrival, then arrival time was approximated. If a pedestrian did not wait until the "Walk" symbol was displayed after pressing the pushbutton, the delay measurement was not stopped, it continued until the "Walk" symbol was displayed. Due to heavy vehicle traffic on SR 436, these instances were rare, and most pedestrians utilized pushbuttons and did not cross SR 436 until the "Walk" symbol was displayed. A pedestrian was not recorded if they did not press a pushbutton and did not wait for the "Walk" symbol. Pedestrians that did not utilize crosswalks were not recorded.

**Fuel Consumption and Emissions**

Emissions were calculated using the microscopic emissions model *MICRO2*, commonly included in GPS computer software (*3, 4*). Fuel consumption and emissions data were compiled for each travel time run and used as inputs in the *MICRO2* model. This model calculates fuel consumption and emissions (HC, CO and NOx) as a function of velocity and acceleration using "instantaneous" GPS data. *MICRO2* is intended to model emissions produced by a typical light-duty vehicle. Fuel consumption and emissions coefficients were not calibrated to this geographic area; however, it is believed that this model provides a reasonable comparison of environmental MOEs.

**RESULTS**

This section provides a comparison of MOEs while SynchroGreen was active and inactive. Results are tabulated and briefly discussed, while additional tables and figures are in the appendices. Arterial travel time and delay results were used as the primary measures for determining SynchroGreen effectiveness, while stops, side-street delay, pedestrian delay and emissions were used to supplement these findings. All data were collected during an average weekday with similar traffic volumes. Miovision average daily traffic (ADT) counts were used to verify that traffic volumes were similar during data collection when SynchroGreen was active and inactive (*5*).

SynchroGreen "period" data for May 24, 2011 is given in Table 1 and Figure 2. These data were recorded while SynchroGreen was active and are compared to the actuated coordinated cycle length that normally operated before SynchroGreen was implemented. These data are typical of period adjustments that occur on SR 436 on a typical weekday and demonstrate how SynchroGreen responds to fluctuating traffic conditions. It should be noted that the average period is lower than the corresponding actuated-coordinated cycle length for all scenarios (AM, MD and PM). The implications of these trends are discussed in the following subsections.

**Table 1 - Cycle Length and Period Comparison May 24, 2011(sec)**

| CONTROL | AM | MD | PM |
|---|---|---|---|
| **SYNCHROGREEN** | 142 | 141 | 155 |
| **ACTUATED-COORDINATED** | 150 | 160 | 200 |

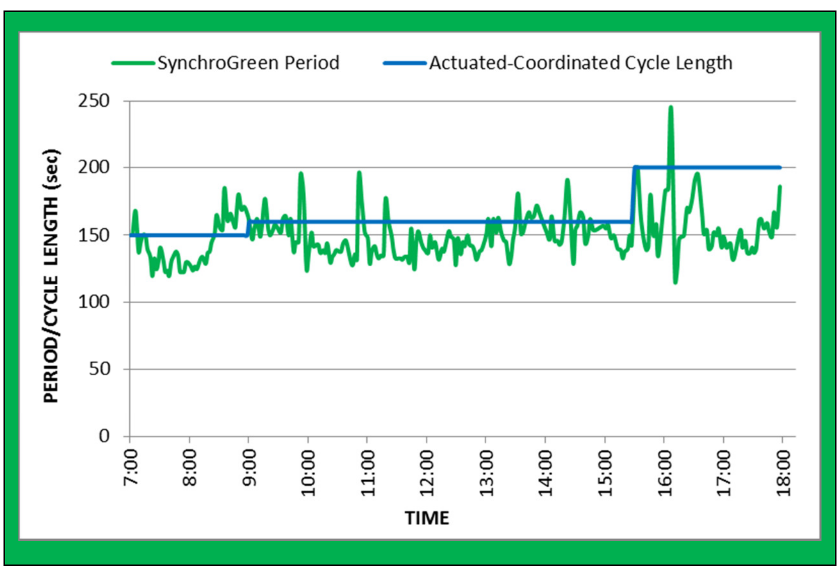


**Figure 2 - Cycle Length and Period Comparison May 24, 2011**

**Arterial Travel Time and Delay Results**

Table 2 and Figure 3 compare travel time and delay on SR 436 when SynchroGreen was active ("ON") and when it was inactive ("OFF"). Additional travel time and delay results are in Appendix A. On average, SynchroGreen produced faster travel times for all time periods. Most notably, MD travel time runs were reduced by 27 percent eastbound and 25 percent westbound, while delay was reduced by 46 percent eastbound and 37 percent westbound. Travel time and delay reduction during the AM peak were more modest. On May 24, 2011 the average period was 142 seconds using SynchroGreen, compared to a 150 second fixed cycle length that normally occurs under actuated-coordinated operation (see Table 1). This is an indication that the fixed cycle length may have provided near-optimal operations and improvement due to SynchroGreen would be expected to be small.

PM peak operations are impacted by oversaturated conditions, and improvement due to SynchroGreen is not as dramatic as during the MD peak. Oversaturated conditions occur near I-4, Cranes Roost Boulevard and Douglas Avenue, where the traffic volume on SR 436 can exceed 700 vehicles per hour per lane. Other factors such as roadway geometry still affect overall intersection capacity, limiting potential improvement. While SynchroGreen can delay the start of oversaturation, it may not provide a "cure-all" when oversaturated conditions occur. This is similar to other adaptive traffic control systems and has been documented in previous research (*6*).

**Table 2 - Travel Time and Delay Comparison**

| | SYNCHROGREEN STATUS | AM Peak | | MD Peak | | PM Peak | |
|---|---|---|---|---|---|---|---|
| | | Travel Time (s) | Delay (s) | Travel Time (s) | Delay (s) | Travel Time (s) | Delay (s) |
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Reductions in travel time and delay are attributed to a number of factors. Travel time improves due to decreased number of stops using the SynchroGreen transition-less offset operation (see Appendix B). Transition-less offsets involve recalculating start time each period to improve vehicle progression. Furthermore, the average period for AM, MD and PM travel time runs are less than would have occurred under actuated-coordinated operations. This results in reduced delay when a vehicle stops at an intersection, as main-street green returns sooner than would have occurred otherwise.

The ability to better accommodate pedestrians is believed to be a critical operational improvement on SR 436 using SynchroGreen. Before SynchroGreen was active, pedestrians crossing SR 436 were known to impede progression and affect operations for multiple cycles as traffic signal controllers transition back to normal timing plans. This problem worsened when pedestrian calls were received for the same phase on successive cycles. It was observed that while SynchroGreen was active, the effect of pedestrians was reduced. Part of this is attributed to improved coordination through transition-less offsets, but also to the ability to adjust phase allocation to accommodate pedestrians. When a


**Figure 3 - Travel Time and Delay Summary**

pedestrian call is received, this may cause increased congestion on non-concurrent phases which increase the period in the future. Hence, when a pedestrian call is received on a successive period, the phase allocation can be redistributed to better accommodate the pedestrian phase and cause fewer disruptions to the main-street greenband. Lastly, the stop-in-walk and minimum phase allocation settings implemented by Seminole County in SynchroGreen (discussed earlier in this report) are believed to have also contributed to improved operations. These settings limit traffic signal controller transition duration due to pedestrians, and were designed to improve traffic signal coordination.

**Side-Street Delay Results**

From field observation after SynchroGreen was active, side-street queues were noticeably shorter or no longer than when SynchroGreen was inactive. This corresponds with results for the HCM side-street delay study summarized in Figure 4. Side-street delay is reduced at southbound Douglas Avenue and southbound Hattaway Drive during both the MD and PM peak periods. On average, side-street delay was reduced by 19 percent at the two study locations, the maximum reduction was 34 percent. Reductions in side-street delay are attributed to the reduced average period; this allows the side-street green to return earlier than would be possible using a fixed cycle length under actuated-coordinated operation.


**Figure 4 - Side-street Delay Summary**

**Pedestrian Delay Results**

Pedestrian delay was measured at Cranes Roost Boulevard, Essex Avenue and Palm Springs Drive during the PM Peak. Results were aggregated when SynchroGreen was active and inactive and a histogram was produced to illustrate pedestrian delay distribution. Histograms are given in Figure 5. Results show that SynchroGreen reduces pedestrian delay, as the distribution shifts towards lower values (to the left). The average pedestrian delay while SynchroGreen was inactive is 83 seconds, compared to 75 seconds while active. This is approximately a 10 percent reduction.

Improvements in pedestrian delay are attributed to the reduced average period using SynchroGreen. Reduced average period allows the pedestrian walk interval to return earlier than would have been provided using a fixed cycle length under actuated-coordinated control. The average period during the PM peak is 155 seconds. Intuitively, a pedestrian should not be delayed much more than the period or cycle length. This is illustrated in Figure 5, and no pedestrian is delayed more than 160 seconds when SynchroGreen is active. Comparatively, pedestrians experience much more delay when the cycle length is 200 seconds under actuated-coordinated control.

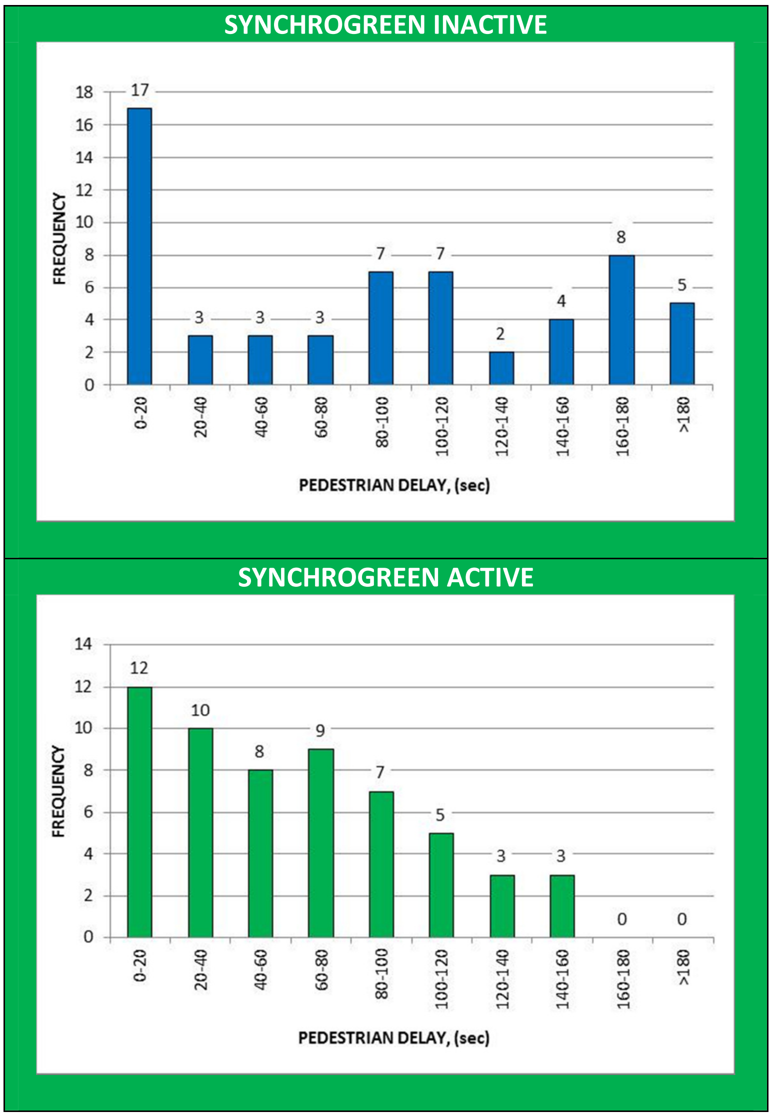


**Figure 5 - Pedestrian Delay**

**Fuel Consumption and Emissions Results**

Fuel consumption and emissions results are given in Figure 6 and Figure 7. Fuel consumption has been reduced for all time periods with a minimum reduction of 8 percent. HC, CO and NOx emissions also show reductions for all time periods. The largest reduction in emissions occurs during the MD peak; this corresponds to the largest improvement in arterial travel time and delay.

**Observations**

Based on the experience of Seminole County staff, traffic on SR 436 is more manageable and platooning on SR 436 has been improved. This is not only attributed to SynchroGreen's ability to handle random fluctuations in traffic, but also the ability to handle disturbances due to pedestrians and preemption. Left-turn pockets have been observed to be more capable of accommodating left-turn traffic. This is due to the reduced average period compared to a fixed cycle length. Left-turns are serviced more frequently and the result is that left-turn traffic no longer impedes through traffic and platooning is more consistent.

Side-street queues have also been observed to decrease when SynchroGreen is active. For example, the I-4 eastbound exit ramp at SR 436 once spilled back onto the freeway during the afternoon off-peak and PM peak. When SynchroGreen was implemented, traffic no longer spilled back onto the freeway. Again, this is attributed to SynchroGreen's ability to lower the period compared to a fixed cycle length and service phases more frequently. Overall, SynchroGreen has proved to be reliable and has noticeably improved traffic.


**Figure 6 - Fuel Consumption and HC Emissions**


**Figure 7 - CO and NOx Emissions**

**SUMMARY**

The unpredictable nature and day-to-day fluctuation on SR 436 make traffic signal timing difficult and not conducive to actuated-coordinated operations. Instead, SynchroGreen, a real-time adaptive traffic control system, provides a solution that adjusts to changing traffic conditions. SynchroGreen continually adjusts phase allocation, periods and start time based on real-time traffic data.

SynchroGreen improved travel time and delay for all time periods. MD travel time runs demonstrated the greatest improvement, where eastbound travel time was reduced by 27 percent and westbound was reduced by 25 percent. Similarly, delay was reduced by 46 percent eastbound and 37 percent westbound during the MD peak. SynchroGreen was not only shown to reduce arterial travel time and delay, but also side-street delay and pedestrian delay. On average, side-street delay reduced by 19 percent, while pedestrian delay reduced by 10 percent. AM peak MOEs did not show large improvement, as the time-of-day plan before SynchroGreen was implemented was believed to provide near-optimal operations. PM peak MOEs did not show larger improvement due to oversaturated conditions near I-4. It is intuitive that MD peak MOEs show the greatest improvement, as this time period has the largest traffic volume fluctuations, which are best suited to adaptive control. Improvements are attributed to lower average period that minimize the time between successive greenbands and start times that recalculate each period in order to facilitate progression. SynchroGreen is also capable of accommodating the large pedestrian volume identified as a major obstacle towards providing consistent traffic signal coordination. SynchroGreen can adjust phase allocation, periods and start time when a pedestrian call is received to minimize the impact to the main-street.

SynchroGreen was implemented on SR 436, a corridor with less than favorable conditions. However, SynchroGreen reduced travel time, delay, and emissions for all time periods and is a promising technology that will be expanded in Seminole County.

## REFERENCES

1 *Traffic Signal Timing Manual*. Publication FHWA-HOP-08-024, U.S. Department of Transportation, 2008.

2 *Highway Capacity Manual*, TRB, National Research Council, Washington, D.C., 2010.

3 Griffin, Richard. *Air Quality Impact of Signaling Decisions*, Colorado Department of Highways, CHOH-DTP-R-80-11, 1980.

4 *PC Travel for Windows Manual*, JAMAR Technologies, Inc., 2004.

5 Schneider, Ray. *Comparison of Turning Movement Count Data Collection Methods for Signal Optimization Study*, URS Corporation, 2011.

6 *Adaptive Traffic Control Systems: Domestic and Foreign State of Practice*, National Cooperative Highway Research Program, TRB, National Research Council, Washington, D.C., 2010.

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**APPENDIX A**

**ARTERIAL TRAVEL TIME**

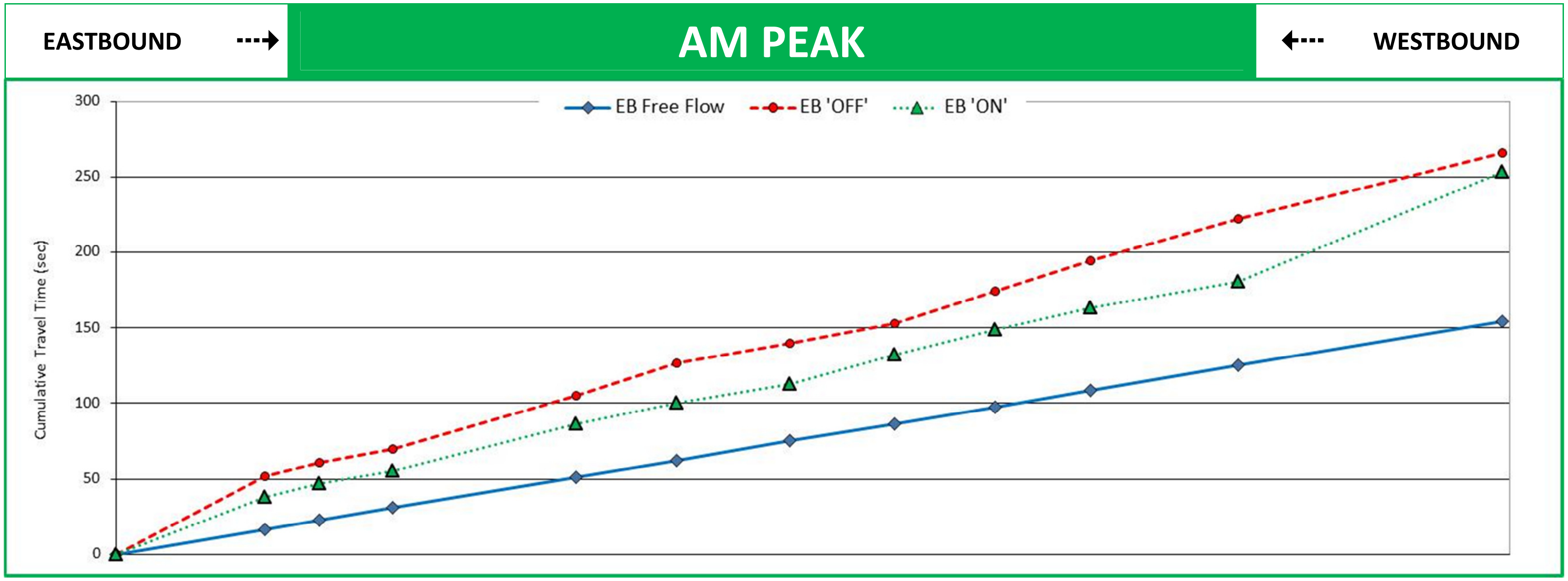


**Figure 8 - AM Peak Eastbound Average Travel Time**

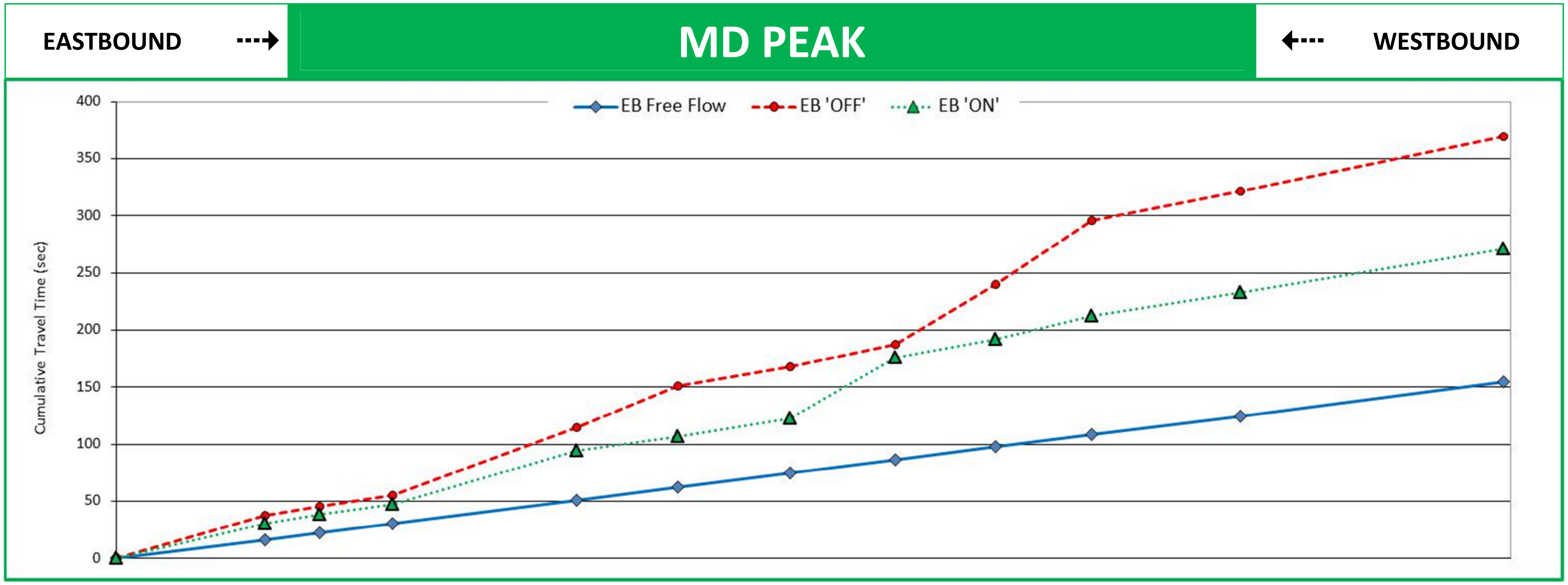


**Figure 9 - MD Peak Eastbound Average Travel Time**

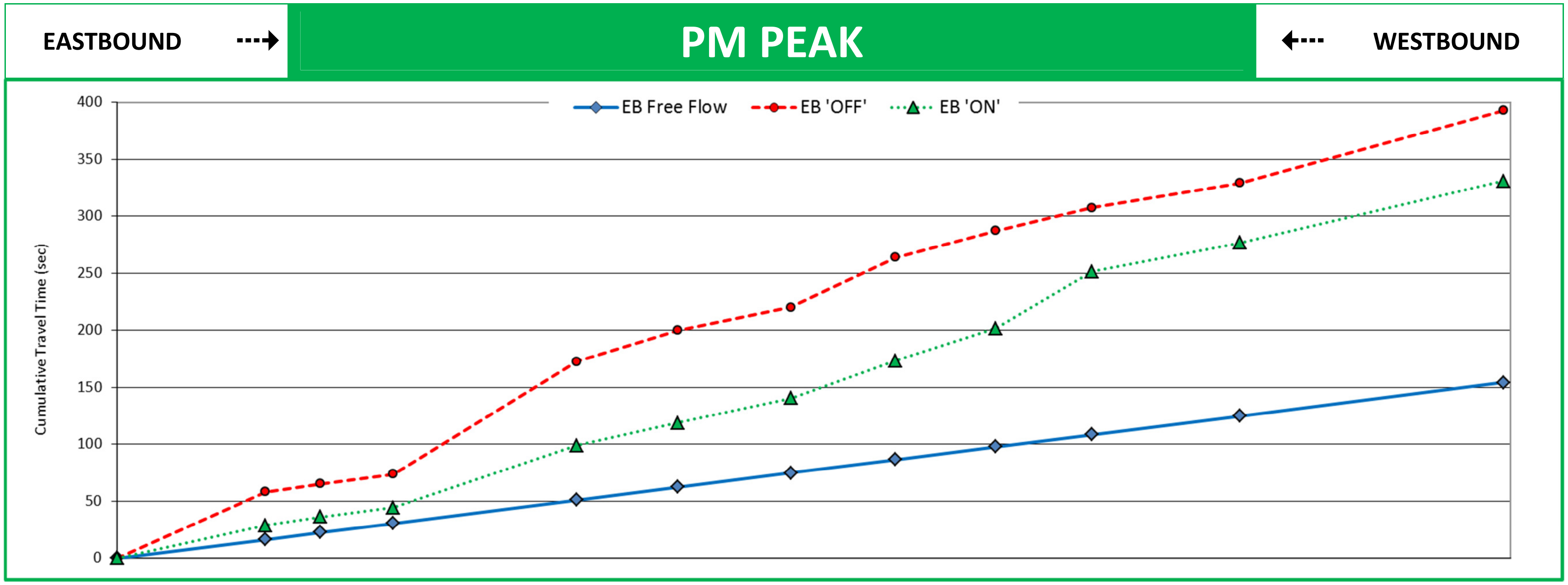


**Figure 10 - PM Peak Eastbound Average Travel Time**

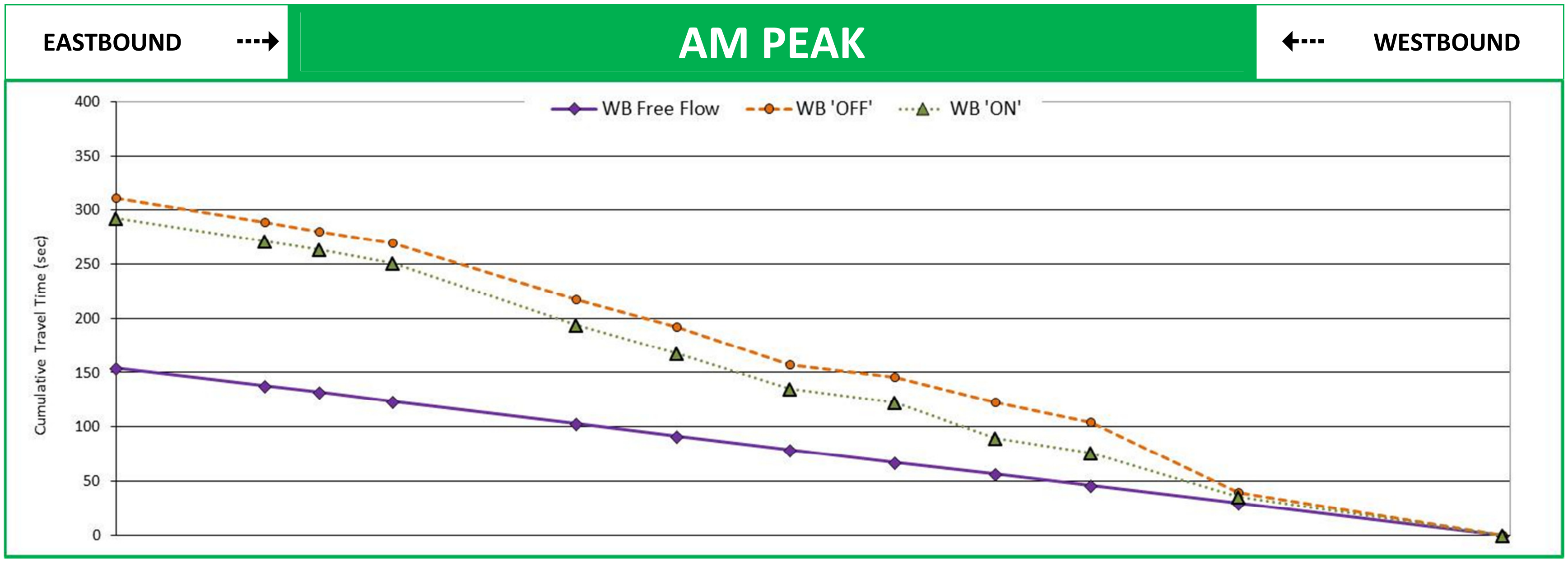


**Figure 11 - AM Peak Westbound Average Travel Time**

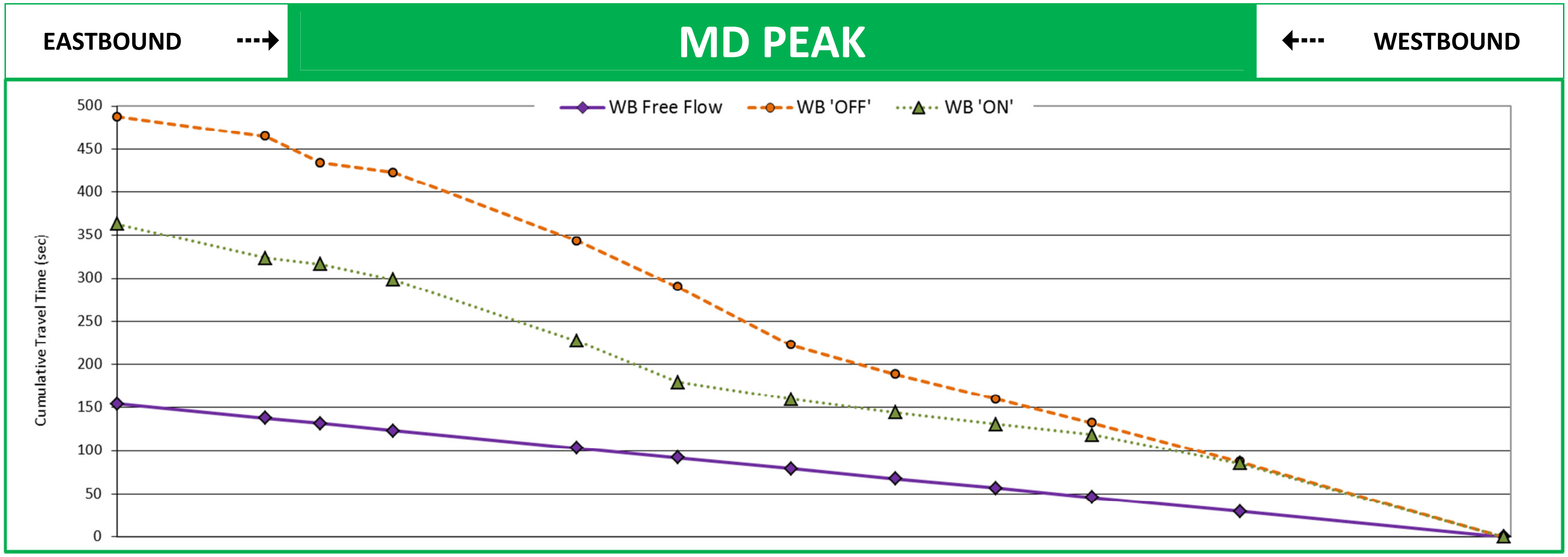


**Figure 12 - MD Peak Westbound Average Travel Time**

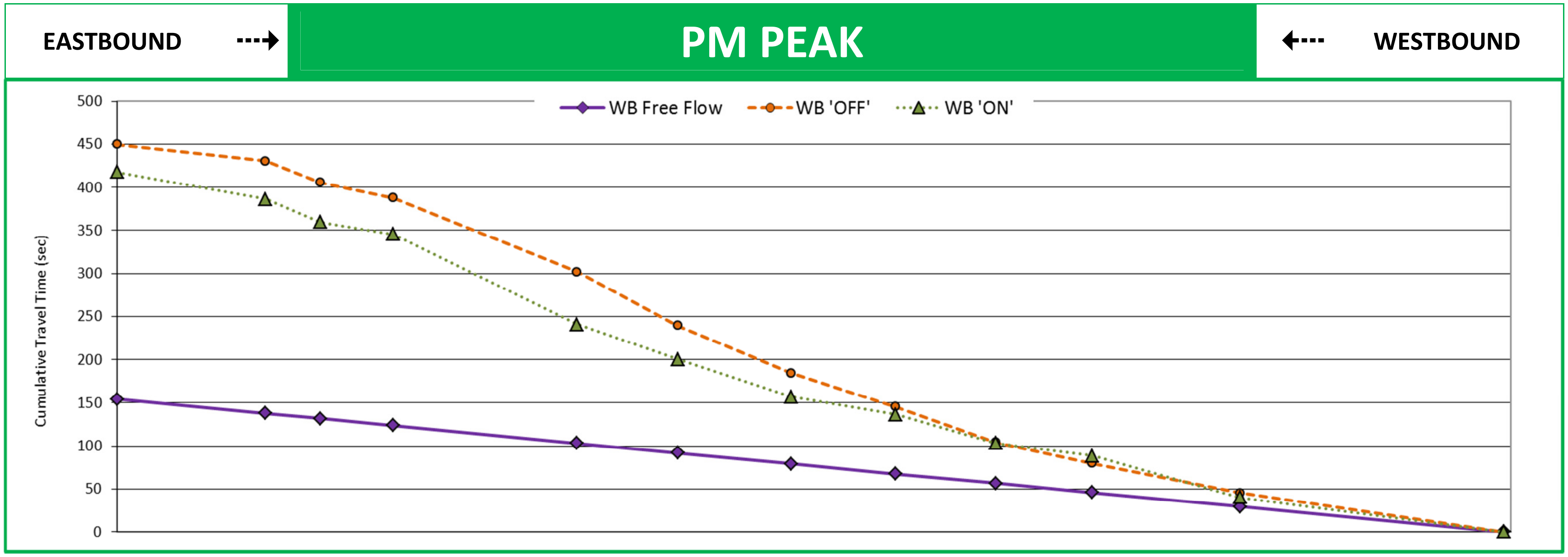


**Figure 13 - PM Peak Westbound Average Travel Time**

## APPENDIX B

## AVERAGE NUMBER OF STOPS

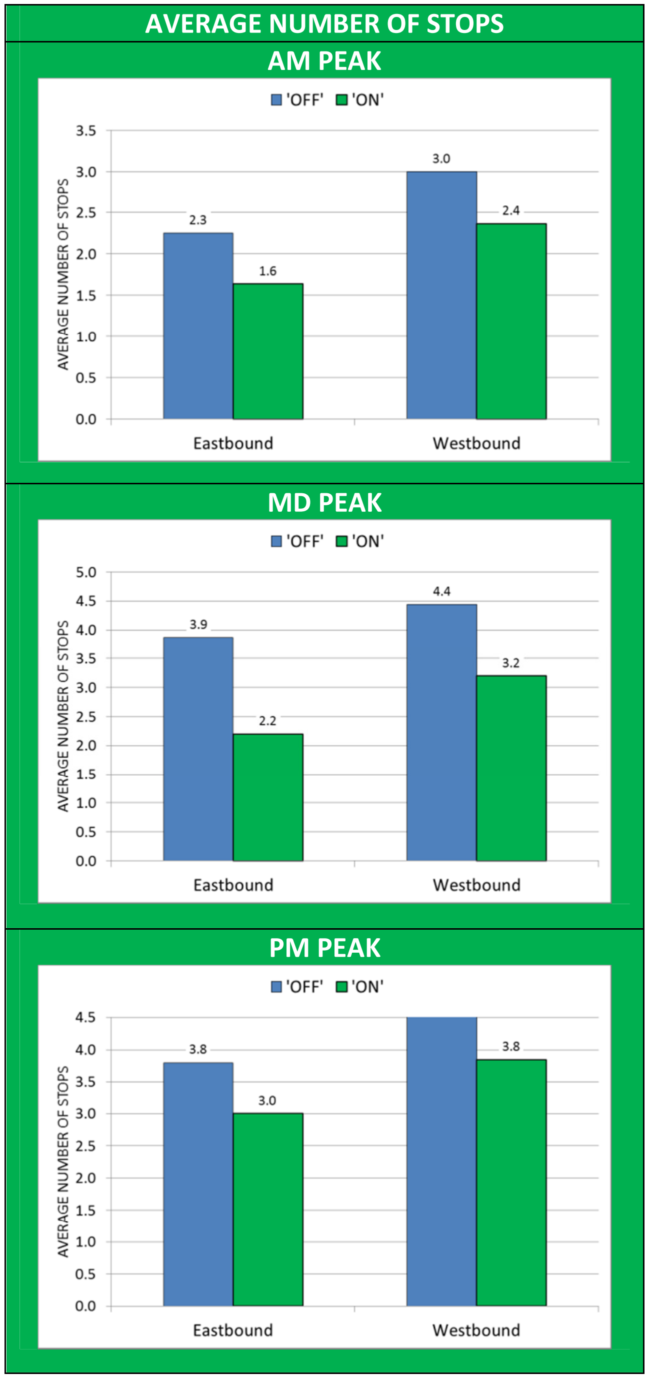


**Figure 14 - Average Number of Stops**