MANAGED LANES: A TMC PERSPECTIVE

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ABSTRACT

The Florida Department of Transportation (FDOT) has begun implementation of the FDOT's first managed lanes, known as 95 Express. The 95 Express Project was implemented by converting the existing High Occupancy Vehicle (HOV) lane, adding a lane, and creating the two managed lanes or High Occupancy Toll (HOT) lanes. Phase 1A of the project was open to tolling on December 5, 2008. The FDOT D6 Transportation Management Center (TMC) played an active role in supporting the ITS/Toll Equipment/Operations Team. This paper presents the FDOT D6 TMC's approach for TMC Control Room Operations, Incident Management, and Dynamic Pricing. In addition, preliminary operational analysis was conducted to evaluate how tolling changed travel patterns along the I-95 corridor, assessment of the dynamic pricing, and the preliminary benefits of I-95 Express Lanes.

Keywords: Managed Lanes, High Occupancy Toll Lanes, Express Lanes, TMC Operations, Incident Management, Intelligent Transportation Systems Applications

INTRODUCTION

The I-95 corridor in Southeast Florida is one of the most traveled corridors in the United States. Sections of I-95 in Miami-Dade carry over 290,000 vehicles per day, with traffic volumes expected to exceed 360,000 vehicles per day by the year 2030. Average speeds during the PM peak period were 18-19 miles per hour in the HOV lanes and also the general purpose lanes prior to the 95 Express Project. This was particularly detrimental to express bus operations serving the Miami central business district. It was further detrimental in encouraging HOV ride sharing and vanpools. With limited right-of-way available, the FDOT had to develop innovative solutions to managing the growing demand in the corridor.

The Florida Department of Transportation (FDOT) has begun implementation of the FDOT's first managed lanes, known as 95 Express. The 95 Express Project is part of a series of operational improvements along the I-95 Corridor in Southeast Florida. The 95 Express project goals are to:

- Provide a reliable transportation option for transit users and HOV
- Increase reliability and reduces travel time
- Add "people throughput" capacity for less cost
- Limit impacts on the community
- Promote sustainable travel

The 95 Express Project is sponsored by the Federal Highway Administration (FHWA), the FDOT, and the Federal Transit Administration (FTA) through the Miami Urban Partnership. FDOT applied for and received funding through the USDOT Urban Partnership Agreement (UPA) $43.4 million for Highway and $19.4 million for Transit. Additionally, the Florida Legislature earmarked an addition $35 million. For the project, an Intelligent Transportation Systems (ITS)/Toll Equipment/Operations Team was formed that included representatives from FDOT District Six (FDOT D6), FDOT District Four, FDOT Central Office ITS and Operations staff, and Florida's Turnpike Enterprise (FTE) toll operation personnel.

The 95 Express Project includes restriping of I-95 as needed to provide an additional lane in each direction. These additional lanes, along with the existing High Occupancy Vehicles (HOV) lane, was converted into two High Occupancy Toll (HOT) lanes, while maintaining the existing right-of-way and existing number of general purpose/local lanes. The project limits extend from downtown Miami to the Broward Boulevard Park-n-Ride Lot in Broward County. The project is divided into the following phases (see Figure 1):

- Phase 1A – I-95 northbound from SR 112 to the Golden Glades Interchange
- Phase 1B – I-95 northbound and southbound from I-395 to the Golden Glades Interchange, plus complete the north bound portion between I-395 and SR 112
- Phase 2 – I-95 northbound and southbound from the Golden Glades Interchange to the Broward Boulevard Park-n-Ride Lot in Broward County.

Notice to proceed for phases 1A and 1B was issued to the Design-Build Firm in February 2008 and by December 5, 2008 the FDOT D6 began tolling operations for Phase 1A. The FDOT D6 Transportation Management Center (TMC) played an active role in supporting the ITS/Toll Equipment/Operations Team.
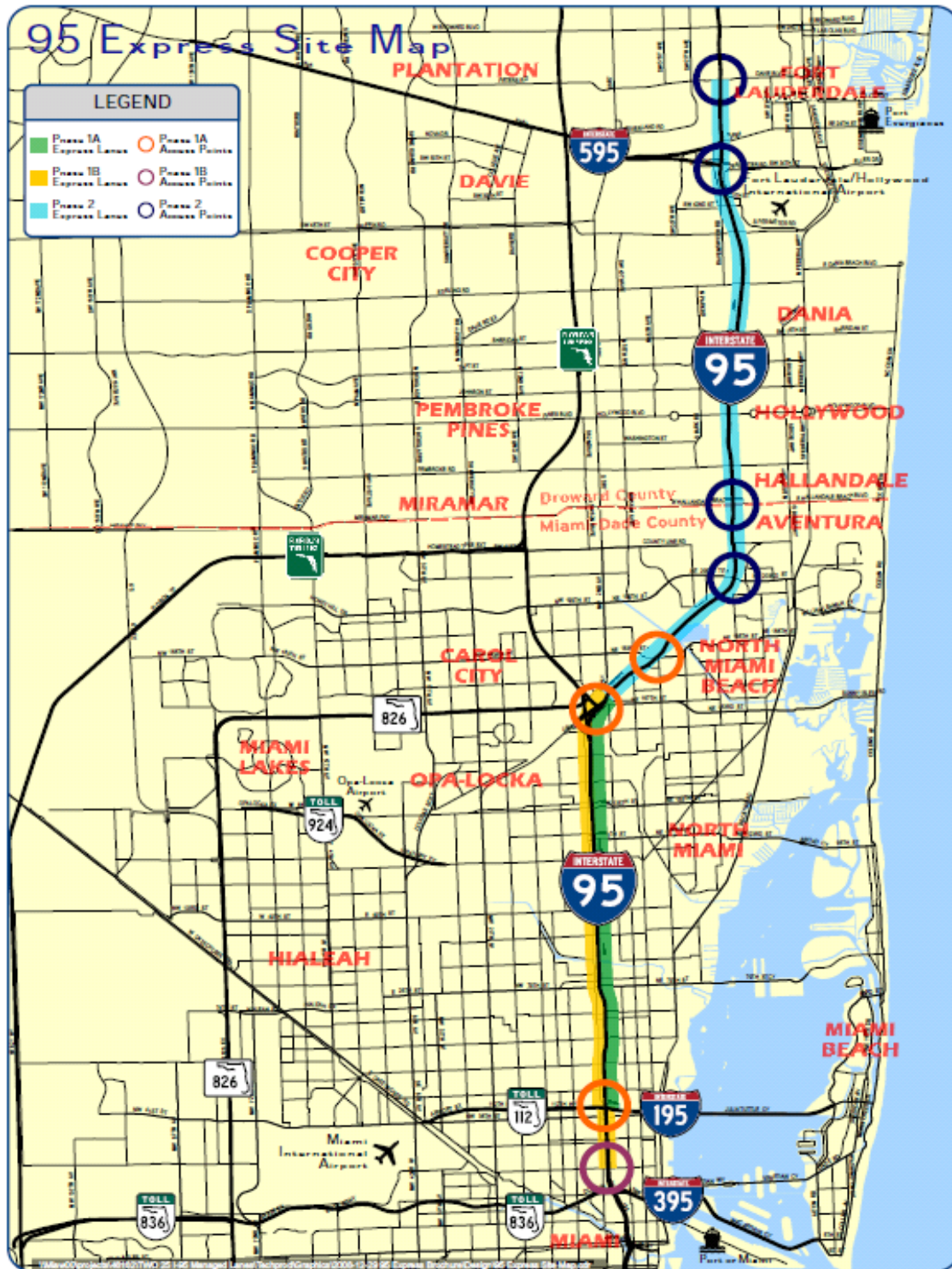

Figure 1: 95 Express Project Limits Source: www.95express.com

Over the past several years, the FDOT has implemented a statewide software (SunGuide Software[SM]) that is used by the various FDOT TMC's. Early in the planning/design stages of the 95 Express project, the FDOT decided to add a module (Pricing Subsystem) to the existing SunGuide Software[SM] for 95 Express operations. Due to a tight 95 Express Project schedule, the initial version of the SunGuide Software[SM] Pricing Subsystem module did not provide dynamic pricing functionality. The scope of the SunGuide Software[SM] Pricing Subsystem module was limited to posting toll rates and lane status on DMS, scheduled time-of-day rate tables, free form manual entry of toll rates, alerts, limited reporting, and the transmission of toll rates to the Florida's Turnpike Enterprise (FTE) Toll Operations system. Recognizing the limitations of SunGuide Software[SM], the FDOT D6 TMC developed a separate software application to implement dynamic pricing.

This paper will discuss the FDOT D6 TMC's approach for TMC Control Room Operations, Incident Management, and Dynamic Pricing. A preliminary operational analysis was conducted to evaluate how tolling changed travel patterns along the I-95 corridor, assessment of the dynamic pricing, and the preliminary benefits of I-95 Express Lanes.

TMC CONTROL ROOM OPERATIONS

In order to provide structure to TMC Operations, the FDOT D6 TMC utilizes Standard Operating Guidelines (SOG). The existing FDOT D6 TMC SOGs were updated to support 95 Express operations. The updates addressed additional 95 Express staff, operational modes, service patrol/incident response team coordination, event management, systems monitoring/reporting, and procedures for 95 Express software applications.

Prior to the 95 Express, the FDOT D6 TMC primary duties included incident management coordination, service patrol dispatching and operations and travel information dissemination. With the addition of 95 Express, active traffic management became an important aspect of the overall TMC operations. To adequately support the 95 Express operations, a new TMC operator position was created, the EL Operator. Unlike regular TMC operators, the EL Operator has different skill sets and knowledge, these operators need to understand basic traffic flow theory and how it impacted the tolling algorithm, as well as the impact that incidents and field equipment and systems malfunction had on the overall project.

Due to an aggressive project deployment schedule, a number of software requirements that were initially identified to effectively operate the 95 Express were unable to be included in the initial release of the SunGuide Software[SM]. This presented a number of challenges that needed to be overcome via the implementation of operational procedures and auxiliary software applications.

The most significant challenge that the TMC had to overcome early in the process was to determine a way to calculate toll rates based on real time traffic conditions along the express lanes in order to maintain free-flow conditions in these lanes. Initially forecasted toll rates were generated from a modeling effort that addressed discrete time periods (weekday midday peak, weekday peak, and weekday off-peak). While these forecasted toll rates were useful in the setting of boundaries (minimum and maximum) that relate toll values and time of day, it did not

provide the practical functionality to effectively manage traffic demand (e.g. what should the rates in between the lower and upper limits be to maintain free flow conditions). The TMC developed a software application called Express Lanes Watcher (ELW), which assists in the calculations of toll rates based on real time traffic conditions. In addition, the ELW provides a way for EL Operators to graphically observe real time traffic parameters per lane (speed, volumes, and occupancy) along the study corridor, TMC management to review EL Operator actions, as well as a number of operational reports for performance measurement and traffic analysis. The ELW is further described in the Dynamic Pricing section of this paper.

The initial SunGuide Software[SM] release has four 95 Express operating modes, these include: normal, zero toll, closed, and retroactive toll adjustment. Each operating mode has a different impact on the toll charged to non-exempt 95 Express motorists and requires differing levels of interaction from the EL Operator. The four operating modes and how they impact the toll implemented for the 95 Express are described below.

- Normal - Normal operating mode is the default mode. The ELW collects and processes real time traffic data (speeds and volumes) from field detectors in the 95 Express every 15 minutes. Using the algorithm incorporated into the ELW, the system calculates a toll rate based on current traffic conditions. The EL Operator acknowledges and confirms that the current toll has been implemented and posted correctly on the roadside toll charge variable message signs (VMSs). When the 95 Express is in zero toll mode or closed mode, the system will provide the calculated toll on the next 15-minute interval. If the 95 Express field detectors fail and are no longer able to collect real time traffic data or the ELW system fails and is unable to calculate a current toll, historical tolls that are stored within SunGuide Software[SM] for weekday and weekend time periods are implemented.
- Zero Toll - is an override mode that is applied when the 95 Express is open, but a zero toll is charged. This mode is typically used during evacuations and for safety reasons when determined by the appropriate authority.
- Closed - is an override mode that is implemented when the 95 Express is closed and a zero toll is charged. The 95 Express will be closed for any incident that results in travel lanes being blocked within the 95 Express or when traffic is diverted from the general purpose lanes (GPL) to the EL because of an incident in the GPL. The diversion of traffic is invoked by the Florida Highway Patrol (FHP) or FDOT. The primary purpose for closing the 95 Express during incidents is responder and motorist safety.
- Retroactive Toll Adjustment - is an override mode that allows the EL Operator to go back in time (up to two hours) and retroactively update the toll that is charged to the minimum toll. This toll adjustment mode is applied when the toll charge VMSs are unable to post the current toll.

A multi-agency incident response plan was developed for the 95 Express Project and details on the plan are documented in the Incident Management section of this paper. In addition to the regular incident response coordination efforts that are typically handled by TMC operators, the EL Operator had to perform a series of additional actions for the 95 Express, such as implementing the "closed" operating mode. As the EL Operator changes the operating mode to "closed", the EL Operator sets the effective time of the closure to ten minutes prior to the

incident confirmation time. This conservative strategy is use to make sure that drivers entering the facility at the time of the incident and prior to the EL Operator confirming the incident will not be charged a toll. The EL Operator is responsible for confirming that the lane status VMS and toll charge VMSs are displaying "CLOSED". If the event is expected to last longer than 60 minutes, the EL Operator dispatches the service patrols (known as Road Rangers in Florida) to the 95 Express entrance ramps to physically close the ramps.

95 Express Phase 1A has three access points (NW 10th Avenue, SR 112 and I-95 entrance ramps); each with a VMS(s) displaying the toll motorists should expect to be charged. Due to the tolling aspect of the 95 Express it is important for field equipment and systems failures to be identified in a timely manner and reported to the respective personnel for immediate action. To support these efforts 24 hours a day, 7 days a week, additional information technology (IT) personnel were added to the TMC. Currently, there is IT on-site personnel Monday thru Friday (24 hours) as well as Saturday (8 am to 5 pm) and on-call IT personnel for the remaining times. Adding to the complexities of this project was the various agencies and entities that could be impacted by such failures (such as Florida's Turnpike Enterprise customer service representatives and Miami-Dade Transit) and the various equipment/systems owners. The TMC IT personnel are responsible for initial troubleshooting of the failures, dispatching maintenance personnel, notifying the impacted parties and coordinating the various actions. At the same time, the EL Operator is responsible for implementing a series of operational steps to mitigate the failures (such as implementing appropriate procedures for mitigating a toll rate "stuck" on a VMS toll rate sign) and coordinating with other impacted stakeholders.

While implementing the "closed" and "zero toll" operating modes are a relatively straight forward process, returning back to regular 95 Express operations requires a number of sequential steps that must be performed by the EL Operator. Furthermore, a series of steps are performed by both EL Operators and IT personnel to compensate for field equipment and system failures. A total of 28 pages of additional procedures have been developed to supplement shortcomings with the current SunGuide Software^{SM} version. It is envisioned that the next version of the SunGuide Software^{SM} will automate most if not all of these processes in order to ensure operational consistency and minimize the opportunities for EL Operators to make mistakes. It is important to point out that many of these shortcomings were not identified until the project was well into construction and making it infeasible to be included in the initial round of software requirements.

INCIDENT MANAGEMENT

In July 2008, an Operational Risk Management Plan was developed by FDOT that identified incident management in both the express lanes and the general purpose lanes as a high probability, high impact and high priority risk. The response strategy recommended a 95 Express Incident Management Plan (IM Plan) be developed to detail mitigation strategies.
In March 2008, FDOT D6 hosted a multi-agency workshop to discuss 95 Express incident management scenarios. At this workshop, additional multi-agency protocols and procedures were identified. The TMC followed with a series of partnering meetings to provide input into an incident management plan that targeted 95 Express operations. The 95 Express Incident Management Plan contains a series of strategies that integrate resources, procedures, and

protocols. Quick clearance was the theme of the plan and the resources necessary to achieve this goal were identified. These resources include two additional service patrols, one additional FHP Trooper, one Incident Response Vehicle (IRV), and one flat-bed tow truck. Special training was developed and delivered to bring these resources together and educate the responders on the new procedures, protocols and maintenance of traffic plans.

The FDOT D6 supplemented their existing service patrol fleet within the I-95 corridor with two additional Road Ranger tow trucks. These trucks are roaming 24/7 within the 95 Express and are available to respond to incidents in both the express lanes and general purpose lanes.

These Road Rangers are supported by additional incident response assets. These assets consist of a specially equipped incident response vehicle (IRV) and a flat bed tow truck. To support Phase 1A of the project, both vehicles are manned 8 hours per day, Monday through Friday from 12 noon to 8 pm. Unlike the Road Rangers, these assets are strategically staged at the beginning of the 95 Express in order to expedite response. Both the IRV and flat bed tow truck respond to incidents that impact traffic conditions along the project limits in both the northbound and southbound directions. Such incidents include shoulder and travel lane blocking incidents in the express lanes and travel lane blocking incidents in the general purpose lanes. Shoulder (right only) incidents along the project limits are responded to by Road Rangers only.

The IRV is a Ford F-350 dual-wheel, covered utility body truck equipped with high intensity lighting to assist responders after sundown. A docking station in the driver's compartment facilitates use of a laptop computer to support incident command activities. In addition, the IRV carries additional maintenance of traffic and spill mitigation equipment such as cones, signs, flares, oil dry, and fuel absorbent.

The driver of the IRV (the IRV Operator) acts as an FDOT incident coordinator on-scene of events impacting the traffic flow in the 95 Express. The IRV Operator assists responding agencies, coordinates maintenance of traffic (MOT) activities of the Road Rangers, and provides liaison between other responding agencies and FDOT resources. The IRV Operator is the primary contact for the EL Operator to ensure all response and clearance times are documented. In addition, the IRV Operator facilitates post-incident analysis meetings with other agencies. The IRV Operator is trained and qualified in the following:

- Incident management and command
- Advanced management of traffic
- Incident clearance procedures
- Severe incident documentation
- Emergency vehicle operation
- First responder functions and responsibilities

The flat bed tow truck is a 21' carrier that is properly equipped for all types of vehicle towing and can carry up to five passengers. The IRV and the flat bed tow truck contain appropriate logos/markings identifying them as part of the FDOT 95 Express Incident Response Team.

All incident response assets, including Road Rangers, are dispatched through the FDOT D6 TMC via the existing FDOT 470 MHz radio system. Mobile and portable units have been furnished to all incident response vehicles to allow for direct communication with the TMC staff. A dedicated radio channel has been designated by the TMC for all 95 Express Lanes communications and coordination during incidents.

Equally important to meeting the quick clearance goal of this project was the active participation and support from law enforcement during incidents. Therefore, FDOT's incident response assets are supported by the Florida Highway Patrol (FHP). One FHP Trooper has been retained by FDOT through the existing hire back program to provide support from 12 noon to 8 pm.

In order to expedite the clearance of both travel lane and shoulder blocking events within the 95 Express, the following quick clearance procedures were implemented:

1. FHP allows for Road Rangers to cross the double white lines and delineators to by-pass traffic congestion when responding to incidents and removing vehicles from 95 Express.
2. Vehicles blocking 95 Express travel lanes are relocated to the right shoulder, emergency stopping sites (along the various off-ramps), or to a designated location in the park-and-ride lot near the Golden Glades Interchange (at the end of the facility). A vehicle is considered to be blocking a travel lane if any part of the vehicle is on or within the travel lane pavement markings. Road Ranger vehicles are equipped to safely move vehicles to the right shoulder only. However, the flat bed truck is equipped to relocate vehicles to the park-and-ride lot near the Golden Glades Interchange until it is removed by a towing company.
3. Disabled vehicles in the 95 Express shoulder (left shoulder only) will be relocated to either the right shoulder, emergency stopping site, or to the designated location in the park-and-ride lot near the Golden Glades Interchange.
4. Abandoned vehicles in the 95 Express shoulder (legally parked) are marked with a grease pen on the rear window by a Road Ranger when it is first discovered and the TMC staff notifies FHP dispatch to log the initial discovery. The markings include the time, date and Road Ranger truck number. At the beginning of each hired back shift, the FHP Trooper "sweeps" the 95 Express for disabled vehicles and call for rotational tow. The rotational tow removes the vehicle from the shoulder if they are able to respond within 30 minutes. If they are not able to respond within 30 minutes, the FHP Trooper requests the TMC dispatch resources to relocate the disabled vehicle to the right shoulder, emergency stopping site, or to the park-and-ride lot near the Golden Glades Interchange. Subsequently, the FHP Trooper requests rotational tow to remove the vehicle at the designated relocation area.

Early results of these incident management strategies have shown improvements in incident clearance times as shown on Figure 2. Most notably the reduction in travel lane blocking duration from approximately 17 minutes prior to the implementation of the plan to approximately 9.5 minutes after implementation (45% reduction in travel lane blocking duration).
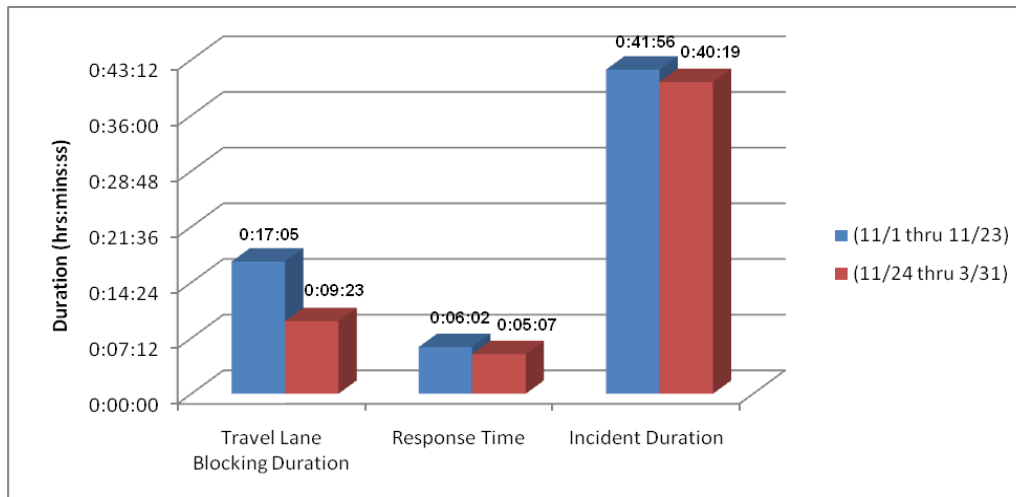
Figure 2: Incident Management Performance Measures

DYNAMIC PRICING

This application is referred to as Express Lanes Watcher (ELW). This section documents the dynamic pricing algorithm and operational tools used by FDOT D6 to implement dynamic pricing.

Dynamic Pricing Algorithm

The 95 Express Project, as the first variable tolling project in the State of Florida, required a rule adoption in the Florida Administrative Code (Rule: 14-100.003 Variable Rate Tolls for Express Lanes), here in referred to as Toll Rules. The Toll Rules established the framework for the dynamic pricing algorithm. Key aspects included:

- Safely operate at free flow conditions in the Express Lanes, while maximizing throughput.
- Minimum toll rate of $0.25 per segment.
- Maximum toll rate of $1.00 per mile per segment.
- The toll rates will be set based on level of service in the Express Lanes.
- When traffic volume in the 95 Express does not allow free flow conditions, the toll rates will increase to improve traffic flow conditions. Once the traffic demand in the express lanes returns to a free flow condition, the toll rate will be reduced.

The dynamic pricing algorithm utilizes concepts proven to be successful by other managed lanes facilities. The concept is to relate toll rate boundaries to facility level of service and adjust the toll rate within and across these boundaries based on how quickly traffic conditions deteriorate or improve. The level of service (LOS) is defined in accordance with the Highway Capacity Manual (HCM) using traffic density (TD), which is a combination of speed and volume. TD is calculated as follows:

$$Traffic\ Density\ (vehicles\ per\ mile) = \frac{Volume\ (vehicles\ per\ hour)}{Speed\ (miles\ per\ hour)}$$

Table 1 depicts the relationship between LOS and TD. LOS A, B and C are considered to be free-flow conditions and should safely allow for maximum throughput in the express lanes. As traffic conditions enter a LOS D and E, traffic conditions will begin to deteriorate and travel speed will be reduced. At LOS F, TDs are expected to be above 45 vehicles per mile per lane (vpmpl) and speeds are significantly reduced.

Level Of Service	Traffic Density	Expected Traffic Conditions
A	0 – 11	Free Flow
B	>11 – 18	Free Flow
C	>18 – 26	Free Flow
D	>26 – 35	Mild Congestion
E	>35 – 45	Moderate Congestion
F	>45	Severe Congestion

Table 1: Level of Service and Traffic Density Relationship

The TD calculations are based on a system wide average of real-time traffic data that is collected and processed to exclude missing and invalid data. The traffic data is processed every 15 minutes and the TD is calculated to the nearest whole number. The toll calculations use configurable settings. The two primary settings are LOS settings and Delta settings. The LOS settings relate the current express lanes LOS with a TD range and a maximum and minimum toll range, as shown in **Table 2**.

Level Of Service	Traffic Density	Toll Rate	
		Min	Max
A	0 – 11	$0.25	$0.25
B	>11 – 18	$0.25	$1.50
C	>18 – 26	$1.50	$3.00
D	>26 – 35	$3.00	$3.75
E	>35 – 45	$3.75	$5.00
F	>45	$5.00	$6.20

Table 2: Level of Service Settings Table

The Delta settings relate a change in TD (ΔTD) with a change in the toll rate (ΔR). A section of the Delta settings table is shown in **Table 3**. The Delta settings are used to define how quickly the toll rates will increase/decrease based on changes in traffic density. This provision supports a quicker response to deteriorating traffic conditions when they occur suddenly.

The steps for calculating the current toll are presented in **Figure 3**. The TD calculated for the previous time period is subtracted from the TD for the current time period to determine the change in TD (ΔTD). Using the delta settings table (**Table 3**), a toll change is determined. The toll change is added or subtracted to the previous toll to determine the current toll. The current
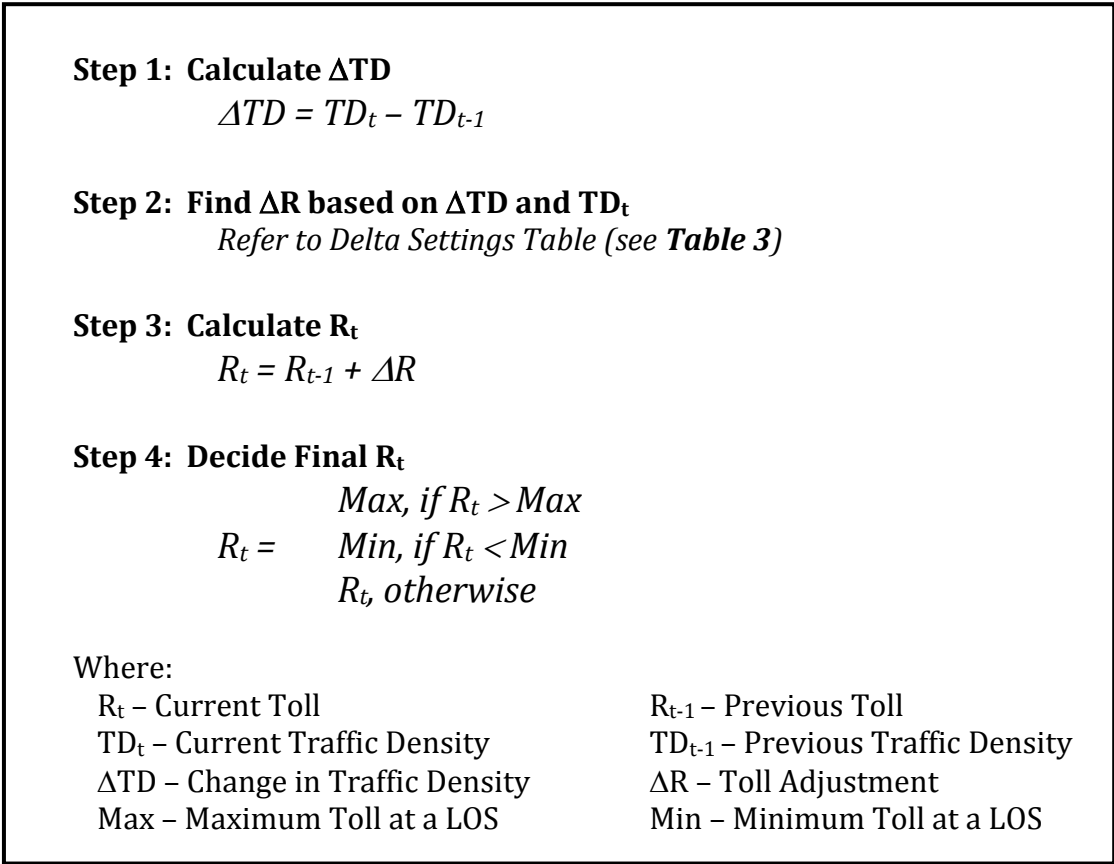
toll is compared to the maximum and minimum toll range in the LOS settings table (**Table 2**). If the current toll falls outside the maximum or minimum toll range for the corresponding TD, then the maximum or minimum tolls are applied, respectively. If the current toll falls within the maximum or minimum toll range, then the current toll is applied. An example of how the current toll is determined is presented below.

The previous toll (R_{t-1}) is \$3.00, the previous TD (TD_{t-1}) is 27, and the current TD (TD_t) is measured as 29. The current toll (R_t) is calculated as follows (based on the process outlined in Figure 3):

- Step 1: $\Delta TD = TD_t - TD_{t-1} = 29 - 27 = 2$
- Step 2: From the initial Delta Settings in **Table 3** - a TD of 29 and a change in TD (ΔTD) of +2 yields a toll change (ΔR) of +\$0.50
- Step 3: $R_t = R_{t-1} + \Delta R = \$3.00 + \$0.50 = \$3.50$
- Step 4: The current TD of 29 falls within the toll ranges for a Level of Service C (from **Table 2**). The minimum and maximum tolls for a LOS C are \$3.00 and \$3.75, respectively. The calculated current toll (R_t) of \$3.50 falls within the associated toll range; therefore, a toll of \$3.50 is implemented.

Level Of Service	Traffic Density	Δ Traffic Density						
		0	**1**	**2**	**3**	**4**	**5**	**6**
D	27	\$0.00	\$0.25	\$0.50	\$0.75	\$1.00	\$1.25	\$1.50
	28	\$0.00	\$0.25	\$0.50	\$0.75	\$1.00	\$1.25	\$1.50
	29	\$0.00	\$0.25	\$0.50	\$0.75	\$1.00	\$1.25	\$1.50
	30	\$0.00	\$0.25	\$0.50	\$0.75	\$1.00	\$1.25	\$1.50
	31	\$0.00	\$0.25	\$0.50	\$0.75	\$1.00	\$1.25	\$1.50
	32	\$0.00	\$0.25	\$0.50	\$0.75	\$1.00	\$1.25	\$1.50
	33	\$0.00	\$0.25	\$0.50	\$0.75	\$1.00	\$1.25	\$1.50
	34	\$0.00	\$0.25	\$0.50	\$0.75	\$1.00	\$1.25	\$1.50
	35	\$0.00	\$0.25	\$0.50	\$0.75	\$1.00	\$1.25	\$1.50

Table 3: Sample Delta Settings Table

Step 1: Calculate ΔTD

$$\Delta TD = TD_t - TD_{t-1}$$

Step 2: Find ΔR based on ΔTD and TD_t

*Refer to Delta Settings Table (see **Table 3**)*

Step 3: Calculate R_t

$$R_t = R_{t-1} + \Delta R$$

Step 4: Decide Final R_t

$$R_t = \begin{cases} Max, & \text{if } R_t > Max \\ Min, & \text{if } R_t < Min \\ R_t, & \text{otherwise} \end{cases}$$

Where:

R_t – Current Toll	R_{t-1} – Previous Toll
TD_t – Current Traffic Density	TD_{t-1} – Previous Traffic Density
ΔTD – Change in Traffic Density	ΔR – Toll Adjustment
Max – Maximum Toll at a LOS	Min – Minimum Toll at a LOS

Figure 3: Toll Rate Calculation

Once the dynamic pricing algorithm was defined, the FDOT D6 was able to determine what elements of the dynamic pricing operations needed to be configurable. These configurable elements were built into ELW. The FDOT D6 gave consideration to all elements that would impact the calculation of toll rates. These include:

- Level of Service (LOS) Settings – ELW allows an administrator to modify the ranges of traffic density and toll rates for each LOS.
- Delta Settings – ELW allows an administrator to modify the toll rate change for each TD and a respective change in TD.
- Detectors – The initial deployment of dynamic pricing assumes the TD is for the entire 95 Express facility. However, the FDOT D6 wanted the flexibility to base the TD on selected detectors (such as at bottlenecks). This provides for additional tweaking of the dynamic pricing algorithm, if desired changes are not met with modifying the LOS and Delta settings. In addition, the FDOT recognized that some detectors may not be part of the TD calculation because they need calibration, but will need to be online during the calibration period.

After the configuration requirements were established, the dynamic pricing algorithm was back-tested to make final adjustments to the LOS and Delta settings to account for typical variations in traffic conditions.

Time of Day Toll Rate Tables

The SunGuide Software[SM] Pricing Subsystem has a normal operating mode that automatically implements a predefined toll rate every 15 minutes. Historical toll rates for associated time periods (time of day and day of week) were develop and stored in what SunGuide Software[SM] Pricing Subsystem refers to as the Normal Rate Table. SunGuide Software[SM] Pricing Subsystem also allows for two types of weekday and holiday/weekend.

The development of the initial tables requires Traffic Density (calculated based on the system wide speed and volume) data aggregated at 15 minutes intervals. A data set was extracted from ELW which includes TD data from October 26, 2008 to November 25, 2008. This data set was then separated into two subsets: weekday data and weekend data. Before the data was used, the data was preprocessed. The data (at a 24 hour base) was excluded from the Normal Rate table development if it contained:

- Missing Data,
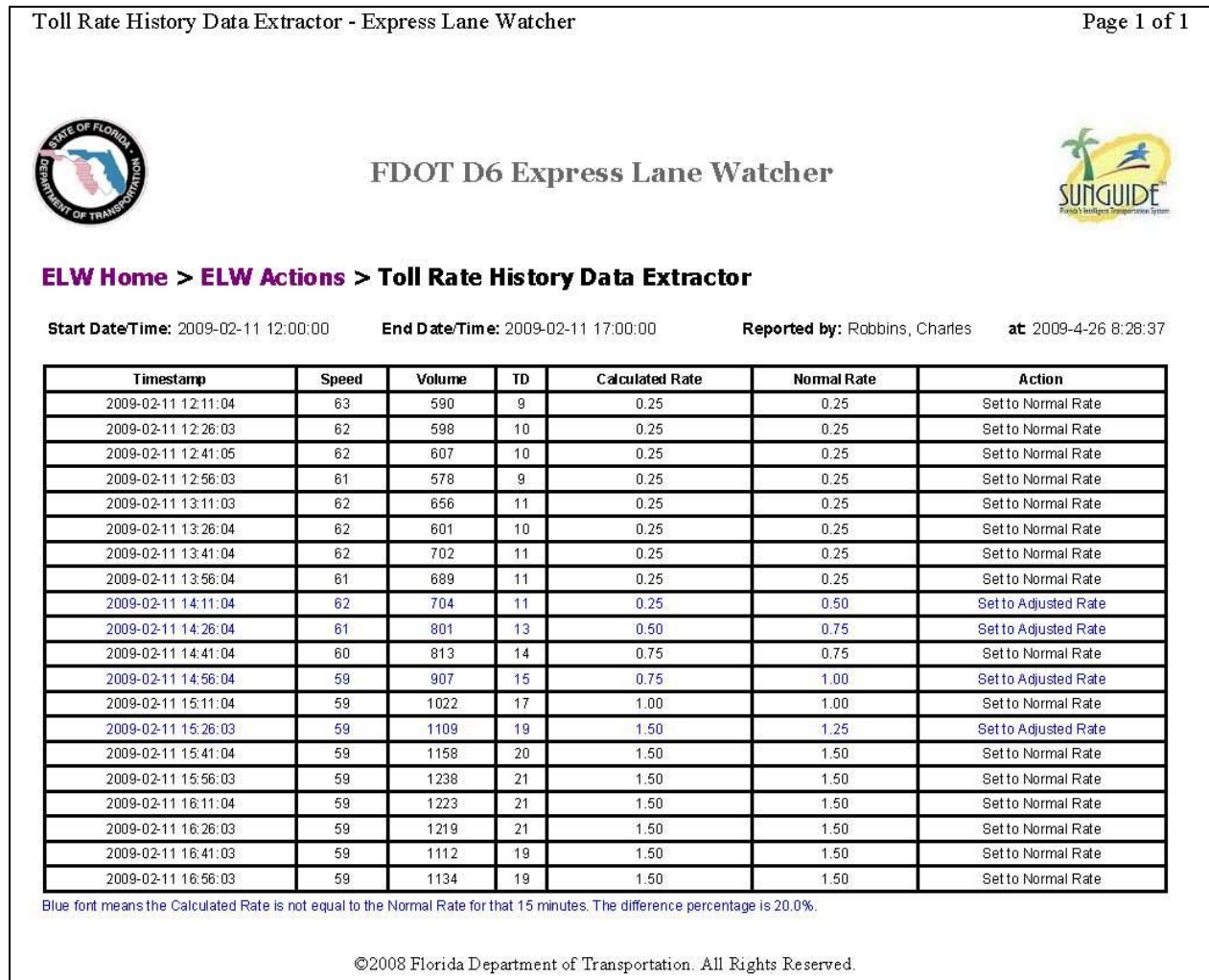- Severe Incident,
- Unusual Variation in TD.

The implementation of the Toll Rate Adjustment logic requires continuous 15 minutes aggregated TD data. Thus a 24 hour TD data with one or more missing data cannot be used and needs to be eliminated. A severe incident will cause long term lane blockage on 95 Express. This is not a "normal condition" and thus cannot be used in Normal Rate establishment. The traffic density over 24 hours was plotted and observed. Any data with unusual variation in TD (the average TD differs more than 25% from the others) was excluded because it did not represent "normal" traffic condition.

After data screening, 24 hour TD data from 18 days was selected for weekday Normal Rate table development and TD data from seven (7) days for weekend/holiday Normal Rate table development. Based on the weekday (or weekend/holiday) daily Toll Rate tables, a 24 hour average TD Table was established by averaging the TD at one particular time period (e.g., 7:15 am to 7:30 am). This average TD is used to represent the "typical" TD at that time of day. Two average TD Tables were established for weekday and weekend/holiday respectively.

The 24 hour average TD table was then fed into a spreadsheet with a well calibrated dynamic pricing logic macro built in. A daily Toll Rate table was calculated by running the macro. By this means, a Normal Toll Rate table was established for weekday and another one for weekend/holiday.

The traffic data used to develop the Normal Rate Table was from a time period in which the Express Lanes were open to the public, but no tolls were enforced. Therefore, it was expected that the traffic conditions would change significantly after tolling began. As a result, these tables were reviewed and updated as needed on a weekly basis for the first four (4) weeks of operations. In order to facilitate the updating of the Normal Rate Table, ELW was developed to track and compare the calculated toll rate with the toll rates from the Normal Rate Table stored in SunGuide Software[SM] Pricing Subsystem. Figure 4 depicts a sample output, showing the time the toll rates were implemented, express lanes speed (mph), express lanes volume (vphpl), traffic

density, calculated toll rate, the normal toll rate, and the action taken. In the report, the rows are highlighted in blue when the calculated toll rate does not match the normal toll rate and the percent difference is reported at the bottom of the report. The FDOT D6 has been able to minimize the percent difference from the Normal Rate Table to less than 15%, with the majority of the differences occurring during the PM peak period. This measure will be used to identify when the Normal Rate Table should be updated.

FDOT D6 Express Lane Watcher

ELW Home > ELW Actions > Toll Rate History Data Extractor

Start Date/Time: 2009-02-11 12:00:00   **End Date/Time:** 2009-02-11 17:00:00   **Reported by:** Robbins, Charles   **at** 2009-4-26 8:28:37

Timestamp	Speed	Volume	TD	Calculated Rate	Normal Rate	Action
2009-02-11 12:11:04	63	590	9	0.25	0.25	Set to Normal Rate
2009-02-11 12:26:03	62	598	10	0.25	0.25	Set to Normal Rate
2009-02-11 12:41:05	62	607	10	0.25	0.25	Set to Normal Rate
2009-02-11 12:56:03	61	578	9	0.25	0.25	Set to Normal Rate
2009-02-11 13:11:03	62	656	11	0.25	0.25	Set to Normal Rate
2009-02-11 13:26:04	62	601	10	0.25	0.25	Set to Normal Rate
2009-02-11 13:41:04	62	702	11	0.25	0.25	Set to Normal Rate
2009-02-11 13:56:04	61	689	11	0.25	0.25	Set to Normal Rate
2009-02-11 14:11:04	62	704	11	0.25	0.50	Set to Adjusted Rate
2009-02-11 14:26:04	61	801	13	0.50	0.75	Set to Adjusted Rate
2009-02-11 14:41:04	60	813	14	0.75	0.75	Set to Normal Rate
2009-02-11 14:56:04	59	907	15	0.75	1.00	Set to Adjusted Rate
2009-02-11 15:11:04	59	1022	17	1.00	1.00	Set to Normal Rate
2009-02-11 15:26:03	59	1109	19	1.50	1.25	Set to Adjusted Rate
2009-02-11 15:41:04	59	1158	20	1.50	1.50	Set to Normal Rate
2009-02-11 15:56:03	59	1238	21	1.50	1.50	Set to Normal Rate
2009-02-11 16:11:04	59	1223	21	1.50	1.50	Set to Normal Rate
2009-02-11 16:26:03	59	1219	21	1.50	1.50	Set to Normal Rate
2009-02-11 16:41:03	59	1112	19	1.50	1.50	Set to Normal Rate
2009-02-11 16:56:03	59	1134	19	1.50	1.50	Set to Normal Rate

Blue font means the Calculated Rate is not equal to the Normal Rate for that 15 minutes. The difference percentage is 20.0%.

Figure 4: Sample Toll Rate History Report

EL Operator Interface

The EL Operator Interface in ELW was developed to provide the easy access to monitor toll rate and traffic conditions, minimize potential errors, and track the EL Operator actions. **Figure 5** depicts the main EL Operator Interface, which is described below:

- Box A - The current toll rate being used at the current time.
- Box B - The current actions being performed on Toll Rate adjustment (e.g., a new rate is acknowledged by an operator). If the font on the right is red, it means the new toll rate has not been confirmed. If the font is green, it means it has been confirmed.

- Box C - A table dynamically shows the toll rate history in the past two hours. Note that currently toll rate is being updated at each 15 minutes, thus this table generally include eight pieces of information. The information will be highlighted in red if any failure in responding to ELW (e.g., fail to acknowledge the notification or fail to confirm an acknowledgement) occurs. The information will be highlighted in blue if middleware communication failure is identified. A middleware communication failure is identified when there are consecutive 20 times communication failures between SunGuide Software[SM] Pricing Subsystem and FTE. By clicking on any piece of information, the user can obtain the detail description in pertaining to the toll rate adjustment at that time interval. Figure 6 shows a sample of toll rate adjustment detailed description.
- Box D – This area displays users logged into ELW, as well as the criteria used for displaying traffic conditions. The options are traffic parameters (volume, speed, or occupancy), travel lanes (EL average, EL Lane 1, EL Lane 2, General Purpose Lanes – EL refers to express lanes), and smoothing interval (1-minute to 15-minute). The volume is displayed in vehicle per hour per lane regardless of the smooth interval to provide a common reference.
- Box E – This area displays the detector names and identifies which ones are used in the toll rate calculations. Shaded detectors are used and those with white background are not used. Also, each detector has a check box as a means to control which detectors are used in displaying the average traffic parameter to the right. The actual traffic parameter value is displayed below each respective detector. When a traffic parameter is shaded blue, it means detector is not collecting data.
- Box F – This area graphically displays the traffic parameters selected in Box D to give the EL Operator a view of the entire facility from south to north (left to right). The EL Operators typically display the speed in 1-minute intervals to assist with detecting incidents within the facility.
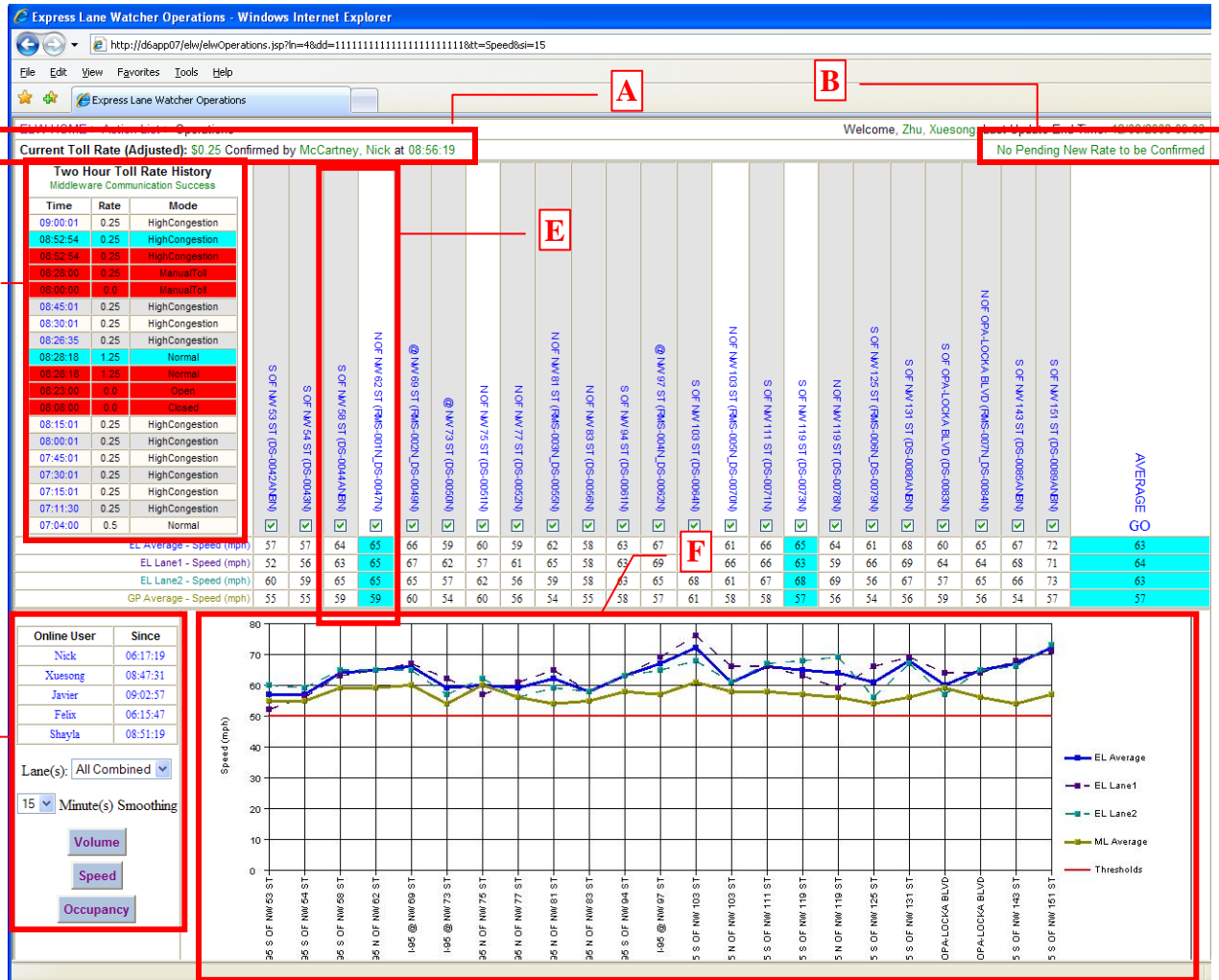
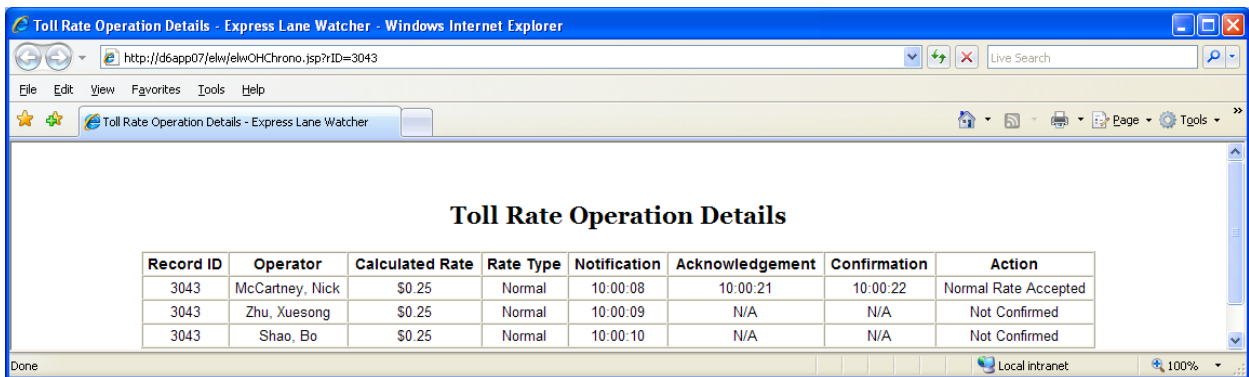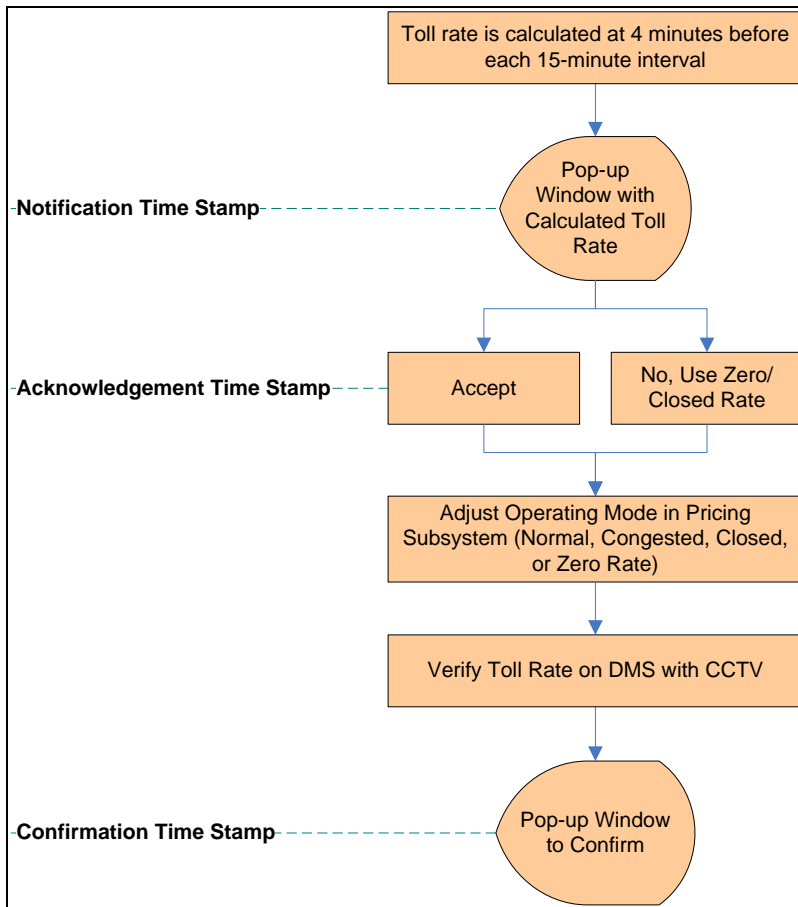**Figure 5: Express Lane Watcher Operator Interface**

Figure 6: Toll Rate Adjustment Detail

A critical part of the EL Operator Interface is implementation of dynamic pricing. The goal was to develop a process to alert the EL Operator of toll rates changes, minimize the potential for error when applying the calculated toll rate and track toll rate change notifications and confirmations. **Figure 7** depicts a high level flow chart of the EL Operator Interface. It identifies the three key time stamps (notification, acknowledgement, and confirmation) that are tracked by ELW and is further explained below.

Figure 7: Operational Flow Chart

- Notification - When a user lingers in the Express Lane Watcher Operations Window, a toll rate adjustment suggestion window (**Figure 8**) will pop up with an audio alarm. This window notifies the operator to use normal rate in SunGuide Software[SM] Pricing Subsystem or manually adjust the toll rate to the calculated toll rate. This window pops up approximately every 15 minutes depending on the type of new suggested toll rate. If it is a normal rate, the window will be popped up at minutes of :00, :15, :30, or :45, with possibly 10 seconds of delay base on the page refreshing pace. If it is an adjusted rate, the window will be popped up four (4) minutes earlier which allows the EL Operator to manually adjust the toll rate in SunGuide Software[SM] Pricing Subsystem.
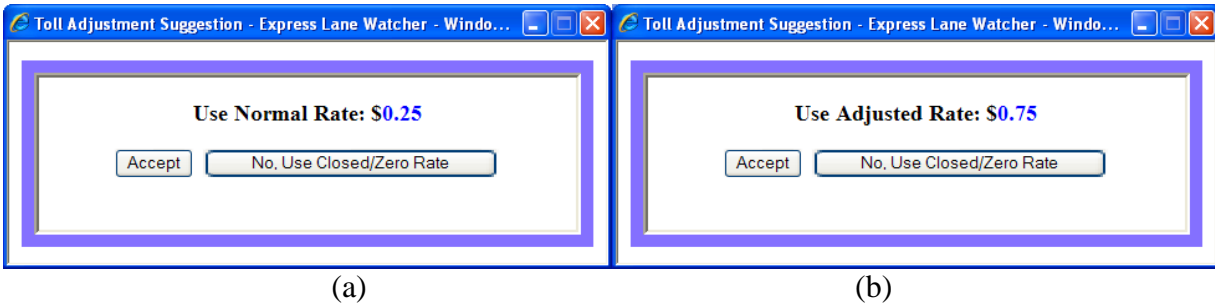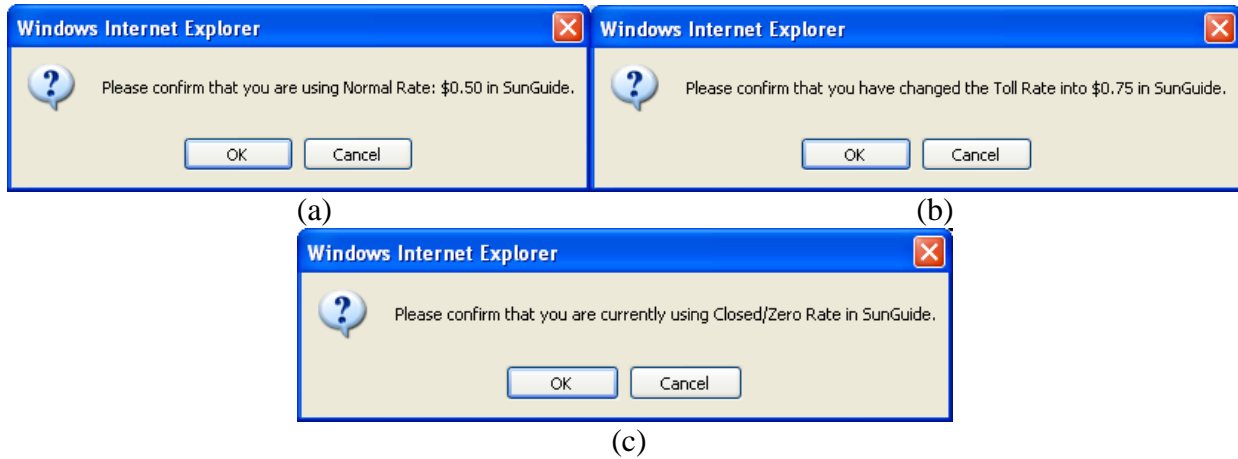
Figure 8: Toll Rate Adjustment – Notification

- Acknowledgement - Once the operator is prompted by this pop-up window, the operator shall respond immediately based on the real situation. In most cases, he/she will "accept" the suggestion unless "closed override mode" or "zero override mode" is being used. Once the operator clicks on "Accept", the new toll rate value will be automatically copied into the clipboard. The EL Operator only needs to paste the new value in SunGuide Software^{SM} Pricing Subsystem when a toll rate adjustment is needed. This facilitates the toll rate adjustment and avoids mistakes due to manual data entry. Note that all of the online users will be notified of the new suggested rate. However, the new rate can only be acknowledged by one notified operator. Other operators attempting to acknowledge this new rate will obtain a pop-up window (**Figure 9**) informing him/her that this notification has been acknowledged by another operator.
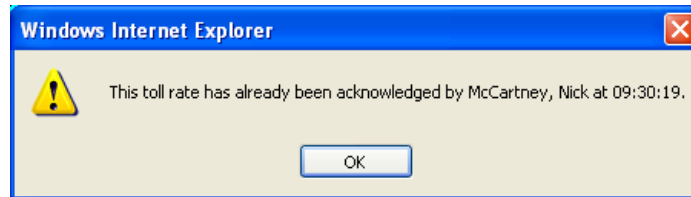
Figure 9: Toll Rate Adjustment- Unsuccessful Acknowledgement

- Confirmation - Once the operator accepts the suggested rate or clicks "No" Use Closed/Zero Rate, another window (a, b or c in **Figure 10** depending on the situation) will pop up asking the operator to confirm the action. Before the operator clicks on any of the buttons, he/she should change the toll rate if needed in SunGuide Software^{SM} Pricing Subsystem. He/she also needs to verify all toll rate VMS are posting appropriate information via CCTVs and other available resources. Once the change and verification are completed, the operator should confirm the action by clicking on "OK". The operator can also click on "Cancel" to re-acknowledge the notification if applicable.

(a)   (b)

(c)

Figure 10: Toll Rate Adjustment- Confirmation

Note that the first operator who acknowledged the notification will have the exclusive authority and responsibility on this notification. If the operator clicks on "Cancel" he/she must re-acknowledge and confirm the notification as appropriate. Other notified operators cannot acknowledge and confirm this notification. After the operator confirms the actions, he/she will be prompted to close the window by another pop-up window (**Figure 11**).

Figure 11: Toll Rate Adjustment- Completion of Confirmation

Operational Analysis Tools

SunGuide Software[SM] Pricing Subsystem was developed without operational analysis tools and very limited reporting capabilities. As a result, ELW was developed to provide the FDOT D6 the ability to review traffic conditions for any historical time period. The criterion was to playback what the EL Operators viewed as they made operational decisions. **Figure 12** contains a screenshot of ELW's historical watcher interface. It is very similar to the EL Operator Interface, except the toll rate history information is replaced with the playback features. A starting date and time is selected when it is launched. Once it is launched, it will begin updating the traffic parameters every minute. The analyst can select to fast forward, rewind and pause the updating of the historical watcher interface in the top left area of the screen.
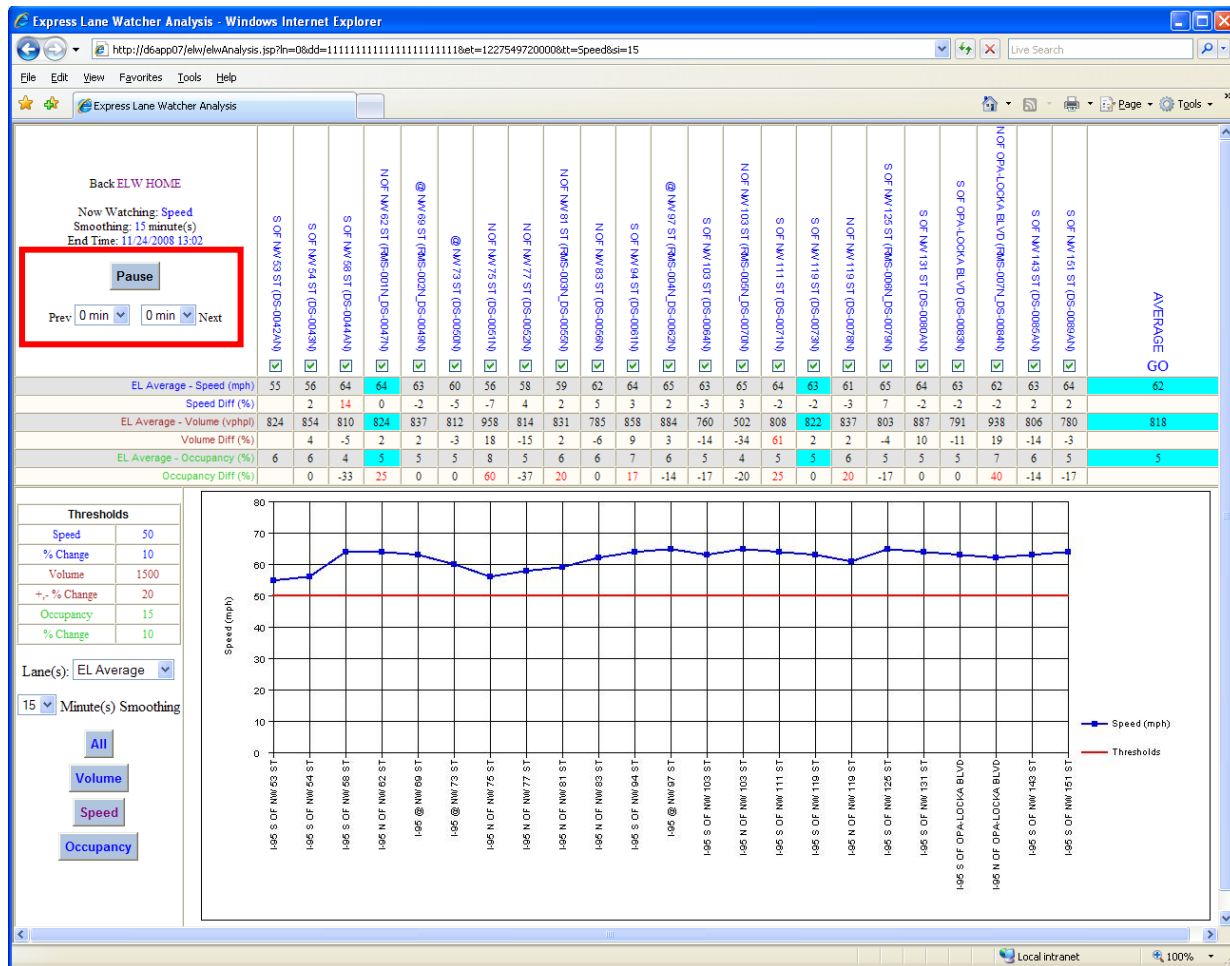
Figure 12: Historical Watcher Interface

In addition, ELW was developed to report on traffic parameters and toll rate history for the 95 Express operations. When generating reports, ELW provides the ability to select a range by date and time. This allows for producing monthly statistics, as well as reporting on specific time periods to review operations. ELW provides the following reports:

- Toll Rate Change Report - This report contains the toll rate change history. The timestamps, such as the time the new rate is scheduled, the time the new rate becomes effective, the time the new rate is sent to the VMS, and the time when the new rate is acknowledged by VMS are included in this report.
- Toll Rate Operation Chronology Report - This report contains detail information in pertaining to how the toll rate has been adjusted based on the interaction between the EL Operators and SunGuide Software[SM] Pricing Subsystem/ELW temporally. The historical Traffic Density, Toll Rate mode, Toll Rate value are retrieved and the detailed actions associated with each toll rate are time stamped as well.
- Toll Rate Operation Summary Report - This report contains the statistical information regarding Operator Actions Status, the Toll Rate Mode has been used and the average time between certain actions.

- Toll Rate History Data Extractor - This report shows the toll rate data in 15 minutes increments within the selected time period. The data include the system average speed, system average volume, the system average traffic density, the calculated toll rate and the normal rate predefined in the normal rate table at every 15 minutes.
- Express Lanes Event Summary Report - This report summaries the information of events occurring on the Express Lanes and on the general purpose lanes within the limits of the 95 Express. The event information is stratified by event type (e.g., crash, scheduled roadwork) and locations (express lanes or general purpose lanes). The information provided in this report includes the total number of events (both travel lane-blockage and non- lane- blockage) and the durations (travel lane blockage).
- Express Lanes Performance Detail Report – Three traffic measurements, system average speed, system average volume (vphpl) and travel time (travel through the express lane section) for both express lanes and general purpose lanes are calculated and compared. The difference between express lanes and general purpose lanes in terms of these three measurements is also computed in this report. The calculation is based on the selected reporting interval (15 minutes or 1 hour).
- Express Lanes Performance Summary Report - This report is a summarized version of "Express Lanes Performance Detail Report". Same as detailed report, the summary report includes three traffic measurements, system average speed, system average volume (vphpl) and travel time (travel through the express lane section) from both express lanes and general purpose lanes, as well as the difference between express lanes and general purpose lanes in terms of these three measurements. The calculation is based on the different time periods, which include AM peak, PM peak, Off-peak, and weekend/holiday.
- Website Typical Rate Report – The FDOT posts typical toll rates on the 95 Express website (www.95express.com) by hour of day. This is posted for weekdays and is updated on a weekly basis. This report generates the a table with the lowest and highest toll rate during the PM peak period, the average speed difference between the EL and GP lanes, and the toll rate posted the most frequently for each hour of the day.

OPERATIONAL ANALYSIS

A preliminary operational analysis was conducted that compared traffic parameters before and after tolling operations began. For the before conditions, the 95 Express was open to the public and tolls were not charge. The analysis documents detail how tolling changed travel patterns along the I-95 corridor, assessment of the dynamic pricing, and the preliminary benefits of 95 Express.

Travel Patterns

The Express Lane Performance Summary Report ran from November 3, 2008 through November 10, 2008 to represent the before condition and from January 12, 2009 through January 19, 2009 to represent the after condition. The data represents an average of all the detectors along the I-95 corridor within the 95 Express facility limits. These weeks were selected to minimize the impacts of holiday traffic patterns on the analysis. The average volumes were adjusted using the weekly

seasonal factors from the FDOT Traffic Data CD (2007). While the average weekday and PM Peak Period (4 pm to 7 pm) total volumes remained consistent; there was a shift in volume distribution among the express lanes and the general purposes lanes (**Table 4**). The data shows a larger shift in volume from the express lanes to general purpose lanes during the weekday than that of the PM Peak Period.

	Weekday		PM	
	EL	**GP**	**EL**	**GP**
Before	26%	74%	29%	71%
After	19%	81%	28%	72%

Table 4: Before and After Volume Distribution

Through four months of tolling operations, the demand for the 95 Express continues to grow, see **Figure 13**. The demand in the PM peak period grew five (5) percent from December 2008 to March 2009.
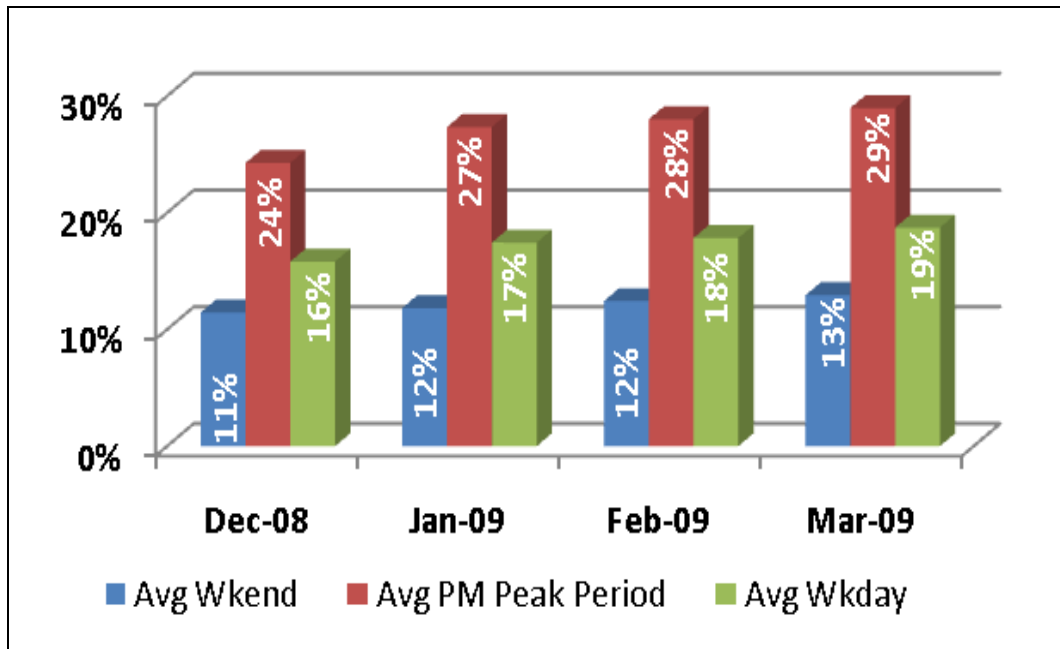
Figure 13: EL Percentage of Overall Traffic (EL and GP).

<u>**Dynamic Pricing Assessment**</u>

The toll rate boundaries in the LOS table were derived from early model runs that produced projected toll rates. The modeling effort was run to optimize throughput instead of revenue. In theory, the dynamic pricing algorithm should result in the maximum throughput and speeds greater than 45 mph when rates are between $2.50 and $3.00. Toll rate data was collected from December 5, 2008 to February 28, 2009. The data was grouped by toll rate and the associated volume (vphpl), speed and traffic densities are shown in **Table 5**. These results validate that the dynamic pricing algorithm is working as expected, where as the toll rates are falling within the

expected TD. It also demonstrates that when toll rates exceed $3.00; the average speeds drop below the targeted 45 mph.

Toll Rate	Average Volume (vphpl)	Average Speed (mph)	Average Traffic Density (TD)
$0.25	302	61	5
$0.50	772	61	13
$0.75	847	60	14
$1.00	913	60	15
$1.25	967	59	16
$1.50	1,118	58	19
$1.75	1,194	57	21
$2.00	1,225	56	22
$2.25	1,245	55	23
$2.50	1,256	53	24
$2.75	1,296	55	24
$3.00	1,234	46	27
$3.50	1,209	41	30
$3.75	1,207	36	34
$4.25	1,240	34	36

Table 5: Toll Rate and Associated Volume, Speed, and Traffic Density

A series of data was plotted to identify motorists' tolerance regarding how much they would pay to enter the 95 Express. **Figure 14** graphs the demand (volume) versus toll rate comparison in the express lanes and general purpose lanes from 4:00 pm (16:00) to 8:00 pm (20:00) on March 31, 2009. The volumes are taken at the I-95 mainline entrance to the 95 Express and represent the average vehicles per hour per lane. In Figure 14, the demand for the express lanes is equal to or greater than the general purpose lanes when $3.00 is posted. However, the demand for the express lanes is reduced by 24% when the rates reached $3.75. It is important to note that reduction in demand occurs at 6:30 PM towards the end of the PM peak period. Therefore, there needs to be more analysis conducted to determine if the motorists' tolerance is $3.00.
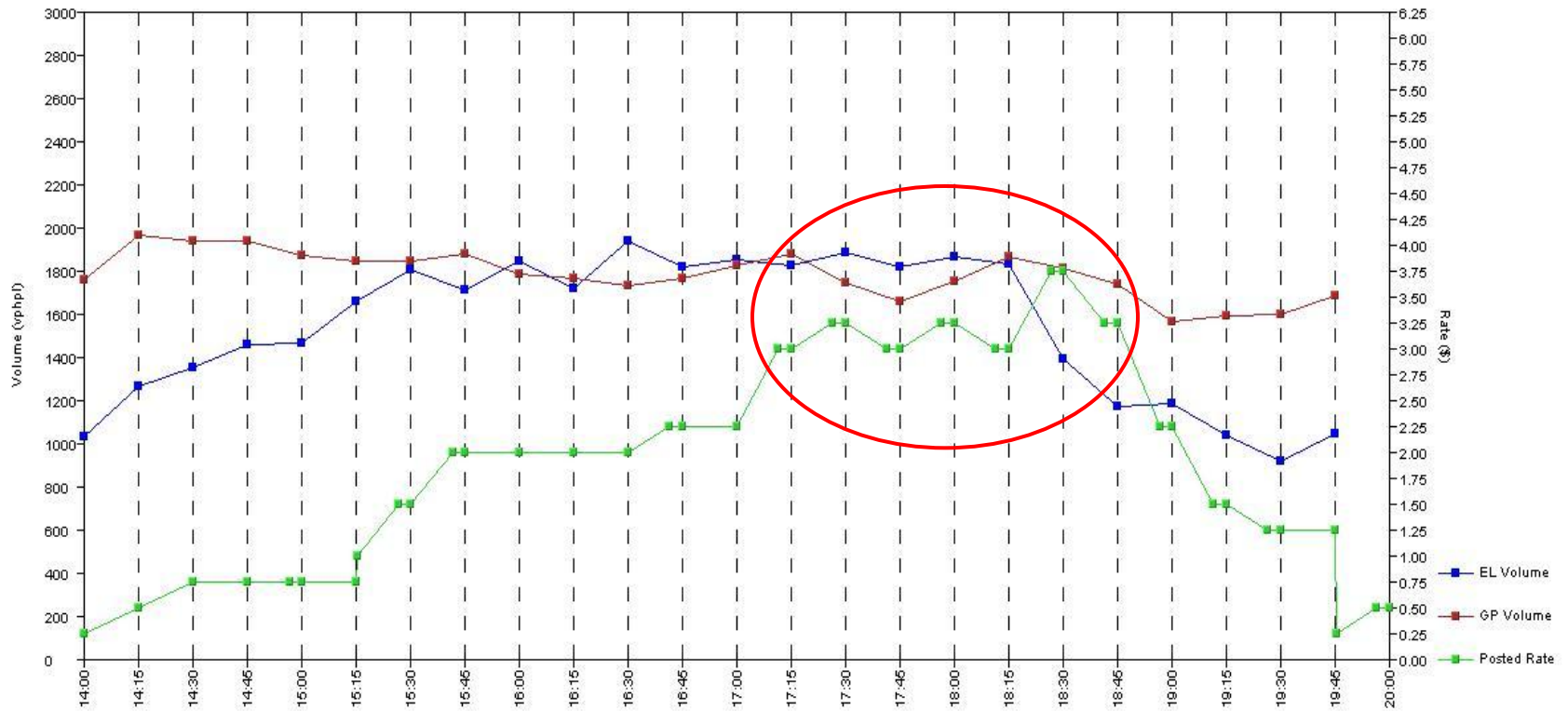
Figure 14: Volume vs. Toll Rate (March 31, 2009)

Benefits

The average speeds for PM Peak Period are shown in **Table 6**. This data shows that the average speeds in the general purpose lanes remained close for before and after scenarios. It also shows how speeds increased in the express lanes after tolling began resulting in an 18 miles per hour (mph) difference. The overall average I-95 corridor (express lanes and general purpose lanes) speed increase from 40 mph to 47 mph.

	EL (mph)	GP (mph)	Difference
Before	43	38	5
After	57	39	18

Table 6: Average PM Peak Period (4PM to 7PM) Speeds

The improved speeds in the 95 Express translate into reduced delays and more reliable travel. The daily I-95 corridor PM Peak Period delay was reduced by 600 hours. The PM peak period travel time index, a measure of reliable travel, continues to operate below 1.0 in the express lanes, while the general purpose lanes typically has a travel time index of 1.59.

REFERENCES

(1) Florida Department of Transportation, "95 Express Toll Facility Operations Manual, Version 1.0", November 2008.
(2) Florida Administrative Code, "Toll Rule 14-100.003 Variable Rate Tolls for Express Lanes", December 2008.
(3) Bo Shao, "Express Lane Watcher User Guide", Florida Department of Transportation, January 2009.
(4) Florida Department of Transportation, "Florida Traffic Information", CD (2007).