EXPRESS LANE OPERATIONAL STRATEGIES FOR MANAGING DEMAND

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ABSTRACT

On December 5, 2008, the FDOT began tolling operations for High Occupancy Toll lanes along the I-95 corridor, known as 95 Express. The FDOT had developed a software application to implement dynamic pricing, which has shown to be an important element in reaching the project's goal of providing more reliable travel options along the corridor. The 95 Express has provided transit users and motorists in both the express lanes (EL) and General Purpose Lanes (GPL) with significant benefits. The popularity of the project has resulted in increasing demand for the express lanes and new challenges for FDOT to provide the level of service expected by express lane users based on existing toll rules. This paper documents an analysis of three operational strategies. These strategies include:

- Adjustments to the dynamic pricing parameters.
- Congestion messaging on lane status signs when the EL experience significant congestion.
- Post incident pricing strategies.

Keywords: Express Lanes, Managed Lanes, Operational Analysis, High Occupancy Toll Lanes, Pricing Strategies, Operational Strategies.

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. Other improvements include ramp signaling, incident management services, and express transit services.

Figure 1: Project Area

The 95 Express Project included 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 express lanes are separated by removable delineators with 10-foot spacing. 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 southbound from Golden Glades Interchange to I-395, plus extend the northbound from I-395 to 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.

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:

- 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 operating conditions within 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.

On December 5, 2008, the FDOT began tolling operations for Phase 1A. The FDOT had developed a software application called Express Lanes Watcher to implement dynamic pricing. Over the last two and half years, the Express Lanes Watcher evolved into Express Lanes Module (ELM) that is part of a suite of TMC operational tools. In addition, it has been improved to;

- Increase the integration with SunGuide Software,
- Reduce manual processes, and
- Enhance the reporting and configuration capabilities.

The implementation of dynamic pricing has shown to contribute in reaching the project's goal of providing more reliable travel options along the corridor. The 95 Express has provided transit users and motorists in both the express lanes (EL) and general purpose lanes (GP) with significant benefits. The 95 Express project has resulted in an increase in the average peak period speeds.

One of the key 95 Express project goals is trip reliability, which is measured by the percent of time the facility operates at speeds greater than 45 miles per hour (MPH) during peak periods. The project requirement is to meet this goal over any continuous 90 day period. In fiscal year 2010/2011, the express lanes operated greater than 45 MPH for 99% of the time during the southbound am peak period and 92% of the time during the northbound pm peak period.

A more reliable trip also translates to greater demand for the express lanes. Since its inception, traffic volumes have increased steadily. For the northbound direction, average weekday traffic volumes have increased from 19,700 vehicles per day (VPD) in December 2008 to 29,900 VPD in June 2011or a 52% increase. For the southbound direction, average weekday traffic volumes have increased from 23,800 VPD in January 2010 to 30,200 VPD in June 2011or a 27% increase. The increasing demand for the express lanes challenges the FDOT to identify and implement operational strategies that maintain the level of service expected by express lane users.

This paper documents an analysis of three operational strategies which have been main tools used by the management/operations team to meet the growth and changing operational characteristics of 95 Express. These strategies include:

- Adjustments to the dynamic pricing parameters.
- Congestion messaging on Lane Status signs when the EL experience significant congestion. These are one line dynamic message signs embedded into static overhead signs that inform the motorist if the EL is opened (tolls enforced) or closed.
- Post incident pricing strategies.

ADJUSTMENTS TO DYNAMIC PRICING PARAMETERS

This section discusses how by adjusting dynamic pricing parameters, the FDOT was able to successfully manage an increase in express lanes traffic due to a change in roadway configuration as part of the construction of Phase 1B and increase popularity.

DYNAMIC PRICING ALGORITHM OVERVIEW

The dynamic pricing algorithm built into the Express Lanes Module (ELM) software was designed to manage traffic demand in the express lanes. It calculates toll amounts based on traffic demand and adjusts the toll amounts based on how quickly traffic demand changes. Traffic demand is measured using traffic density (TD), which is a combination of speed and volume. TD is calculated dividing the traffic volume (vehicles per hour or VPH) by speed (miles per hour or MPH).

The toll amount changes are controlled to ensure a toll amount range will consistently match a range in level of service (LOS). The Highway Capacity Manual (HCM) defines the relationship between LOS and TD (see Table 1). 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

For 95 Express, 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 ELM software was developed to allow fine tuning of the dynamic pricing algorithm through 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, then to a maximum and minimum toll amount 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	$5.00
E	>35 – 45	$3.75	$6.00
F	>45	$5.00	$7.00

Table 2: Level of Service Settings Table

The Delta settings relate a change in TD (ΔTD) with a change in the toll amounts (ΔR). A section of the Delta settings table is shown in Table 3. The Delta settings are used to define the magnitudes of increases or decreases of tolls based on changes in TD. This provision supports a quicker response to deteriorating traffic conditions when they occur suddenly.

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

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. The following is a sample calculation. The previous toll amount (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 2):

- 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 \$5.00, respectively. The calculated current toll amount (R_t) of \$3.50 falls within the associated toll range; therefore, a toll of \$3.50 is implemented.

There are three key configurable elements:

- Level of Service (LOS) Settings – To modify the ranges of traffic density and toll amounts for each LOS.
- Delta Settings – To modify the toll amount change for each TD and a respective change in TD.
- Detectors – The flexibility to base the TD on selected detectors, such as at bottlenecks.

ADJUSTMENTS TO THE PARAMETERS

On February 22, 2010, the Phase 1B northbound (NB) entrance was opened that changed the lane configuration for I-95 NB at the entrance to the express lanes (see Figure 2). During Phase 1A, the I-95 NB entrance was a single lane with a second lane being created as a ‘add on’ at the SR 112 entrance. For Phase 1B, two I-95 NB express lanes existed prior to SR 112 and the SR 112 entrance became a merge condition versus a add condition. The additional capacity to receive vehicles wanting access from I-95 in conjunction with the success of 95 Express produced an increase in traffic volumes along I-95 within the 95 Express project limits. The maximum peak period volume (VPH) in the express lanes increased from 2,900 VPH to 3,317 VPH (14.4%) and the general purpose lanes increased from 6,154 VPH to 6,669 VPH (8.4%) as a result of this improvement. And though the capacity and demand had increased at the beginning of this segment of 95 Express; at this time there were no improvements to increase the capacity at the end of the express lanes leading into the Golden Glades Interchange (GGI). However, the FDOT is about to complete a capacity improvement project in the GGI that will increase capacity at the GGI. In summary, by maintaining the limited capacity at the GGI and increasing the capacity at the express lanes entrance (for both EL and GP) the EL performance deteriorated. From February 22, 2010 to March 11, 2010, the EL operated greater than 45 mph only 80% of the time during the PM peak period.

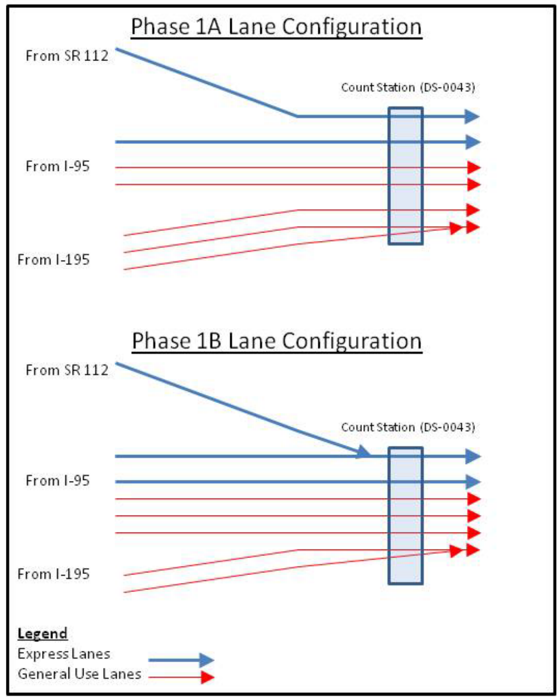

Figure 2: Northbound 95 Express Lanes Configuration Changes

On February 26, 2010, the northbound express lanes toll amount reached the then maximum allowed amount of $6.20 (before the maximum was raised to $7.00). It was primarily due to the increased in demand. However, it should be noted that there other non-lane blocking (shoulder events that resulted in on-looker delays) conditions that contributed to the reduced speeds in the express lanes. The 15-minute volume per lane (VPHPL) for the EL and GP were plotted against price (see Figure 3) for detector station DS-0043N on February 26, 2010. Detector DS-0043N was selected instead of the facility average to focus on demand to the facility and exclude the congestion that occurs at the GGI egress. It is important to note that the toll amount is calculated based on the average all detector stations for the tolling portion of the express lanes. Therefore, Figure 3 does not show the volumes representing a traffic density used to calculate the toll amount.

Historically, the EL demand began to drop when toll amounts rose above $3.00. This is depicted in Figure 3 from 15:45 to 16:00; where the toll rate of $3.75 had an initial impact to EL demand. However, it did not discourage motorists enough to bring the EL demand below the target maximum volume of 1,500 VPHPL to ensure a reliable trip. After further investigation, it was determined average speeds at the beginning of the EL was greater than 50 mph, while the speeds in the GP where approximately 23 MPH and creating visible congestion that is typically not present. Therefore, it can be concluded that when the GP speed at the ingress is below 25 MPH, the motorists' threshold increase to approximately \$5.00 instead of \$3.00. This is observed from 17:15 to 18:30, where the EL volume decreased from 1,604 VPHPL to 1,010 VPHPL and the toll amounts were \$5.00 or greater.

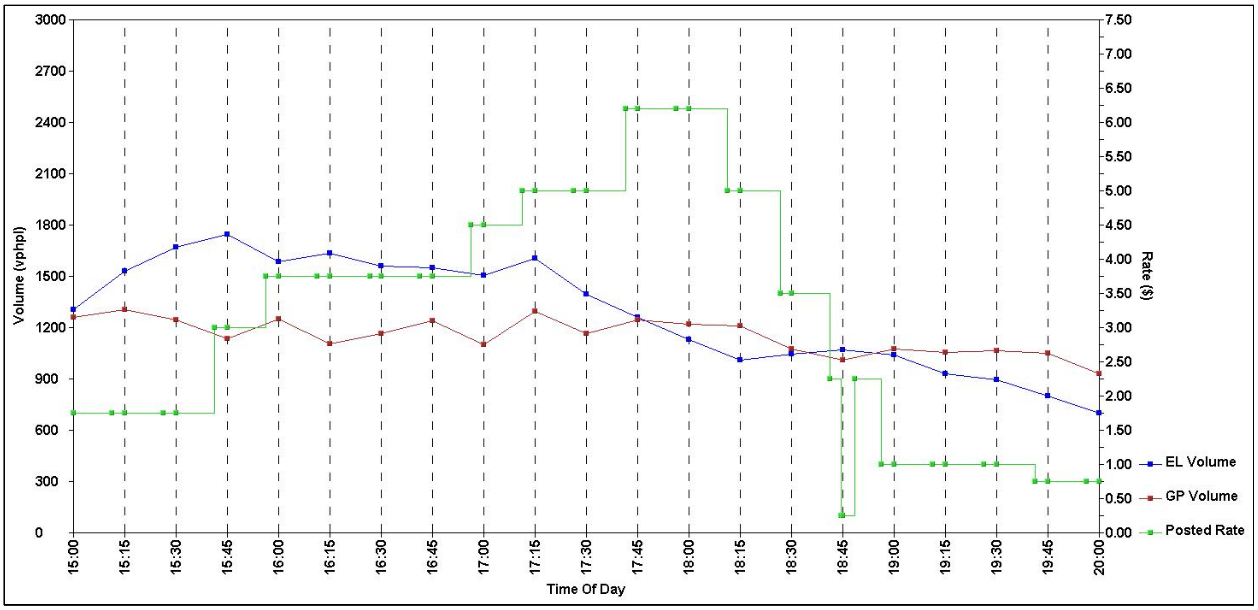

Figure 3: Volume versus Toll Amount (February 26, 2010)

After reviewing the toll amount calculations for February 26, 2010; it was observed that the even though the TD was increasing, the calculated toll amount was constrained by the parameters in the original LOS table. The original LOS table was set to the following parameters:

LOS	Min TD	Max TD	Min Toll	Max Toll
D	27	35	\$3.00	\$3.75

On February 26, 2010, the TD jumped from 27 to 30 during a 15-minute period (from 15:45 to 16:00) because of the visible congestion in the GP at the beginning of the EL. The original delta table had a price increase of \$0.75, bringing the toll amount to the maximum of \$3.75 for a TD of 30. As the TD increased from 30 to 35, the toll amount was capped at \$3.75. By limiting the toll amount to \$3.75 as the demand continued to grow, the facility began to breakdown significantly resulting in the toll amount reaching the maximum at the time of \$6.20. Therefore, the parameters were adjusted to expand and the limits for a given traffic density in the LOS table, as shown previously in Table 2. This adjustment will allow for the dynamic pricing to be more proactive to deteriorating conditions in the EL and improve trip reliability. Figure 4 compares the toll amounts for the original delta/LOS tables with the adjusted delta/LOS tables. Figure 4 demonstrates the adjustments to the parameters will result in a more aggressive tolling strategy. On March 11, 2010, the adjustments were implemented. From March 11, 2010 to April 3, 2010, the EL operated greater than 45 mph 89% of the time during the PM peak period. Therefore, the adjustments to the dynamic pricing algorithm parameters proved to be an effective operational strategy for managing demand in the EL.

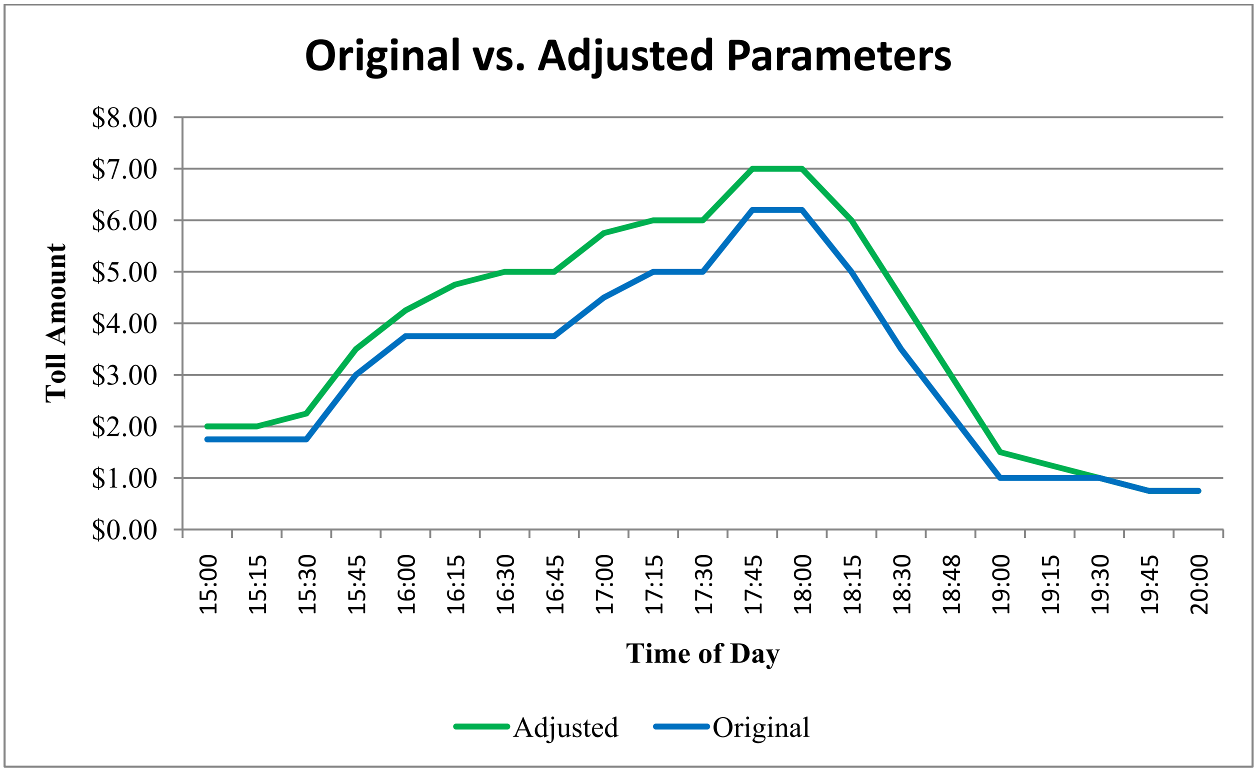

Figure 4: Comparison of Original and Adjusted Parameters (2-26-2010)

CONGESTION MESSAGING

Many motorists take I-95 (including the express lanes), through the GGI, to Sun Life Stadium, which holds various special events. On October 4, 2010, the Miami Dolphins played a Thursday night game which resulted in the EL reaching the maximum toll amount of $7.00. The adjustments to the dynamic pricing algorithm, which proved to be successful for typical peak period conditions, was unable to reduce demand to maintain speeds above 45 mph for special events. Subsequently, the FDOT received feedback from some motorists that misinterpreted the basic concept behind the dynamic pricing strategy. The concept is to increase the price as demand increases to discourage motorists from taking the EL. Some motorists were under the impression that as the toll amounts increased, so did the benefits of using the EL over the GP. Immediately, the FDOT further ramped up its public outreach efforts to better educate the media/public on the concept behind the dynamic pricing strategy. From an operational standpoint, the FDOT implemented a new strategy that better informed the motorists of traffic conditions inside the EL before they entered.

On November 18, 2010, the FDOT began to post congestion messages on the Lane Status signs for special events, such as Miami Dolphins football games that occurred on weekday nights. By implementing this strategy, this was the first time the EL did not reach a maximum toll amount during similar special events. On December 22, 2010, the FDOT expanded this policy from special events only to cover any congestion in the EL. As a result when 50% or more of the facility was observed to be congested and average speeds dropped below 45 MPH, FDOT would implement this congestion procedure. However, on January 3, 2011 another special event occurred (Orange Bowl) was held and the maximum toll amount was reached. It is important to note that this particular special event also included a series of police escorts through the facility that significantly impacted performance.

The effects of posting congestion messages on Lane Status signs was evaluated for non-special event days. Since it has been established that toll amounts impacts the volumes entering the facility, two days (before and after) were selected in which there was similar toll amounts posted and similar times of day (PM Peak Period). The days selected were December 6, 2010 (before) and January 19, 2011 (after). On January 19, 2011, "CONGESTED" was posted on the Lane Status signs from 17:40 to 18:15, instead of the typical "TOLLS ENFORCED" message. Table 4 below compares the volumes from both days and how they changed due to an increase in toll amounts, as well as the posting of "CONGESTED" on January 19, 2011. On both days, the toll amount increased from $3.50 to $5.00. On December 6, 2010, the EL volume decreased by 16% as a result of the toll amount increasing to $5.00; whereas on January 19, 2011, EL volume decreased by 19% as a result of the toll amount increasing to $5.00 and the posting of a congested message. Therefore, the posting of "CONGESTED" had a minor impact on the volume.

Date	Begin Time	EL Volume (VPHPL)	GP Volume (VPHPL)	Toll Amount	Volume % Difference
12/6/2010	17:45	1118	1051	$3.50	16%
12/6/2010	18:00	944	1027	$5.00	
1/19/2011	17:30	1080	1175	$3.50	19%
1/19/2011	17:45	890	1175	$4.75	
1/19/2011	18:00	878	1156	$5.00	

Table 4: Volume Comparison

It is important to note that motorist decision to drive the EL maybe based on factors that may change from day-to-day, such as reaching an event by a certain time or just for convenience.

POST INCIDENT PRICING STRATEGIES

Another remaining challenge for the FDOT was the time to return to free flow conditions in the EL once an incident had occurred during heavy demand for the EL. Previously, the toll amounts would use the amount before the closure until the next update, then time of day toll amounts for two 15-minute cycles before adjusting to demand. The primary reason for this was that the dynamic pricing algorithm would be based on traffic data during a reduced capacity condition, instead of normal capacity, thus skewing the traffic density calculation and not accurately reflecting the traffic demand in the facility.

On January 3, 2011, there was a special event (Orange Bowl) that generated high demand for the

EL. Figure 5 depicts the volumes and speeds as they relate to toll amounts for that day for detector station DS-0043N. The EL were closed at 16:59 and re-opened with the previous toll amount of $3.75 at 17:07. For EL closures less than 30 minutes, a soft closure procedure is implemented, where “Closed” is posted on the Lane Status signs, but the entrance ramp is not physically blocked. As a result, there was some reduction in volume (from 1,552 VPHPL to 1,360 VPHPL). At the next update interval (17:11), the toll amount was set to the time of day amount of $2.00, which increased demand into the EL at a volume of 1,672 VPHPL. The demand remained high for the next interval, which was also set to the time of day toll amount of $2.25. The demand was too much for the EL and queues began to back up within facility. Figure 5 shows the EL speeds dropped at detector station DS-0043N to below 45 MPH. Meanwhile, the average speed (not shown in Figure 5) for the entire facility was below 45 MPH from 17:15 to 19:00. Once the dynamic pricing algorithm kicked back in at 17:45, the volume entering the EL decreased from 1,608 VPHPL to 1,164VPHPL. Subsequently, the demand was successfully managed by the toll amount until the EL was able to recover.

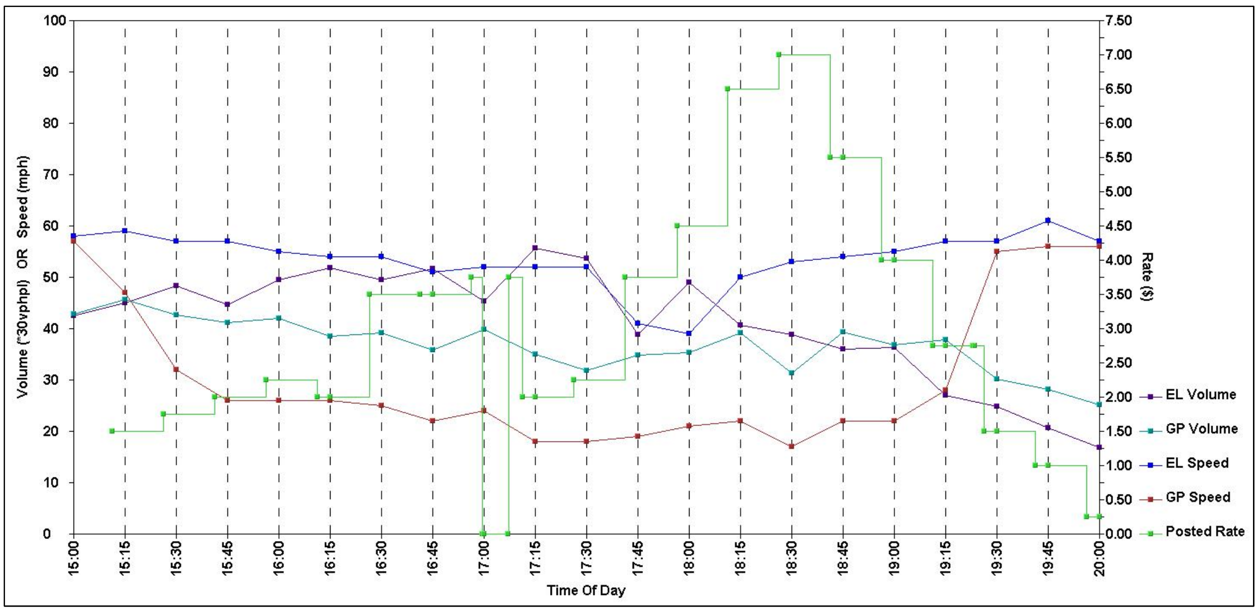

Figure 5: Volume and Speeds versus Toll Amount (January 3, 2011)

Recognizing that price is the most powerful tool for managing demand, the FDOT implemented a new strategy that expedites the restoring of dynamic tolling. The new strategy was launched on August 1, 2011 and is fully automated in the ELM. The strategy includes a continuous calculation of TD and toll amount regardless if the EL is closed or open. The proposed procedure is demonstrated in Figure 6.

As shown in Figure 6, once the EL is reopened, immediate effect toll amount (R_i) will be either the Time of Day toll amount (R_n) or the last calculated toll amount (R_0), whichever is greater. This ensures the most aggressive toll amount is utilized to better manage traffic demand. When a proposed scheduled interval of toll calculation starts, the toll amount for the first interval (R_1) is calculated using current TD_1, and a combination of either TD_0 and R_0, or TD_n and R_n, depending on which toll amount was selected when reopened. Dynamic tolling is fully recovered in the first scheduled interval.

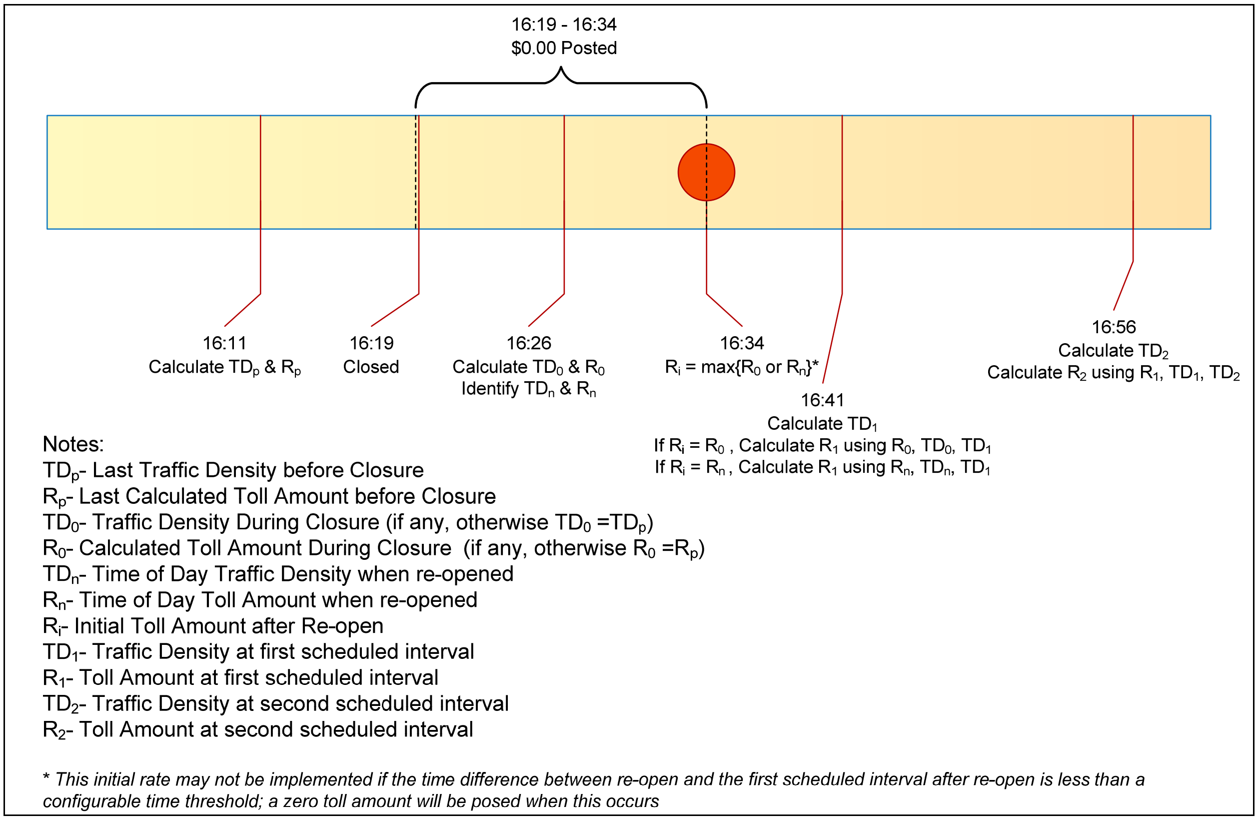

Figure 6: Proposed Procedure for Toll Calculation during EL Recovery from Closure

The new recovery strategy has not been tested for special events yet, but it appears to better manage demand after an EL closure. Figure 7 depicts the volumes and speeds as they relate to toll amounts on August 12, 2011for detector station DS-0043N. There was a soft closure in the EL from 15:20 to 15:28. The EL re-opened with a toll amount of $3.75 instead of a time of day toll amount of $2.00. Figure 7 shows that this increase in toll amount contributed to the managing the increase in demand entering the facility, such that the average speeds (not shown in Figure 7) in the facility remained above 45 MPH. At 17:19, there was another soft closure in the EL and the volume was reduced from 1,496 VPHPL to 1,140 VPHPL. At 17:55, the EL re-opened at $4.00 to maintain a reduced volume and the EL average speed (not shown in Figure 7) was maintained above 45 MPH for the entire PM peak period.

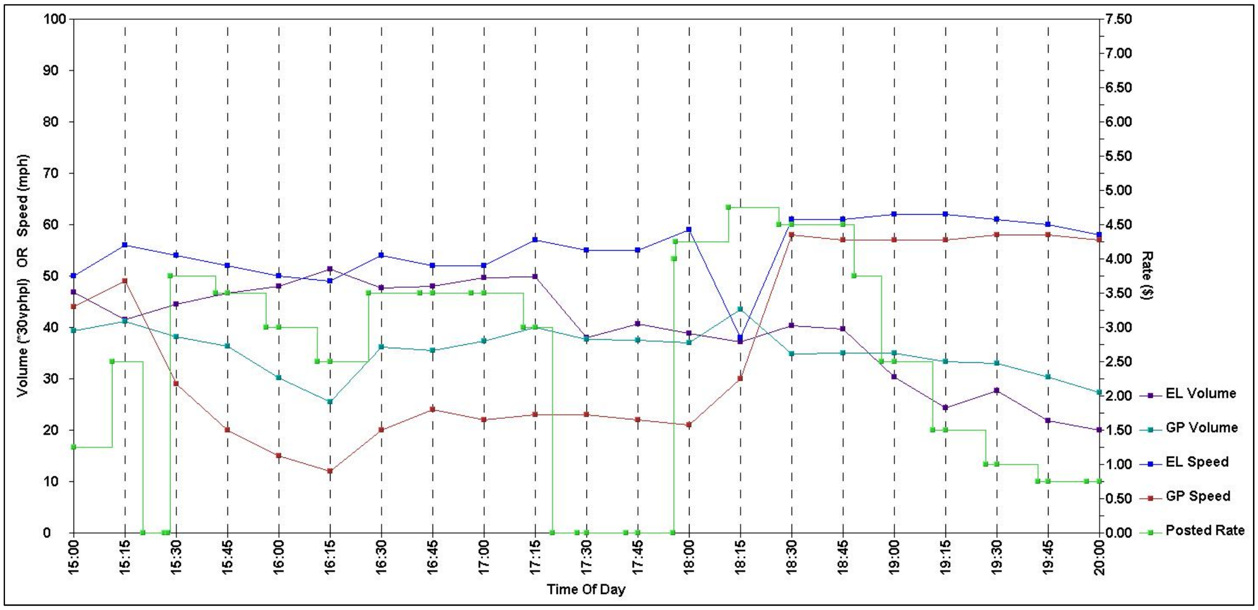

Figure 7: Volume and Speeds versus Toll Amount (August 12, 2011)

CONCLUSION

The 95 Express Project has been very successful to date for many reasons. One important reason is that the FDOT takes a proactive approach to monitoring traffic conditions inside the EL and developing new operational strategies to ensure a more reliable trip for motorists as the EL mature and motorists adapt to a new travel option.

This paper shows that by implementing operational strategies, agencies can more effectively manage demand and improve overall performance of managed lanes. All three operational strategies presented in this paper demonstrated a positive impact towards maintaining one of the projects goals: trip reliability.