FLORIDA'S TURNPIKE ENTERPRISE/ALL ELECTRONIC TOLL COLLECTION

THE VISION – THE CHALLENGES

Gerald W. Sudimick P.E.
Senior Project Manager
Post, Buckley, Schuh & Jernigan
105 Fieldcrest Avenue Edison, New Jersey 08837
USA
Telephone: 732-417-0890
Email: gwsudimick@pbsj.com

Prepared For
4th International Geometric Symposium Valencia, Spain

FLORIDA'S TURNPIKE ENTERPRISE/ALL ELECTRONIC TOLL COLLECTION

THE VISION – THE CHALLENGES

Gerald W. Sudimick P.E.

ABSTRACT

As part of the Florida's Department of Transportation, Florida's Turnpike Enterprise (FTE) oversees 454 miles of limited access toll highways. Original design and construction began in South Florida in the late 1950's and has continued to expand, presently crossing through 16 counties comprising nearly 60 percent of the State's population. Toll collection methods on the system have evolved through the years from stop and go cash-based collection; to slow speed dedicated electronic lanes with cash, to high speed lanes with cash, with the ultimate goal of providing all electronic tolling at open road speeds without cash. Through this evolution, the limiting effect of the original low speed plaza geometry and the physical constraints associated with the old plaza designs has become apparent.

The Vision of FTE is to convert forty seven miles of a high volume urban freeway to a cash-free, high speed, all electronic toll collection facility. Within the project limits there are four (4) mainline plazas and forty two (42) ramp plazas, all located in a densely populated urbanized section of South Florida. Simultaneous construction phases include; geometric alignments; new tolling point structures; demolition of the existing plazas; deactivation and removal of the old collection system; installation and testing of the new electronic system all being performed without disruption to toll collection or impact to the customers.

This report presents the challenges faced when removing existing stop and go cash toll plazas, and installing a cashless all electronic toll collection system at open road speeds.

KEY RELATED TERMINOLOGY

The following terms and abbreviations are used in this paper:

FTE Florida's Turnpike Enterprise, Orlando, Florida. USA
HEFT Homestead Extension of the Florida's Turnpike System
AET All Electronic Tolling
ORT Open Road Tolling is Electronic Tolling at posted speeds with adjacent cash lanes.
ARRA American Recovery and Reinvestment Act of 2009
TSR Toll System Replacement Program provides and updates the existing collection equipment
OSLOT Onsite Live Operational Testing of the new electronic collection equipment
PPM Florida Department of Transportation's Plans Preparation Design Manual
TPPPH Turnpike Plans Production and Preparation Handbook
ITE Institute of Transportation Engineers
NCHRP National Cooperative Highway Research Program
AASHTO American Association of State Highway and Transportation Officials
NTP Notice to Proceed

INTRODUCTION

The Turnpike Enterprise is part of the Florida's Department of Transportation, overseeing a 454 mile system of limited access toll highways. Design and construction began in the early 1960's and has continued to expand, presently crossing through 16 counties comprising nearly 60 percent of the State's population. Figure 1 presents the location of the Homestead Extension of Florida's Turnpike (HEFT) at the southernmost end of the Turnpike mainline. Agricultural, industrial, and residential areas line the forty seven (47) miles of the HEFT which not only functions as an outer beltway to the City of Miami but also serves as the most direct route for visitors and commercial vehicles to reach the Florida Keys. The HEFT also serves as a major hurricane evacuation route for South Florida and the Florida Keys.

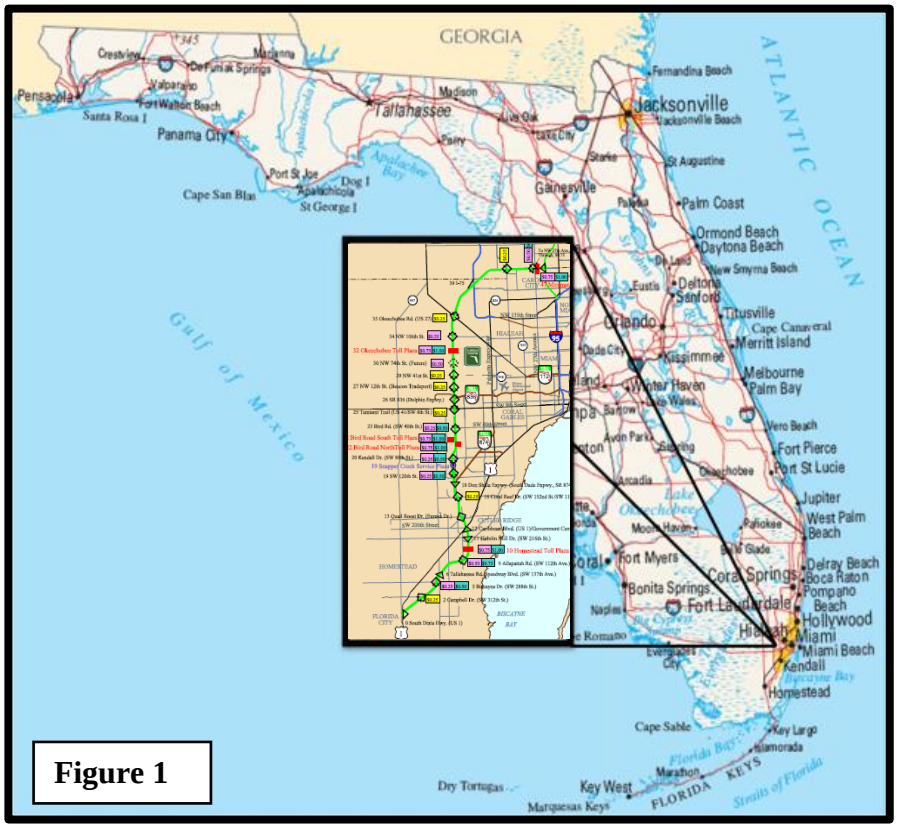

Figure 1

Serving as an outer belt way to the City of Miami, the primary function and the highest use is by commuters traveling to and from their work destinations. Congestion, customer service, safety, operational costs, incident management are just a few of the concerns that makes the HEFT one of FTE's top projects slated for future widening.

Toll collection methods on the system have evolved through the years from stop and go cash-based collection, to slow speed dedicated electronic and cash lanes, to processing electronic toll collection at a higher lane speeds. The ultimate goal being electronic tolling at open road speeds without cash. Introduction of SunPass electronic toll collection occurred in 1999, to date the average electronic participation rate on the HEFT is 73% with some variance at certain plaza locations. The continued utilization of the old plaza designs are a concern due to the limiting effect of the original low speed plaza geometry, physical constraints, operational turbulence and driver decision making associated with mixed collection methods.

As a stepping stone to the conversion to an all electronic toll collection system, a series of construction projects were initiated to convert components of the existing barrier plazas to a modified form of higher speed electronic toll collection adjacent to the existing stop and go cash collection system. This conversion was defined by FTE as Open Road Tolling (ORT) with seven (7) mainline plazas opened between late 2007 and late 2008 including two of the four mainline plazas on the HEFT. This interim project improved traffic turbulence on the approach roadways; influenced driver decisions at diverge/merge location points; installed concrete barrier separation between the adjacent cash lanes and higher-speed lanes (for safety); increased capacity and improved customer service. One year after the last plaza was converted, FTE Traffic Operations finalized a before and after study analyzing the benefits of ORT. The analysis looked at crash rates, crash frequencies and social economic impact analyses. Their report concluded that the application of open road tolling resulted in an overall 58% reduction in the crash rate at the converted plazas. *Florida's Turnpike Traffic Operations - ORT Toll Plaza Analysis* (1)

From the success of the interim conversion, a decision was made to remove all points of conflict in converting all mainline and ramp plazas to a cash-free, high speed, All Electronic Toll (AET) collection system. All Electronic Tolling at open road speeds is the collection of tolls utilizing an electronic transponder in the vehicle. If the vehicle does not have a transponder, overhead cameras will capture the vehicle license plate, and drivers without transponders will receive an invoice in the mail. In conjunction with the conversion, a Tolls System Replacement Program (TSR) contract was put in place to update the existing electronic collection system.

The initial approach divided the HEFT into four segments, or construction phases, with each phase being sequentially converted to the all electronic form of collection. Through conceptual development, early evaluation of the initial approach concluded that a four phase sequential conversion would introduce uncertainty as to the form of collection at each plaza, impact plaza safety, affect operational impacts, decrease capacity, and produce loss of revenue and customer frustration. A revised recommendation was proposed on the sequence that served to mitigate the previous concerns, identified critical milestones and accepted by FTE for the conversion. The recommendation provided for the implementation to all electronic tolling (AET) by a "flip the switch" overnight process.

The method selected to deliver this project was Design Build as it was necessary to adhere to a very tight and demanding schedule which involved the conversion to an all electronic system by removing all the existing plazas, maintaining toll collection while providing and installing the new electronic equipment. All of this was to be accomplished in coordination with a sister toll agency in Miami that simultaneously was converting their system to all electronic.

With all mainline plazas located in the first three phases, Phases I & II or the southern portion were combined and funded by FTE while the northern portion, or Phase III, was funded through the American Recovery and Reinvestment Act of 2009 (ARRA). Phase IV is currently in conceptual design phase. The process of simultaneous construction phases including geometric alignments, new tolling point structures, demolition of the existing plazas, and deactivation and removal of the old collection system; as well as the installation and testing of the new electronic system has to be accomplished without disruption to toll collection or impacting the customers.

A two year construction schedule was developed addressing all the critical milestones and concerns, i.e. design, fabrication of tolling structures/ new equipment buildings, Onsite Live Operational Testing (OSLOT) for TSR equipment, sequence of critical plaza conversions, twenty one day window for equipment installation and testing for each plaza, complete re-signing of HEFT, holiday and major event

restrictions, a mandatory date when critical plazas would be ready for implementation, no existing plaza demolition until the conversion and no lost revenue. The two year schedule with the restrictions and critical dates for both projects required dedicated staffing, with open communication and cooperation to meet the mandatory date for implementation.

PREVIOUS STUDIES

Toll agencies, publications and research have previously examined the issue to convert existing barrier plazas to a form of electronic toll collection. They also identified the need to provide design criteria and guidelines for toll plaza design. Several such studies and publications are noted here: *NCHRP Synthesis 240 on Toll Plaza Design* (2) noted that after extensive literature and standards search revealed that no general standards exist and the only standards are those developed by the individual toll operators. *ITE Geometric Design Handbook on Freeway and Interchanges* (3) states creating uniformity and consistency of design standards with the newest technical advances promotes a safer roadway environment for the motorist and incorporates technology that reduces queues and improves operations at the toll plaza. Chapter 14 on toll road facilities supplements previous research and presents the current toll plaza design practices to the design community. *American Association of State Highway and Transportation Officials (AASHTO 2004)* (4) suggest that consistency in design elements is needed to meet driver expectations.

FLORIDA'S DESIGN CRITERIA

Florida's *Plan Preparation Manual (PPM)* (5) is utilized throughout the State of Florida for highway design, but does not specifically address criteria or geometric guidance for toll plaza design let alone the complete removal of toll plaza barriers and replacement with open road tolling structures. Over the years as the FTE system expanded through new construction, reconstruction, or expansion projects and the experience and knowledge gained through toll plaza design, FTE recognized the need to provide design criteria and guidelines to achieve design consistency. As a result, FTE developed and published toll plaza design criteria and guidelines in their *Turnpike Plans, Preparation and Practices Handbook (TPPPH)* (6). The TPPPH does not address or consider the complete removal of toll barriers and replacement with electronic tolling structures. This was the first all electronic toll conversion on an FTE system and a new set of guide lines and criteria was needed. This conversion would serve to develop the guidelines and approach for future conversion projects for inclusion in the TPPPH. Aside from guidelines and criteria, engineering judgment is also required in order to apply design principles. This is particularly evident when the first three phases being converted included four (4) mainline plazas and thirty three (33) ramp plazas to all electronic/cashless system for toll collection without reconstructing entire ramp(s) or significant lengths of the HEFT mainline and Phases I – III.

As the AET conceptual process moved forward, the following design protocols were imposed and incorporated.

- Tolling structures shall be located on tangent with cross slopes no greater than 2 %.
- For Phase III with ARRA Funding no design exceptions would be allowed.
- Preliminary Design & Environmental (PD&E) studies have been completed on the HEFT and to the extent possible new tolling structures and supporting infrastructure would accommodate the future widening.
- With the imminent widening of the HEFT, the AET conversion should minimize extensive reconstruction of the ramps and mainline.
- With the evolution of electronics and the tolling technology, a 12 to 15 year design year would be applicable.
- An integral component to the AET conversion was the inclusion of the Tolls System Replacement Program (TSR) with the stipulation that one of the mainline plazas be available to conduct ON SITE Live Operational Test (OSLOT). OSLOT shall be accomplished prior to the installation of toll equipment on the remainder of the HEFT.
- The implementation or "flip the switch" date for conversion to all AET is February 15, 2011.

RAMP PLAZAS

The only similarity between the 33 ramp plazas is they each provide a location for toll collection. The challenge was to sequentially install a new tolling structure and equipment, remove the existing plaza, evaluate design speeds, geometric alignments, and grades, cross slopes, minimize costs, and avoid disruption to toll collection and accomplish this within a ramp distance of 400 feet or less. Figure 2 is a Typical Ramp Toll Plaza

Figure 2

Ramp configuration - entrance and exit plazas on trumpet and diamond interchanges are strategically positioned at different locations along the ramp. Ramp geometry, sight distance, topography right of way, plaza access, are a few of the factors involved in selecting the plaza locations. Aside from a collection point plazas/barriers also slow vehicle speed on both the approach and departure side of the plaza. With the plaza removed (Figure 3) and replaced with a new open road tolling structure the stop and go traffic would now free flow. How would the ramp perform with an open road tolling structure?


Figure 3

Design Speed - FTE's plans data base was researched to obtain original or as-built plans, evaluating the original geometry on every ramp and with few exceptions determined that the ramps complied with current criteria. However, ramps are not posted at design speeds but rather with advisory speeds. Intuitively drivers tend to over drive the advisory speeds until they reach the plaza or ramp terminal. This was observed on several long diamond interchange exit ramps. Would there be impacts when the existing plaza is removed and the existing toll plaza pavement remains in place?

Grades – within the immediate vicinity of the plaza proper profiles varied in design from 0 to 1% with zero at the point of collection. Removal of the toll booths, islands and canopies would allow vehicles to drive unrestricted traversing the existing pavement profile and encounter a slight up lifting and control of the vehicle. Although advisory speeds should be adhered to this is not always the case, the existing profile would not support likely speeds over the old or remaining ramp profile. With limited criteria or research, engineering judgment and institutional experience with the facility determined to remove the existing pavement and correcting the profile.

Ramp Terminals – on trumpet interchanges several plazas were located on the only available tangent section of the ramp at or near to the ramp terminals with the local signalized crossing road. New tolling structures had to be located on tangent with unimpeded flow under the new tolling structure. Would there be queuing impacts from the signalized crossing road and what if any would be the

associated operational impacts at the new tolling structure? As the entry from the crossing road under the tolling structure would be improved the focus was on the exit side of the tolling structure. A queue analysis for the provided design year was generated for every plaza location and in all but a few locations did the queue extend under the existing plaza. Evaluation of the queues as well as the free traffic flow at the new tolling structure(s) determined the tolling structure be located on the approach side of the existing plazas extending the distance to the terminal, more available queue length and providing to the extent possible improved operations at the ramp terminal.

Lane and shoulder widths - adherence to PPM criteria for lane and shoulder widths for freeway design criteria related issues was considered, but other factors, including; long term maintenance of the electronic equipment on the tolling structure, realignments associated with future traffic growths, and the maintenance and protection of traffic during AET construction required evaluation of increased widths greater than freeway criteria. It was determined that the final dimensions under the tolling structure (including fifty (50) feet either side of the structure) would meet PPM freeway criteria with the exception of single lane ramps. In the case of single lane ramps, one shoulder was dimensioned at ten (10) feet wide. This shoulder would be electronically tolled and during periods of maintenance allow motorists to use the shoulder while the ramp travel lane was closed.

The Anomaly Memo –the existing approach and departure shoulders to the AET tolling structure were below standard and would not be corrected under the AET program. Discussion with FTE determined that short substandard shoulders were not applicable to the design exception process. The anomaly memo was recommended to FTE as a means to document the decision to leave the existing shoulder correction for a future widening as well as to advise the design build contractor on the appropriate design criteria for shoulder transitions. The memo served to document and summarizes the design methodology for non-critical design elements resulting in cost effective solutions that may not yield a design which meets or exceeds standard criteria, but provides an acceptable and safe design approach solution within the specific constraints of the project. Substandard cross slopes were also part of this process.

Substandard Shoulder Widths - One of the design protocols was to minimize ramp reconstruction. The full width paved shoulders under the tolling point had to transition to the existing shoulders on the approach and departure side of the new tolling point previously designed to several criterions; freeway, urban, and retro-fit. Typically, deficiencies associated with design elements require design variations, considering the project intent and all the ramp deficiencies would be corrected with the future widening. It was determined that the design variation process would not be the form of documentation for this project. However, documentation was required for several reasons, i.e., to provide the design build team design criteria/guidance and as a record document to the project files. The solution as noted above for shoulder transitions was included in a design *Anomaly Memo.*

Cross slope –was the other design element addressed in the *anomaly memo*. Except for a few isolated plazas, a new tolling structure would be constructed on a tangent section of the ramp, 200 feet from the existing plaza and within a cross slope transition that varied from zero cross slope under the existing canopy to normal cross slope on the ramp. Application of design criteria would impact existing barrier walls, guard rail and curbing thus extending the limits and costs of reconstruction. As the only guidance associated with cross slope at the immediate plaza comes from the TPPPH to warp and adjust cross slopes and, considering the new canopy is within 200 feet of the existing plaza, the application of new design criteria would not be applicable. Therefore, the anomaly memo directed that the design build team should when practical, follow PPM design criteria. However, the memo allowed for cross slopes less than criteria as long as all drainage issues have been evaluated within the immediate plaza and tolling structure, and follow the guidance provided in the TPPPH of warping/adjusting cross slopes to meet the existing conditions.

MAINLINE PLAZAS

All the mainline plazas shared some similarities, yet each was unique with respect to location, geometric alignments, design speeds, operational issues and methods of toll collection.

- An in line barrier with stop and go lanes and part of an earlier interim project removing part of the existing canopy, converting several cash travel lanes to a modified form of electronic open road tolling. As the modification was a precursor to the imminent all electronic tolling, freeway design criteria was not utilized.
- A split barrier plaza with stop and go lanes and the second interim project removing part of the existing canopy, converting cash travel lanes to a modified form of electronic open road tolling. Access tunnels are under both plazas.
- Figure 4 is an in line barrier at a system to system interchange with stop and go lanes, free lanes and electronic dedicated lanes at 25 mph.
- Figure 5 displays new construction and realignment of the mainline to 65 mph design criteria installing split electronic signature gantries with adjacent stop and go lanes.

Figure 4

Figure 5

The design and construction of the HEFT began in the late 1960's with a design speed of 60 mph and continued until completion in 1978. With four completely different plazas with posted speeds varying from 55 mph to 70 mph as well as dissimilar design criteria the clear decision was made to follow the States PPM design criteria for freeways and a design speed of 65 mph. The mainline challenge was not geometric but operational, safety, how to implement, demolish and provide maintenance and protection of traffic.

The mainline carries the highest traffic through four completely different plazas contributing to potential conflicts at the mainline plazas including; driver hesitancy on toll lane selection, merge/diverge, weaving movements all contributing to reduced capacity, operational issues and safety. Geometrically the mainline would be realigned and the fixed barriers removed improving on many of the operational issues. At the same time there was valid concern that a one at a time conversion on the mainline to all

electronic would continue to influence the operation and safety of the mainline. The preference was made to convert to all electronic tolling on the mainline at the same time however; the decision did not come without problems and unknowns.

Before any conversion work on the mainline plazas could take place it was mandatory and part of the TSR equipment replacement to go through on site live operational testing (OSLOT) at freeway speeds. One mainline plaza met the requirements and selected for OSLOT. The duration for OSLOT was three months during this interim period all existing collection systems remained operational.

The OSLOT plaza received a new tolling structure and equipment and functioned under testing mode while all existing systems remained active as testing progressed. At the same time, how to efficiently correct the mainline geometry, construct new tolling structures, demolish the old plaza and maintain traffic, were challenges. Each plaza went through an extreme evaluation process with focus on safety, inconsistent tolling, customer perception, speed of construction and operational issues as key objectives.

Tolling structures with new equipment buildings were moved away from the existing plazas, allowing for installation and testing of the new equipment. Existing collection systems remained active and the demolition phase of the old barriers would not take place until the new system at all the mainline plazas was fully activated. With all testing complete, the public information office campaign very active and all new signing in place, over night the new system was activated, old systems de energized, cash lanes closed; AET was now implemented.

The last phase was to complete construction of the remaining geometric corrections and through a detailed plan for the maintenance and protection of traffic at each plaza the demolition phase was implemented.

INNOVATIONS

Expedited reviews - Once the Design Build Firm was selected for the project, FTE created an innovative management concept of a team of dedicated professionals to expedite plan reviews. The "team" members were the same individuals that worked together and wrote the criteria document for the project so they were very knowledgeable with the project particulars. The team would be available to the designers and participate in plan reviews in the designer office, releasing the plans for construction without the typical long duration reviews. The team made these projects priority one by being available 24/7, which ensured that task assignments on the AET conversion took precedence over other project assignments. The dedicated individuals consisted of personnel from project management, roadway, drainage, structures, signing & pavement markings, toll engineering and lighting. The "team" was utilized throughout design and continued until project completion in construction.

Simplified Toll Gantry – FTE has a preferred Signature Gantry for the mainline tolling points and a simpler version for the ramps. The mainline gantry allowed for technicians to maintain toll equipment with the use of a unique retrieval system and without the use of lane closures. This gantry took over six-months to fabricate and would not work with the schedule. The design build team was allowed to design and fabricate a simplified gantry that could be installed within the reduced schedule.

Construction complexities – Mainline as well as a significant number of ramp plazas were heavily travelled, and the project was on a very tight schedule, the construction sequences were complex. A comprehensive plan was developed during the acquisition phase and then continued after NTP by working closely with the design-build firm and resident CEI staff. There were multiple lane closures, weekend and extended closures in congested plazas requiring new electronic systems, mainline realignment and demolition of the barriers. The first priority for the entire team was the safety of the Turnpike customers.

Design anomalies memo - served to document and summarize the design methodology for non-critical design elements that result in cost effective solutions that may not yield a design which meets or exceeds standard criteria, but provides an acceptable and safe design approach solution within the specific constraints of the project

Weekend and extended closures – policy on the turnpike system is not to implement lane closures for

construction on the weekends. The weekends were left to the customers to move easily through the mainline and interchanges. Extended closures were typically associated with catastrophic events. After each plaza went through the extreme evaluation process with focus on safety, inconsistent tolling, customer perception, speed of construction and operational issues as key objectives it was evident that certain components of the work could not be achieved without weekends or extended closures. Detailed traffic analysis as well as reducing construction time, and inconvenience to the customer was documented with the benefits to selectively close on limited weekends and specific locations for extended closures. A recommendation was presented to management requesting and receiving approval. This approval had a major impact on the completion schedule.

SOCIAL AND ECONOMIC BENEFITS

The social and economic benefits from the conversion to AET would be dramatic:

- Reduced congestion on the (HEFT)
- Reduced driver delays thus reducing economic impacts to the area
- Reduced pollution from stop-and-go traffic
- Reduced costs by increasing "Sun Pass" usage
- Increased safety by eliminating the fixed barriers as wells the roadside appurtenances typically associated with a standard barrier toll plaza
- Expedited delivery to all electronic tolling

CONCLUSIONS

A vision and a challenge - In a densely populated, urbanized area of South Florida, four (4) mainline and forty two (42) ramp toll plazas would be removed and replaced with an all electronic toll collection system . This was the **Vision**. A project on a high speed freeway with a length of forty seven (47) miles, to be converted without disruption to operations or loss of revenue was the **Challenge**. On a given day motorists or users on their evening commute would see cash lanes and overnight the cash lanes are gone. The following morning commute the facility is entirely electronic.

This report was written after a demanding twelve month period leading up to the date set for advertising for design build firms to compete for the projects. Overnight cash collection is gone, how did we get there? This paper highlights some of the issues, problems and solutions. As toll facilities consider ways to evaluate and convert to all electronic tolling there is an over whelming number if issues that have to be addressed, this paper describes just a few of the issues to be considered. In addition, what did FTE and the dedicated team, learn and carry forward to the next phase?

The process to convert a cash collection barrier system to all electronic tolling starts with a vision, and is accomplished with a team strategy built around a core of senior engineers and construction personnel extremely dedicated and committed to meeting the challenges which involve working with all the stakeholders in evaluating short-term and long-term goals, setting priorities, and assessing benefits while building relationships. This is accomplished by making a firm commitment to expend endless energy and time in order to bring this project to a successful conclusion.

We started with the initial concept and moved forward. Right from the beginning we knew this was not a cookie cutter design. A specific design criterion to remove fixed toll barriers and replace them with tolling structures to support the electronic equipment was not fully available. However, through application of the sciences, and by utilizing the full depth of the team's experience, seemingly endless geometric decisions, evaluations, multiple concepts and approaches were resolved. Everything was a challenge; criteria, policy, process, conflicting discipline goals, budgets and schedule. At times it seemed like the challenges were unlimited and provided new challenges for the team to deal with.

First and foremost it is imperative to assign a seasoned and knowledgeable Project Manager (PM) and subsequently make a commitment to the PM by providing the best and most experienced senior staff, and then listening to the issues, making decisions and giving direction. They must be ready and prepared to make difficult decisions and comprises and be innovative and creative. Every problem has a solution.

On this project the nucleus of senior staff were on call 24/7 even through vacations. This was an awesome project and experience and it was the because of the commitment and dedication of the team that the project was successful.

At the same time it is necessary to be aware of burnout. This phenomenon can be disastrous to a project of this scope. It is up to the Team Leaders to provide distractions - something as small as saying thanks" or forcing the group to totally stop everything for 30 minutes to enjoy lunch has tremendous rewards. Also, the document control system should be simple and centralized.

Other Toll Road Agencies have their own issues that are unique to their system, but there are also many similarities. Agencies can benefit from issues identified in this paper to provide a starting point for developing specific solutions to convert existing barrier plazas to an all electronic collection system.

Research is recommended to further study ramp speed relationships compatible with engineering intuition at stop and go cash plazas, to speeds associated with an all electronic tolling structure and applications during design. Also, research should be conducted in the development of design criteria and guidelines to facilitate the removal of fixed barrier plazas and their replacement with the all electronic tolling system; as well as other forms of collection at open road speeds.

ACKNOWLEDGEMENTS

The author would like to thank the support of the Florida's Turnpike Enterprise and PBS&J during the preparation of this paper.

Many thanks also go to Katherine Alexander for her technical support and advisor.

REFERENCES

1. Florida's Turnpike Traffic Operations, ORT Toll Plaza Analysis July, 2009

2. Albert E. Schaufler, P.E., P.P. - NCHRP Toll Plaza Design Synthesis of Highway Practice 240 Transportation Research Board, National Research Council, Washington, D.C 1997

3. David R. McDonald Jr., Ph. D., P.E., PTOE, Chapter 14 Design Elements and Operational Characteristics of Toll Road Facilities, ITE Geometric Design Handbook for Freeway and Interchanges 2005

4. American Association of State Highway and Transportation Officials. A Policy on Geometric Design of Highways and Streets, 2004 *Washington*, DC, 2001.

5. Florida Department of Transportation, Plan Preparation Manual (PPM), Volume I and II, January 2009 (Topic No. 625-000-007 and 625-000-008, http://www.dot.state.fl.us/rddesign/PPMManual/2009/PPM2009.shtm

6. Florida's Turnpike Enterprise, Turnpike Plans, Preparation, and Practices Handbook (TPPPH), Volume I and II, April 2009, http://design.floridasturnpike.com/prod_design/tppph/2009/tppph2009.html