Capacity of the OOCEA Network of Toll Roads with ETC

Submitted by:

Dr. Essam Radwan, P.E
CATSS Executive Director
College of Engineering and Computer Science
University of Central Florida
Orlando, FL 32816-2450
Phone: (407)-823-2945
Fax: (407)-823-4676
Email: aeradwan@mail.ucf.edu

Submitted to:
Research Center
Florida Department of Transportation
605 Suwannee Street, M.S.30
Tallahassee, FL 32399-0450

Final Report

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Principal Investigator
Dr. Marguerite L. Zarrillo, Ph.D.
University of Massachusetts Dartmouth
Physics Department
285 Old Westport Road
North Dartmouth, Massachusetts 02747
Tel: 508-999-9268
FAX: 508-999-9115
MZarrillo@UMasssD.edu

External Project Contact – UCF Campus
Dr. A. Essam Radwan, Ph.D., P.E.
CEE Chair & CATSS Executive Director
University of Central Florida
College of Engineering & Computer Science
Civil & Environmental Engineering Department
P.O Box 162450
Orlando, Florida 32816-2450
Tel: 407-823-2945
AERadwan@mail.UCF.edu

External Project Contact – UMD Campus
Debby Marisi, Director
Research Sponsored Programs
University of Massachusetts Dartmouth
285 Old Westport Road
North Dartmouth, Massachusetts 02747-2300
Tel: 508-999-8942
FAX: 508-999-8868
DMarisi@UMassD.edu

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16. Abstract The primary objective of this research project was to quantify the capacity of the OOCEA network of highways (Orlando Orange County Expressway Authority). The capacity of the network included combined capacities of the toll roads and all the toll collection facilities in the network. A secondary objective is to determine the reliability of the TNCC methodology (Toll Network Capacity Calculations). There were three tasks to this study namely incorporate the TNCC methodology into a simple Visual Basic Program that automates the calculations for the capacity of individual toll facilities, test a new capacities-calculating methodology by applying it to highway sections containing toll plazas, and quantify the capacity of consecutive highway sections on the OOCEA network of toll roads, thus identifying bottlenecks.		
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Capacity of the OOCEA Network of Toll Roads with ETC

Completion of the Project Objectives

The primary objectives of this research study have been completed. The capacities and maximum service flow rates have been computed for all segments on the Orlando Orange County Expressway Authority's, OOCEA's, network of highways. This led to the identification of bottlenecks, *near* bottleneck situations and *potential* bottleneck situations. This was accomplished by comparing a segment's maximum service flow rate in vehicles per hour, *vph,* to their incoming approach traffic volumes. A bottleneck occurred whenever the demand exceeded a segment's ability to accommodate traffic.

The network was divided up into 295 highway segments, 20 of which contained a toll facility. In addition, capacities and service flow rates for 38 on-ramp and off-ramp toll facilities were calculated. A system of identification, ID, was constructed for all segments. These ID numbers with their corresponding capacities, service flow rates and approach volumes, appear in the appendices displayed in tables and displayed on maps reporting the results of this study. A compact-disc, CD, is also included with this report.

A 23-page map was constructed of the entire network in Autodesk Mechanical Desktop Software. In addition to displaying all 295 segments, the map portrays the 38 on-ramps and off-ramps each containing a toll facility, and all other on-ramps and off-ramps. The map is also printed on a large 4-foot by 5-foot map. It clearly labels all roadways in the region of the network. It displays the borders of the 295 segments, their $_{ID}$ numbers, the lane configuration of all 58 toll facility segments and the individual lanes within the segments including interchanges, deceleration lanes and acceleration lanes of the on and off ramps. Maximum service flow rates and approach volumes of all 295 segments have been incorporated into the segments' $_{ID}$ numbers and are also listed on the map near their corresponding segments.

The Highway Capacity Manual, HCM, 2000 provided the methodology for computing most of the highway segment capacities. However, a methodology had to be designed for computing the capacities and maximum service flow rates of the 20 segments containing a toll facility.[1] A logic flowchart of the Toll Network Capacity Calculator, TNCC, methodology was constructed and TNCC was programmed in Microsoft Visual Basic software.[2] The flow chart is included on the CD and is also provided on a 4-foot by 5-foot poster. Using TNCC, the capacities and maximum service flow rates of the 20 segments containing toll facilities situated on the highway network were calculated. They are listed in Table 1 of Appendix C. In addition, the capacities and maximum service flow rates

[1] The logic for TNCC was developed shortly prior to the onset of this study, January 2000. It was published in a TRB RECORDS paper #1781. It was also presented at the 81st Annual TRB Meeting held in Washington D.C. in January 2002. The paper was entitled *TNCC : Operations Management & Assessment Tool for Toll Network Operators*, by Marguerite L. Zarrillo, PhD, A. Essam Radwan, PhD and PE, and Joseph H. Dowd, see Appendix G.

[2] The TNCC Logic Flow Diagram is presented and described in a paper presented at ASCE's AATT 2002 Conference held in Boson, MA, on August 5-7, 2002. The paper is entitled, *Case Study Application of TNCC: a Simulation Tool to Identify Plaza Bottlenecks on a Toll Network of Highways* by Joseph H. Dowd, Marguerite L. Zarrillo, PhD, and A. Essam Radwan, PhD and PE, see Appendix H.

of the 38 on-ramps and off-ramps containing a toll facility were also calculated using TNCC. They are listed in Table 2 of Appendix C.

The traffic using the network was broken into four categories: vehicles using the Electronic Toll Collection, ETC, service, vehicles using the Automatic Coin Machine, ACM, service, vehicles other than semi-trucks using the Manual service and semi-trucks using the Manual service. These categories were given symbols E, A, M and T respectively. Typical morning peak rush hour volumes for the 58 highway segments containing a toll facility were extracted from August 16, 2000, transaction data, provided by the OOCEA. Volumes were extracted for each of the four categories and are provided in Tables 3, 4, 5, 6, 7, 8, 9 and 10 of Appendix C. As a result, the percentage of the arrival traffic belonging to each of the four categories was known for each of the 58 toll facilities and served as input into TNCC. Videotaping of the network during the morning peak rush hours on mornings of August 15, 16 and 17, 2000, verified the lane configuration at each of the 58 toll plazas. Lane configurations were important input to TNCC's capacity calculations. The videotapes also provided important segment-characteristics, which were complemented by roadway horizontal and vertical curve data, lane widths and lateral clearance information, provided by Post, Buckley, Schuh & Jernigan, Inc., PBS&J, the OOCEA's consultant in Florida. Finally, PBS&J, also conducted a volume study of the network during the year 2001. Approach volumes to the 295 segments used in this analysis were extracted from Tables provided in PBS&J's final report.

In addition, the Levels of Service, LOS, were determined for each of the 275 basic segments. Based on the estimated FFS, an appropriate speed-flow curve was chosen. Based on the flow rate and the speed-flow curve, an average passenger-car speed is determined using the speed equations in the HCM 2000. The hourly flow rate reflected the influence of heavy vehicles. However, it was assumed that the peak hourly factor and the population factor were not much of an influence and were given values of 1.0. From 7:00 a.m. to 8:00 a.m., 15-minute traffic volumes do not vary widely among these four time periods. Furthermore, drivers mainly consist of commuters who are familiar with the road network. With the flow rate in pcphpl and the average speed in miles per hour, the density was determined for the 275 segments in units of pcph per mile. LOS density thresholds for basic freeway segments, taken from the HCM 2000, determined the LOS for each of the 275 segments. These LOS for all 275 segments is located in the last column in an Excel File on the CD included with this report. This file is an extension of Tables 11, 12, 13, 14, 15 and 16 in Appendix D. The expanded version of these Tables display all steps in the capacity and LOS calculations.

Finally, a sensitivity analysis was conducted on each input variable to TNCC. All input variables into TNCC were held constant except for one input variable. The TNCC program was executed several times varying this one variable resulting in calculated capacities. For instance, traffic and plaza characteristics were held constant as the percentage of ETC usage increased. The resulting output of TNCC indicated that the capacity of the plaza increased.

The sensitivity study indicated that TNCC predicts capacities and maximum service flow rates in an expected and reasonable fashion for simple plaza lane configurations. However, it also revealed that TNCC could mimic more complex plaza performance characteristics such as the overflow movement of vehicles out of dedicated ETC lanes and into lanes providing mixed services. Mixed lanes may provide a combination of Manual and ETC services or a combination of ACM and ETC services.[3] The sensitivity study of TNCC also clearly emphasizes that optimum plaza performance occurs whenever a good match is made between the lane configuration of the plaza and the

[3] Complex queuing behavior is discussed in the conclusions of a paper presented at ASCE's AATT 2002 Conference held in Boson, MA, on August 5-7, 2002. The paper is entitled, *Identification of Bottlenecks on a Toll Network of Highways*, by Marguerite L. Zarrillo, PhD, A. Essam Radwan, PhD, PE, and students Angus Mak, Joseph Dowd and William Cyr, see Appendix I.

characteristics of the approaching traffic. The demand for each type of service set by the traffic arrivals is an important consideration when designing the plaza configuration pattern. A surplus of lanes for any one service, for instance, may lead to queues in other services and thus resulting in higher capacity values.

Milestones and Dates

The work on the project began toward the end of April 2001. A Dell computer was purchased along with software, including Microsoft Visual Basic 6.0 and Autodesk Mechanical Desktop release number 4.

During the first programming phase, Joseph H. Dowd, a graduate student, was given financial support for his work in programming the first version of TNCC, Toll Network Capacity Calculations, during the summer of 2001. The software code and executable file for TNCC are included on the CD inside this report. Data extraction and the tabulation activities for the input into the TNCC computer program were also completed during this time. This input data was extracted from transaction data taken during the August 16, 2000, morning peak rush hour. The tabulated input included traffic and plaza characteristics for all 58 plazas. Undergraduate students assisted in this data extraction and entry process.

In addition, the construction of the preliminary network map was begun during the summer 2001. Angus Mak, a senior mechanical engineering student, received an internship for this work. He continued to contribute to this project using his Work Study Financial Aid during the academic year 2001 to 2002. The final map is also included on the CD inside this report. Both Autodesk and Microsoft Word files are included.

TNCC was used to determine the individual capacities of each of the 58 facilities on the OOCEA network. Through the use of hand calculations, the output of the computer program was validated. A qualitative sensitivity analysis was also completed. Angus Mak received an 2002 summer internship for his contribution to the computational side. Using the HCM 2000 methodology, the capacities and maximum service flow rates for all 295 highway segments were calculated. Comparison of the capacities to the volumes extracted from PBS&J's Final Report facilitated the identification of Bottlenecks, *near* bottlenecks and *potential* bottlenecks.

Student Involvement (e.g., Thesis, Assistantships, Paid Employment)

UMD undergraduate students Beth Higgens and Mykola Stefantsiv extracted traffic volumes from the OOCEA's transaction data of August 16, 2000. Volumes for each of the 4 categories of traffic were tabulated. This was done for each of the 58 toll collection facilities on the portion of the OOCEA's network of toll roads under study. Joseph H. Dowd later formatted this data for input into TNCC.

Early in the project, a search and hiring process took place to fill the two 2001 summer internship positions. UMD students, Angus Mak and Joseph H. Dowd, were chosen for the summer internships. Joseph H. Dowd had previously taken Visual Basic training as a 3-hour credit course with the PI, Dr. Zarrillo. He used his internship to train himself in the TNCC methodology and program it in Visual Basic 6.0. At the end of the internship he had decided to continue working with Dr. Zarrillo in the area of Transportation Engineering and go for his Masters Degree. Angus Mak trained himself in Mechanical Desktop software and began to map out the network. Early in the summer of 2001, the group underwent three software workshops in under the guidance of Bob Baglini, who was compensated for his instruction. Bob was a senior student in Civil Engineering at

UMD at the time he presented these workshops. During the summer, Angus Mak developed the network layout using the videotape of August 16, 2000, and electronic photographs viewed from the air captured off the Orlando web page. He consulted with Sandra Cornelius of the OOCEA whenever there were questions concerning lane configurations of the highway segments. After completion of the general layout of the map, Angus Mak began dividing up the network into its 295 segments.

In the fall semester 2001, William Cyr was hired to continue dividing up the network into its 295 segments. He also developed a numbering system for the segments.[4] He began typing the 295 identification numbers on the map in the proper location.

Joseph H. Dowd received a Graduate Research Assistantship in the fall semester 2001 and continued the validation process of TNCC. He also began the sensitivity analyses. William Cyr and Angus Mak continued verification of the network map as well as dividing up the map into its 295 segments. Both Joseph H. Dowd and Angus Mak wrote papers, which were published in the proceedings and presented at ASCE's 7th International Conference of Advanced Applications of Technology in Transportation, AATT, held in Boston, MA, August 5-7, 2002.

Throughout the duration of the project, groups as well as individual student meetings were held with Professor Zarrillo. In the summer, these meetings occurred twice weekly, during the semester, these meetings occurred weekly.

Technology Transfer Activities

There is a strong preliminary indication that the TNCC methodology to calculate the capacity of toll facilities is both reliable and useful. Although this calculation can be performed without a computer, the calculation is long and tedious. The user-friendly TNCC computer program is constantly undergoing validation.

The capacity calculation is an iterative procedure in which the vehicles are shifted from one lane to another until an optimum capacity value is attained. The calculated capacities converge to their correct values after several iterations. In the final iteration, constraints on the traffic characteristics at the plaza and constraints on the processing rates are all met. Processing rates for the single services, for instance, must be equivalent to those observed. Processing rates for ETC vehicles in the mixed lanes depend on the percentage of ETC vehicles utilizing the mixed lane. If higher portions of vehicles are using the traditional slower services, than the processing rate for ETC vehicles in those mixed lanes also slows. At the end of each iterative step, constraints on traffic characteristics are checked for consistency with observations and vehicles are shifted to correct discrepancies, thus facilitating the calculation of a new capacity in the next iteration.

Bottleneck Identification

The following is a summary of Bottleneck-Identification on the OOCEA's toll network of highways exclusively under typical morning peak rush hour traffic conditions from 7:00 a.m. to 8:00 a.m. A summary of the bottleneck situations along the network as well as *near* bottleneck situations and *potential* bottleneck situations for this time-of-day are identified and reported here. A more thorough and detailed analysis is discussed in Appendix A. Bottleneck situations occur when approaching traffic volumes exceed segment capacity. *Near* bottleneck situations occur when

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[4] This numbering system is well described in a paper published in the Proceedings of ASCE's 7th International Conference of AATT 2002, held in Boson, MA, on August 5-7, 2002. The paper is entitled, *Identification of Bottlenecks on a Toll Network of Highways,* by Marguerite Zarrillo, PhD, A. Essam Radwan, PhD, PE, Joseph H. Dowd, Angus Mak and William Cyr, see Appendix H.

approaching traffic is just below segment capacity. *Potential* bottleneck situations occur when the capacity of a segment unjustifiably and substantially drops below the capacity of the previous adjacent segment without a possibility for traffic to exit.

Methodology

Capacities, in passenger cars per hour, pcph, are converted to service flows, in vph. This allows a comparison analysis to volume values, also in vph. If a highway segment's approaching traffic volume is larger than the segment's service flow, then a bottleneck is identified.

Calculated capacities, in pcph, and service flows, in vph, are based on traffic and roadway conditions of August 16, 2000. Plaza lane configurations are also those lane patterns on this day at that time. Traffic volumes leaving the plazas are also taken from transaction data at the plazas from 7 to 8 a.m. on August 16, 2000 provided by the OOCEA. Volumes on highway segments between the plazas, on the other hand, are 2001 traffic volumes, also from 7:00 a.m. to 8:00 a.m., extracted from tables provided by Post, Buckley, Schuh and Jernigan, Inc., PBS&J. Most all volumes are Wednesday volumes, except a few are taken on Tuesdays. All approach traffic volumes to each of the 295 highway segments are from 7:00 a.m. to 8:00 a.m.

It is emphasized that bottlenecks identified in this analysis are only for the morning commuter traffic. For the evening commuter traffic, a new analysis would produce a different set of bottlenecks and bottleneck locations. As will be proposed here, and as an expansion to this project, this study could be used as a foundation, in which evening commuter traffic bottlenecks could easily and rapidly be identified. Sixteen consecutive hours can be analyzed, resulting in bottleneck location shifts during the day from 6 a.m. to 10 p.m. A time simulation of these sixteen hours could graphically illustrate bottleneck location shifts on the network map during a typical day.

Segment Identification

Segment identification numbers refer to the maps that follow in Appendix F and to the Microsoft Excel spreadsheets, Tables 11, 12, 13, 14, 15 and 16 in Appendix D. The Tables contain a list of all the 295 highway segments on the network, their ID numbers, their capacities or service flow rates and the approach traffic volumes. Comparing the two columns (the approach volume column and the service flow rate column) immediately identifies bottlenecks. An expanded version of these Tables in Microsoft Excel format, listing all the columns necessary for the capacity and maximum service flow rate calculations, is provided on the CD accompanying this report. The highway segments in all Tables that are highlighted in dark green indicate a bottleneck, in other words, the approach volumes are larger than the segment capacity. Light green indicates a *near* bottleneck; the approach volumes are just below the segment capacity. Light blue indicates a *potential* bottleneck; the capacity significantly decreases along the direction of traffic flow. Yellow indicates that the traffic volume data is taken on Tuesdays rather than Wednesdays. Darker blue indicates that the volume data may not be valid. Segments highlighted in gray are interchange ramps that do not lie on the mainline. Both the approach volume columns and service flow columns are highlighted in soft orange to assist the reader with a visual comparison of their values for the same highway segment.

Every segment was assigned an ID number. This consisted of nine names/numbers connected by dashes: the Highway Number & Direction – Segment Number – Exit or Entrance Number linked to the Segment – Number of Lanes on the Segment – Design Speed of the Segment – whether a Plaza exists on the Link – Service Flow Rate – Approach Volume - Map number. The segment numbers are also boldly typed on each map's highway segment. The segment number determines the order in which the ID numbers are listed. For computer programming purposes, the pound sign fills in spaces so that there are always four spaces in the first three names. For example, segment 417S-01.0-37#X-2-65-PP-4587-2926-01 is the first segment, 01.0, on the freeway traveling south on the 417. The third name in the identification number, 37#X, indicates that Exit 37 is linked to this segment and leads drivers off of the 417. If there is an entrance ramp associated with Exit 37, then the X for exit ramp becomes an N for entrance ramp. In other words, the nomenclature becomes 37#N. If the exit or entrance number is 14B, then the nomenclature becomes either 14BX or 14BN. If there is no exit or entrance associated with a segment, then the nomenclature for the third name of that segment is #NA#. In this example, here are 2 lanes on the segment and the design speed is 65 miles per hour. The exit ramp connected to this segment also contains a toll ramp plaza, indicated by the name PP. If a plaza is situated on the segment, the identification will also carry PP. This becomes NP for all other cases. This first segment on the 417 South has a capacity or service flow rate of 4587 vph and an approach volume of 2926 vph. The last name in the ID # indicates on what map the segment is illustrated. There are 22 such maps. There is also one large map that pastes all 22 smaller maps together, similar to Figure 1. These maps are in Appendix F.

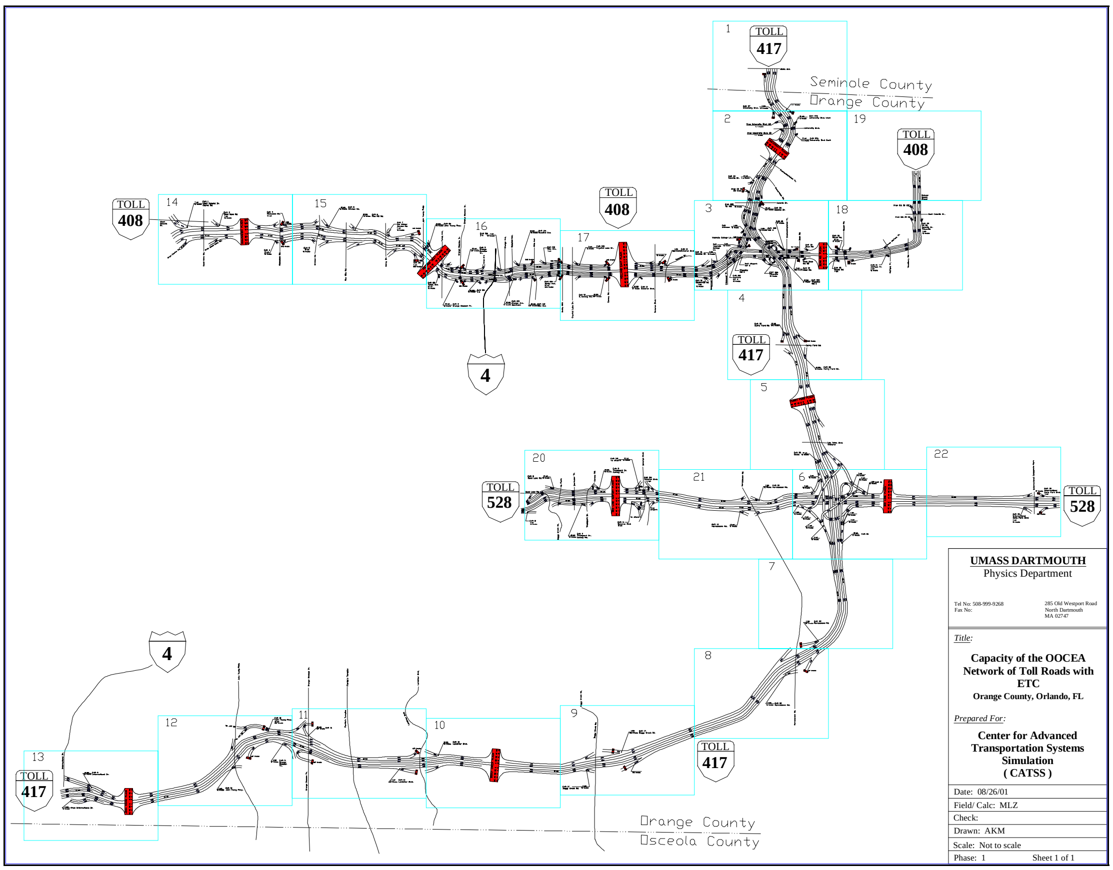

Figure 1. Toll Road network under study, not to scale.

Capacity Calculations

Traditional methods, taken from the Highway Capacity Manual 2000, HCM, were used to calculate capacities of the segments between the plazas. The number of lanes along any one segment is constant along any one segment, as is the lane width and right lateral clearance. The heavy vehicle factor and driver population adjustment factor were also uniform within each segment. Freeway segments did not include more than one entrance or exit. Entrance ramp freeway segments included the region 1500 feet downstream of the on-ramp. Exit ramp freeway segments included the region 1500 feet upstream of the off-ramp. No regions were found in which further division would be necessary where there were speed limit changes or whenever grades were larger than 2% and prevailed a distance longer than a quarter of a mile.

Figure 2 is a sample view of the network that contains a basic freeway segment, ID number 417S-21.0-#NA#-2-65-NP-4548-2230-04. Equation (1) was used for the capacity calculation of the basic freeway segments in pcph for E Level of Service, LOS. It is the product of the number of lanes, N, and the Maximum Service Flow, MSF, under ideal conditions listed in the HCM 2000. The MSF is the sum of 1700 and 10 times the FFS. For instance, at a FFS of 70 mph, the MSF is 2400 vph. Multiplying this capacity by the heavy vehicle factor, f_{HV}, and the driver population factor, f_P, result in the Service Flow, SF, rate in vph, as illustrated by equation (2). SF is the Service Flow rate during the peak 15 minutes for LOS E.

Terrain is best described as somewhere between level and rolling. This is because some of the time, heavy vehicles on the basic freeway segments are able to maintain the same speed as passenger cars. In addition, the freeway segments consists mostly of terrain that includes short grades of no more than 2%. Thus, the passenger car equivalent for a heavy vehicle is taken to be a value of 2.0. Finally, most drivers are commuters and familiar with the facility so that a value of 1.0 is taken for the driver population factor, f_P.The ideal freeway Free Flow Speeds, FFS_{ideal}, of 70 mph in the urban environment and 75 mph in the more rural environment are used. Corrections are applied to the FFS_{ideal}, resulting in the Free Flow Speed, FFS, described by equation (3), also in mph. Appropriate Speed Flow Curves for basic freeway segments determine the Maximum Service Flow, MSF, rate, for LOS E. The lanes are 12 feet wide so there is no need for a lane width adjustment; f_{lw} has a value of 0.0. In addition, no adjustments are made for right lateral clearance; f_{lc} has a value of 0.0. There are few obstructions and those are continuous and drivers have become accustomed to them so that their influence on traffic flow is negligible. On some of the basic freeway segments, however, a correction was necessary due to the number of lanes, f_n. Two, three and four lanes on a basic freeway segment reduce the FFS_{ideal} by 4.5, 3.0 and 1.5 mph respectively; f_n is described by equation (4). In addition, a reduction in FFS_{ideal} is necessary due to the interchange density, f_{id}. This interchange density factor correction, f_{id}, also taken from the HCM 2000, is described by equation (5) where IPM is the number of interchanges per mile.

$$C = N \times MSF = N \times (10 \times FFS + 1700) \qquad \text{(pcph)} \quad (1)$$

$$SF = C \times f_{HV} \times f_P = N \times MSF \times f_{HV} \times f_P = N(10\ FFS + 1700) \times f_{HV} \times f_P \qquad \text{(vph)} \quad (2)$$

$$FFS = FFS_{ideal} - f_{id} - f_n - f_{lc} - f_{lw} \quad (3)$$

$$f_n = 7.5 - 1.5N \quad (4)$$

$$f_{id} = 5 \times IPM - 2.5 \quad (5)$$

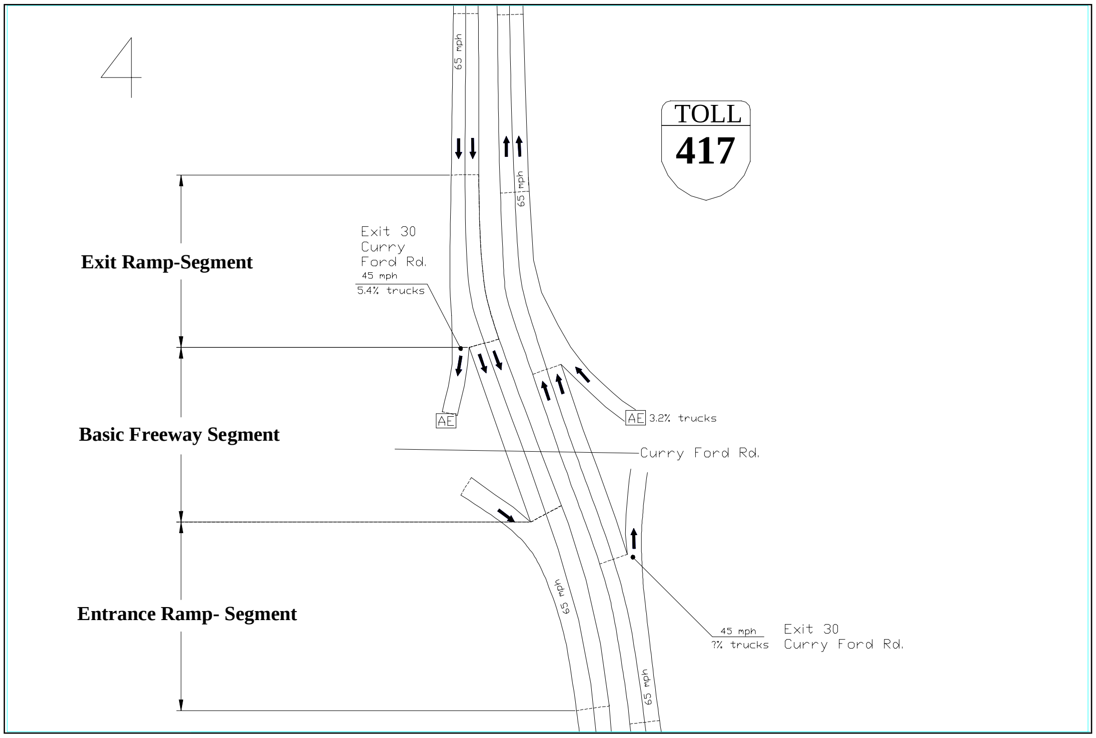

Figure 2. Sample view of the network containing typical freeway segments.

Morning Bottlenecks and Near Bottlenecks

There were no bottlenecks identified on the 417, the Central Florida Greeneway, in the 7:00 a.m. to 8:00 a.m. morning rush hour traffic. However, there was one *near* bottleneck traveling north on the 417 and one *near* bottleneck traveling south. Approach traffic volumes arriving between 7:00 a.m. and 8:00 a.m. to the highway segment, ID number 417N-51.0-#NA#-3-30-PP-1960-1462-02, containing the three-lane northbound University Main Plaza were 1462 vph on October 10, 2002. This approaches the 1960 vph service flow rate or maximum number of vehicles that the Plaza is able to process in one hour assuming typical morning traffic characteristics which are an ETC usage rate of 51 percent and a 1.6 percent of arrivals that are trucks. The lane configuration pattern for the Plaza was one dedicated E-Pass lane and two mixed lanes offering manual as well as E-Pass toll collection services.

The *near* bottleneck located on the southbound side of the 417 is more critical. The segment is located at the 417/408 interchange and not on the mainline. It is a single left merge lane onto the 408 westbound from the 417 southbound with ID number 417S-14.0-#NA#-1-65-NP-2271-2258-03, see map number 3. The approach traffic volumes to the segment arriving between 7:00 a.m. and 8:00 a.m. on October 31, 2001, were approximately 2258 vph. This is just under the service flow rate calculated for this segment, 2271 vph, or the maximum number of vehicles that this segment can process in one hour.

There were bottlenecks identified on the 408, the East-West Expressway, in the 7:00 a.m. to 8:00 a.m. morning rush hour traffic. In the eastbound direction three bottlenecks occurred, all at highway segments containing plazas: the eastbound side only of the Hiawassee Main Plaza, HMP, the eastbound side only of the Holland West Main Plaza, HWP, and the eastbound side only of the Dean Main Plaza, DMP. Eastbound arriving traffic volumes to the HMP, 3068 vph, were larger than the calculated maximum service flow rate of 3023 vph. Eastbound arriving traffic volumes to the HWP, 3901 vph, were larger than the calculated maximum service flow rate of 3864 vph. Eastbound arriving traffic volumes to the DMP, 3036 vph, were larger than the calculated maximum service flow rate of 2304 vph. Maximum service flow rates were based on typical traffic characteristics at the plazas.

In addition, there were several *near* bottleneck situations on the eastbound 408. The exit ramp to Interstate 4 from the 408 eastbound and the entrance ramp from the Interstate 4 onto the 408 eastbound were both *near* bottleneck situations. There were 1047 vph traveling eastbound on the 408 that exited onto the one lane ramp to I-4 and there were 1350 vph entering the 408 eastbound traffic from I-4. Four segments prior to the HWP contained approach volumes very near the maximum service flow rates and were therefore *near* bottleneck situations: segments with ID numbers beginning with 408E-12.0, 408E-13.0, 408E-14.0 and 408E-16.0. Vehicles entering the highway from Kirkman Road, Pine Hills Road and Mercy Drive added to the eastbound traffic volumes. Finally, segment ID number 408E-43.0-18AX-3-65-NP-6807-2503-03 may be classified as a *near* bottleneck situation. It is the segment just prior to the 408/417 interchange. It is categorized as a *near* bottleneck situation because although its approach volume is only 2503 vph, the majority of its traffic volume, 1722 vph, is concentrated in just one of its three lanes. This lane is the outermost right lane leading to a diverging segment of highway leading either to the 417 south or a continuation of the 408 east. The innermost left two lanes serve traffic directed onto the 417 north.

Westbound on the 408 mainline, there were no bottlenecks in the 7:00 a.m. to 8:00 a.m. morning rush hour traffic. However, there were bottlenecks on two exit ramps that could not process all approaching vehicles from 7:00 a.m. to 8:00 a.m. These ramps were the Rosalind Avenue exit number 11A and the Interstate 4 exit number 10A. Volumes during that time period were 1483 vph and 1903 vph respectively.

In addition, westbound on the 408 mainline, there were several *near* bottleneck situations. The westbound side of the four-lane DMP had a maximum service flow rate of 3159 vph. Approaching volumes were 3083 vph, just under this limit, and therefore creating a *near* bottleneck situation. Also, the westbound side of the Holland East Main Plaza, HEP, had a maximum service flow rate of 6777 vph and approaching volumes of 6295 vph. These volumes were also just under the maximum service flow rate, creating a *near* bottleneck situation, although not as critical as the DMP. Furthermore, the highway segment following the HEP westbound was also a *near* bottleneck. Although the plaza could process 6777 vph, it typically processed a somewhat smaller 6530 vph, and these approach volumes to the segment immediately after the HEP westbound were just below this segment's 6806 vph maximum service flow rate.

Between the DMP and HEP, there were another five *near* bottleneck situations. Approaching traffic volumes were near the maximum service flow rate in segment ID numbers beginning with 408W-18.0, 408W-19.0, 408W-20.0, 408W-22.0 and 408W-23.0, see maps number 3 and 17. These volumes are swollen due to the traffic entering from the 417 and Goldenrod Road. Typically 1245 vph entered onto the 408 west from the Goldenrod Road entrance ramp, a *near* bottleneck in itself. Finally, located on the fourth segment after the HEP westbound on the 408, immediately after the Crystal Lake Drive exit ramp, there is a *near* bottleneck situation, segment 408W-31.0-#NA#-3-55-NP-6798-6053-17. The lane number on the mainline decreases from four to three, however, exiting traffic is only typically 496 vph and approach volumes are 6053 vph which is very near the maximum service flow rate of 6798 vph.

Morning Potential Bottlenecks

There were no bottlenecks identified nor were there *near* bottlenecks situations identified on the 528, the East-West Expressway. However, there were *potential* bottlenecks situated on the 528 as well as on the other two highways, the 417 and the 408. A total of 6 on the northbound side of the 417 were identified and 6 on the southbound side. A total of 2 on the eastbound side of the 408 were identified and 2 on the westbound side. A total of 2 on the eastbound side of the 528 were identified and 3 on the westbound side. *Potential* bottlenecks exists whenever there is a sudden decrease in the capacity or maximum service flow rate of consecutive segments in the direction of traffic flow without a possibility for traffic to exit. Although the capacities widely exceed the 7:00 a.m. to 8:00 a.m. volumes along these locations identified as *potential* bottlenecks, these locations are certainly worth noting for future planning of the network. Tables 11, 12, 13, 14, 15 and 16 highlight these *potential* bottlenecks in light blue.

The Mechanics of TNCC and its Logic Sequence

The following logic sequence follows TNCC's flow chart included on the CD within this report. The flow chart is too large to view on an 8½ by 11 inch paper. The flow chart files provided on the CD are in both Autodesk and Microsoft Word and can be viewed on the computer monitor by zooming. It is also printable on a large plotter.

1. INITIAL ASSIGNMENT of the CAPACITY:

   The collection of Traffic and Plaza Characteristics allow for an initial assignment to TNCC's input variables. These include the lane configuration or the number of each lane type, N_E, N_{MTE}, N_{AE} . These also include the processing rates for each toll collection service type, S_E, S_A, S_T and S_M. And finally, these also include the percentages of the arrivals that belong to each customer group. These are named *arrival-percentages* and include the ETC usage rate at the plaza, the percentage of arrivals that are ACM users, the percentage of arrivals that are manual users, and finally, the percentage of arrivals that are Semi-trucks using the manual services.

   Using the capacity equations listed below, TNCC falsely calculates the initial first iteration values for H, K1 and K2, whose sum in the first iteration is an initial over-estimate of the plaza's capacity.

   $$H = N_E S_E$$

   $$K1 = N_{MTE} S_{MTE} = N_{MTE} \frac{100\%}{\left(\frac{P_M}{S_M} + \frac{P_T}{S_T} + \frac{1-(P_M + P_T)}{S_E} \right)}$$

   $$K2 = N_{AE} S_{AE} = N_{AE} \frac{100\%}{\left(\frac{(1-P_E)}{S_A} + \frac{P_E}{S_E} \right)}$$

   H calculates the capacity of the dedicated ETC lanes. Depending upon the speed limit at the plaza, a fair estimate of the optimum number of vehicles able to pass through the dedicated ETC lanes is possible. K1 calculates the capacity of the mixed lanes MTE. These lanes offer ETC service as well as manual toll collection services for all vehicles including semi-trucks. The percentage of arrivals into the mixed MTE lanes for each of the served customers, M, T and E, are unknown. Therefore, in order to arrive at an initial value for the plaza's capacity, TNCC must assume these percentage values. It falsely substitutes the known *arrival-percentages* into the capacity equations. Similarly, TNCC calculates K2, the capacity of the AE mixed lanes. These lanes offer ETC service as well as ACM toll collection services. Again, the percentage of arrivals into the mixed AE lanes for each of the served customers, A and E, are unknown. Therefore, TNCC falsely assumes and substitutes the known *arrival-percentages* into the capacity equations in order to arrive at an initial capacity.

It should be noted that the percentage of ETC users, P_E, floats in K1 equation. In other words, P_E is the remainder of the 100% after P_M and P_T are both subtracted out. This initially, grossly underestimates the number of Semi-trucks being processed in the MTE lanes; generally, Semi-trucks without transponders cannot use the other lanes. Thus, the Capacity for K1 is overestimated. Similarly, the percentage of ACM users, P_A, floats in K2. P_A is the remainder of the 100% after P_E is subtracted out in the AE lanes. This initially, grossly overestimates the number of ETC vehicles in the AE lanes; most vehicles use the dedicated ETC lanes. Thus, the Capacity for K2 is also overestimated.

The values for the processing rates are listed in Table 17 of Appendix E and were extracted from the videotaped plazas. The processing rate for Manual users that were not Semi-trucks, S_M, was 498 vph. The processing rate for ACM users, S_A, was 618 vph. The processing rate for Semi-trucks using the Manual collection service, S_T, was a low 138 vph. The maximum processing rate for ETC users, S_E, was 1560 vph. However, vehicles using the ETC service in the mixed lanes had reduced processing rates described by the functions below. These functions are displayed graphically in Appendix G of this report in the TRB RECORDS paper #1781. The processing rates for the ETC vehicles in the mixed lanes varied according to the proportion of vehicles in the mixed lanes that were using the ETC service. The more vehicles in the mixed lanes that were using the ETC service, the higher the processing rate.

$$S_E^{MTE}(P_E) = 1037 - 523\cos(1.80 \times P^{MTE}{}_E)$$

$$S_E^{AE}(P_E) = 1089 - 471\cos(1.80 \times P^{AE}{}_E)$$

This completes the first iteration in TNCC resulting in a first estimate of the plaza's capacity. Other assignment methods to estimate the initial value for the plaza's capacity were applied. All resulted in the same final value for the plaza capacity after many iterations. However, some required a smaller number of iterations to finally arrive at the correct plaza capacity.

2. DETERMINATION OF THE NUMBER OF VEHICLES IN EACH CATEGORY:

   This capacity is multiplied by the *arrival-percentages* after the first iteration, thus finding the initial number of vehicles in each of the customer-groups, M, T, A and E. After any other iteration, the capacity is multiplied by the newly calculated percentages. These percentages, $P_M{}^{MTE}$, $P_T{}^{MTE}$, and $P_E{}^{AE}$, are discussed in the next step 3.

3. PLACING VEHICLES INTO THEIR APPROPRIATE LANES AND DETERMINING NEW PERCENTAGES IN ALL LANE TYPES:

   - M, T and ETC vehicles are placed in MTE lanes, and the new percentages of the manual vehicles in the MTE lanes, $P^{MTE}{}_M$ and $P^{MTE}{}_T$ are determined.
   - ACM vehicles are place in the AE lane, and the new percentage of ACM vehicles in the AE lanes, $P^{AE}{}_A$, is determined.

- E vehicles are placed first in E lanes, then if there is overflow, they are placed in AE lanes. Finally, if there is still overflow, than they are placed in MTE lanes.

4. PLACEMENT OF ETC VEHICLES AND OVERFLOW OF ETC:

Overflow is calculated by computing the number of vehicles that exceed whatever can be processed in the dedicated ETC lanes in one hour. H is determined as follows:

- If there are more ETC vehicles than 1560 per dedicated ETC lane, then H is the number of ETC lanes times 1560.
- If there are less ETC vehicles than 1560 per dedicated ETC lane, then H is the number of ETC vehicles.

5. CAN ALL VEHICLES BE PROCESSED IN ONE HOUR OR IS THERE A QUEUE?

Queuing conditions need to be checked to determine whether all vehicles are being processed in the allotted hour. If a queue still remains in any one of the plaza's lanes, then the estimated capacity is still too large, in other words the actual capacity is still being over-estimated. Another iteration of TNCC is required. If after several iterations, the capacity has been reduced enough so that all vehicles can be processed in the one-hour allotted, then the iterations stop.

✓ First check: Is there a queue in the AE lane?

a) If the time to process all A vehicles exceeds one hour, then the percentage of ACM vehicles in the AE lanes, P^{AE}_{A}, is 100%, the percentage of ETC vehicles in the AE lanes, P^{AE}_{E} , is 0% and $K2 = N_{AE}S_{A}$, or the number of AE lanes times 618 vph. Another iteration is required because there exists a queue in the AE lanes.

b) If the time to process all ACM vehicles does not exceed one hour, but the time to process all ACM and overflow of ETC vehicles does exceed one hour, then all ACM vehicles are placed in the AE lane and only some of the overflow is placed in the AE lane. It should be noted that the new percentage of ACM vehicles in the AE lane, $P^{AE}_{A,}$ can now be determined and is used to calculate the percentage of ETC vehicles in the AE lane, P^{AE}_{E}, as $(1 - P^{AE}_{A})$. The new capacity equation stated in step 6 is used to determine K2 using the new values for the percentages.

c) If the time required to process all ACM and overflow ETC vehicles does not exceed one hour then a queue does not exist in the AE lanes and K2 = A + overflow E, or the sum of ACM vehicles and the overflow of ETC vehicles.

✓ Second check: Is there a queue in the MTE lane?

a) If the time to process all M and T vehicles exceeds one hour in the MTE lanes, then all T vehicles are place in the MTE lanes and only some of the M vehicles are placed in the MTE lanes. Thus the percentage of ETC vehicles in the MTE lanes, P^{MTE}_{E} , is 0%, the percentage of M vehicles in the MTE lanes, P^{MTE}_{M} , becomes $(100\%-P^{MTE}_{T})$ and K1 is determined by the new capacity equation stated in step 6. It should be noted that the new percentage of semi-trucks in the MTE lane, $P^{MTE}_{T,}$ can now be determined and is used to calculates P^{MTE}_{M}. Another iteration is required because the M vehicles are not all being processed in the allotted one-hour time.

b) If the time to process all M and T vehicles does not exceed one hour, but the time to process all M, T and the remaining overflow of E vehicles does exceed one hour, then there still remains a queue in the MTE lane and another iteration is required. K1 is calculated using the new capacity equation stated in step 6.

c) If the time to process all M, T and remaining overflow of E vehicles does not exceed one hour then there is no longer a queue in the MTE lanes and K1 = M + T + remaining overflow of E vehicles, or the sum of all manual vehicles and the remaining overflow of ETC vehicles.

6. A NEW PLAZA CAPACITY VALUE IS CALCULATED:

A new Plaza Capacity value, equal to the sum of the new H, K1 and K2, is used for the next iteration and the process is started again with step 2 above. The Plaza Capacity value converges to a reduced value. The percentages of the M, T and ACM vehicles in their corresponding lanes, ${P^{MTE}}_T$, ${P^{MTE}}_M$, and ${P^{AE}}_A$, also converge to correct values replacing the *arrival-assignment* values in step 1.

$$H = N_E S_E$$

$$K1 = N_{MTE} S_{MTE} = N_{MTE} \frac{100\%}{\left(\frac{{P^{MTE}}_M}{S_M} + \frac{{P^{MTE}}_T}{S_T} + \frac{1-\left({P^{MTE}}_M + {P^{MTE}}_T\right)}{S_E} \right)}$$

$$K2 = N_{AE} S_{AE} = N_{AE} \frac{100\%}{\left(\frac{{P^{AE}}_A}{S_A} + \frac{\left(1 - {P^{AE}}_A\right)}{S_E} \right)}$$

7. RETURN TO STEP 2 WHENEVER A QUEUE EXISTS:

Iterations stop when there are no remaining queues in any of the lanes. Capacity is defined such that whenever the capacity at a plaza is exceeded, there will be queues established in at least one of the lanes. The TNCC methodology begins with a large overestimated capacity with likely queues in all lanes. As the traffic constraints are met, queuing conditions are reduced one lane type at a time. This continues until in the final step of the iteration process, queues have been eliminated. This lower limit is the Capacity of the plaza and is what the plaza can process in one hour without the occurrence of queuing given the characteristics of the hourly arrival volumes.

Findings of TNCC Applications & Benefits

Whenever lanes must close at a toll collection facility due to maintenance or incidents, disruption in traffic flow occurs due to a reduction in capacity. TNCC may assist in disruption management. It may determine the impact of a lane closure and assist operators in the adjustment of the remaining lane configuration. To help alleviate the disruption, TNCC may suggest opening up the remaining lanes to other services. Traffic characteristics, such as the percent ETC usage, manual usage and ACM usage, serve as input to TNCC using a new lane configuration containing the closed lanes.

Suppose there is an incident in the morning rush hour at the Holland East Main Plaza, traveling west, for example. The Holland East Main Plaza is located on the East-West Expressway, S.R. 408, on the OOCEA’s network in Orlando, Florida. The capacity of the westbound side of the Holland East Main Plaza is 6777 vehicles per hour, *vph*, and has five MTE lanes, two AE lanes and two dedicated ETC lanes. The AE lane serves the A and E categories of traffic. The MTE lanes serve the M, T and E customers. According to TNCC, if there is an MTE lane closure due to an incident, the plaza's capacity is reduced to 5998 *vph*. To alleviate the disruption, operators may consider converting the other dedicated ETC lane to a manual service lane, MTE. TNCC would compute that this would further reduce the capacity to 5706 *vph*, thus this action should not be taken. Furthermore, TNCC can indicate the logic behind this decision. In this case, there is a high 53% ETC usage rate and taking away a dedicated ETC lane would not adequately serve the ETC customer-group. TNCC is designed to use these percentages, and other characteristics of the hourly arrival volumes, in conjunction with the new configuration to deduce a plaza's ability to perform.

TNCC also alleviates disruption due to scheduled maintenance. Suppose that there is required maintenance scheduled for the eastbound side of John Young Parkway Main Plaza, which requires closure of one lane. The configuration contains two MTE lanes and one dedicated ETC lane. In this case, if there is an MTE lane closure, the capacity is reduced drastically from 1394 to 697 *vph*. To alleviate the disruption, operators may again consider converting the dedicated ETC lane to a manual service lane, MTE. Unlike the previous example, TNCC would recommend this as a best practice choice because it would increase the capacity to 1081 *vph*. Therefore, during scheduled maintenance requiring one lane closure on the side of the John Young Parkway Main Plaza in which traffic is directed east, the configuration with the highest capacity would be an MTE-MTE rather than an E-MTE configuration.

TNCC can also help configure toll lanes whenever a planned special event occurs in the region. If heavy usage of the toll facilities is expected, increased volumes in manual usage may occur. The changes in the proportion of customer-groups arriving to the plaza will change the capacity. TNCC may serve as an assessment tool of the toll collection facility under these new conditions. For instance, there may be a special event requiring heavy traffic to flow westbound through the John Young Parkway Main Plaza, configuration E-MTE-MTE. The new traffic characteristics may not reflect the typical 46% ETC usage, but rather a lower 33% ETC usage rate. Special events often attract non-commuters that may or may not possess a transponder for ETC usage. TNCC predicts a capacity reduction from 1767 to 1448 *vph* due to the lower ETC usage rate. TNCC also predicts that the performance of the plaza could be improved by converting the dedicated ETC lane into a third MTE lane. This conversion could increase the capacity to 1656 *vph*.

Finally, TNCC may also assist with planning plaza lane configuration patterns to meet future developments. At the Holland East Plaza, the early morning rush hour westbound traffic, on August 16, 2000, had a 53% ETC usage rate. The two dedicated ETC lanes adequately serviced ETC users. However, if the percentage of ETC users increases to 57% or more, TNCC indicates that a third dedicated ETC lane converted from one of the MTE lanes would be beneficial. However, until the 57% ETC usage is attained, a third dedicated ETC lane would reduce capacity and would probably take away from the performance of the plaza. According to TNCC, this premature action would specifically reduce the 6777 *vph* capacity to as much as 5999 *vph.*

Conclusions from TNCC's Sensitivity Analysis[5]

Results from the sensitivity analyses indicate that TNCC calculates higher capacities for plazas with a large number of lanes. Also, traffic with a higher percentage of arrivals that are semi-trucks using non-ETC service results in lower calculated capacities. These vehicles have the lowest processing rates and should be encouraged to use ETC. In addition, capacities calculated by TNCC do not depend upon hourly arrival volumes; however, capacities depend upon the distribution of arrivals among the customer-groups and whether the lane configuration can meet these requirements.

[5] Much of these conclusions are quoted directly from the TRB paper presented at the 81st Annual Meeting, January 2002, and published in TRB RECORDS #1781, entitled *TNCC: Operations Management & Assessment Tool for Toll Network Operators* by Marguerite L. Zarrillo, PhD, A. Essam Radwan, PhD and PE, and Joseph H. Dowd, see appendix G.

TNCC correctly simulates the effects of the traffic characteristics. Consideration of some of the ramp plazas clearly demonstrates this result. For instance, ramp plazas containing a dedicated ETC lane, may actually have calculated capacities smaller than 1560 *vph*. At first glance this result may seem incorrect. However, the traffic characteristics determine the proportion of vehicles arriving to the plaza and therefore impact the capacity. Greater ETC usage resulted in larger calculated capacities. Keeping the percentage of ETC usage and manual usage consistent with the data requires an upper limit on the number of ETC users that can be serviced during the rush hour through the plaza. For example, through the John Young on-ramp AE-E plaza there is a 54% ETC usage and a 46% ACM usage rate. There is a capacity of 618 *vphpl* for the AE lane assuming all ETC users utilize the dedicated ETC lane. This is not a bad assumption because there are less than 1560 ETC users, proportionately, approaching the plaza in one hour; thus all ETC are using the dedicated ETC lane and no ETC drivers are using the mixed AE lane. If only 618 vehicles are processed in the AE lane, then there can only be an optimum value of 727 vehicles being processed in the dedicated ETC lane in one hour, or 618 times the ratio of 54 to 46. Keeping the portion of traffic volumes consistent with observation is a requirement by TNCC and restricts the resulting optimum calculated plaza capacity. In this case, the total capacity of this AE-E plaza is 1346 *vph*, smaller than 1560 *vph.*

TNCC also takes into account the shifting of ETC vehicles among the dedicated and mixed lanes. Configurations that provide enough dedicated ETC lanes for the approaching ETC traffic volumes all have an increase in capacity with an increase in ETC usage. In other words, if there are sufficient dedicated ETC lanes for the ETC volumes, then there is no overflow of ETC users into the mixed lanes and capacity becomes dependent on ETC usage rates. However, whenever there is overflow of ETC vehicles into the mixed MTE and AE lanes, then the ACM usage rate rather than ETC usage rate plays a large role in determining the capacity.

To illustrate an increase in capacity with an increase in ETC usage rate, six plazas all with the configuration E-MTE-MTE were considered. These plazas were the east and west side of John Young Main Plaza, the east and west side of Boggy Creek Main Plaza, Curry Ford Plaza northbound-side and University Main Plaza northbound-side. There is no ETC overflow from the dedicated ETC lane into the MTE lanes in any of these six plazas. Thus, capacities should increase with the ETC usage rates. Indeed, the rates, 30%, 38%, 46%, 51%, 51% and 56%, correlate well with the plazas' capacities of 1394, 1529, 1767, 1960, 1966 and 2107 *vph.* Another good comparison is the east and west side of the Bee Line Main Plaza. Both sides have the same configuration E-MTE-MTE-MTE and there is no overflow of ETC vehicles into the MTE lanes. The eastbound traffic volume has a slightly higher ETC usage rate, 49%, compared to the westbound traffic of 48%. Capacity is also slightly higher, 2763 rather than 2689 *vph.*

To illustrate how the ACM usage rate rather than the ETC usage rate plays a role in determining the capacity when ETC overflow occurs, both sides of the Holland West Plaza are considered. Both sides have the same configuration: 2 AE lanes, 3 MTE lanes and 1 dedicated E lane. Furthermore, the percentage of arrivals that are semi-trucks using non-ETC services are also the same on both sides, 0.9%. Only ETC and ACM usage are different. ETC usage is slightly higher for the eastbound traffic, 51% rather than 50%, and the ACM usage is significantly higher for the same eastbound traffic, 23% rather than 18%. In other words, there is less usage of the slow manual service in the eastbound direction, leading one to believe that the plaza with eastbound traffic would result in a higher capacity, 3864 *vph.* However, the calculation results in a higher capacity for the plaza with the westbound traffic, 4353 *vph*. To make sense of this, it can be observed that there is only one dedicated lane for ETC usage on either side. And with a high 50% or 51% ETC usage rate, ETC overflow will occur on both sides of the plaza. In the plaza with eastbound traffic, more of the ETC overflow is shifted into the MTE lanes because the AE lanes are already full, it has the higher 23%

ACM usage. Thus, two observations can be made. In the plaza with eastbound traffic, the capacity of the AE lanes is smaller than that of the plaza with westbound traffic, there are less ETC vehicles proportionately using the AE lanes. Also in the plaza with the eastbound traffic, the capacity of the MTE lanes is higher than that of the plaza with the westbound traffic, there are more ETC vehicles proportionately using the MTE lanes. The higher MTE capacity, however, is not high enough to offset the lower AE capacity and therefore results in a lower total capacity for the eastbound direction.

A similar case can be made for Airport Main Plaza. Both sides have the same configuration and again the ACM usage, 13%, for the eastbound traffic is higher than the ACM usage, 11%, for the westbound traffic. However, in this case, there is no overflow of ETC vehicles out of the dedicated ETC lane in the eastbound direction, thus, ETC vehicles are not shifted into MTE lanes. Here, the difference in the capacity of the plaza that has eastbound traffic compared to the plaza that has westbound traffic, 4123 versus 3723 *vph*, is due to the large difference in ETC usage. In the westbound directed traffic, there is a large portion of the vehicles using ETC, 47%, rather than the 36% usage in the eastbound directed traffic.

Appendix A: Detailed Description of Bottlenecks

In the following 6 sections of appendix A, the SF in vph is referred to as the capacity.

Central Florida Greeneway 417 North – Refers to Table 11

Traveling north on the 417, the Central Florida Greeneway, starting at the International Drive entrance, traffic volumes are a low 469 vph. Capacity, however, is quite high, 7067 vph, but it decreases to 4682 vph in the highway segment prior to the John Young Parkway Main Plaza north. At the plaza, three lanes out of four were opened, resulting in a plaza capacity of 1394 vph, sufficient to meet the 469 vph approaching traffic volumes. Although the one lane in the plaza that was closed could be opened to increase plaza capacity, the plaza segment was categorized as a *potential* bottleneck due to the sudden decrease in capacity without the possibility for vehicles to exit. The highway segment just prior to this was also categorized as a *potential* bottleneck, ID number 417N-03.0-#NA#-2-65-NP-4682-469-13, see map 13 and Table 11. Segments that are *potential* bottlenecks are highlighted in a light blue color both on the maps and in the Tables.

Capacities of highway segments following the plaza continue to be slightly higher than 4600 vph until the Boggy Creek Main Plaza except when it accommodates incoming traffic from Orange Blossom Trail, exit 11, and then it jumps temporarily to 7011 vph. However, in the 7:00 to 8:00 a.m. morning rush hour, incoming volumes only increased slightly to 612 vph after traffic had entered from Orange Blossom Trail.

Volumes increased again to 988 vph at the Landstar Boulevard entrance, and these volumes entered into the Boggy Creek Main Plaza. At this plaza, three of the five lanes are opened, resulting in a capacity of 1529 vph, well over the incoming volumes of 988 vph. This is a *potential* bottleneck situation because the capacity of the highway segment prior to the plaza has a much higher capacity than the plaza itself, 4618 over 1529 vph. The plaza can open up two lanes that are now closed. This will increase the plaza's capacity, however, it would still be a *potential* bottleneck situation.

After the Boggy Creek Main Plaza, capacity continues to be slightly larger than 4500 vph between segments 18 and 31. This easily meets arriving traffic volumes, which were less than 1000 up through segment 29. At segments 30 and 31, arriving traffic volumes surged slightly to 1281 vph due to the traffic entering from the interchange 528.

Following segment 31, approaching traffic volumes continued to surge to 1307 vph just before the Curry Ford Main Plaza. Capacity along this route also increases from 4549 to 6872 vph just prior to the plaza. The plaza had all three of its lanes opened in the northerly direction resulting in a computed capacity of 1966 vph. This is a *potential* bottleneck situation because the capacity of the highway segment prior to the plaza has a much higher capacity than the plaza itself, 6871 over 1966 vph.

After the plaza, arriving traffic volumes increased to 1463 vph due to the Curry Ford Road entrance in segment 37 and then decreased to volumes less than 1000 vph due to losses in traffic volumes at the 408 interchange. Capacities remain slightly higher than 4500 vph in these same segments and easily meet traffic volume demands. Also at the interchange, at segment 44, traffic from the 417N and the 408E merged and volumes surged to 1616 vph, however, capacity also surges at this point to 9287 vph.

Capacity doesn't decrease until segment 47 where approach volumes also decreased due to exiting traffic onto Colonial Drive, exit 34. These volumes decreased to 1356 vph and the capacity decreases to 4593 vph.

Approaching the University Main Plaza, volumes increased slightly to 1462 vph due to entering traffic from Colonial Drive. The accommodating capacity surges to 6942 vph. The segment, just prior to the plaza however, has a capacity reduction to 4601 vph for the same volume of 1462 vph and this is a *potential* future bottleneck. At the plaza, there are only three lanes in the northerly direction with a capacity of 1960 vph, barely enough for the 1462 traffic volume demands. This is a *near* bottleneck situation.

Immediately following the plaza, volumes decreased to a low 953 vph due to the University Boulevard exits but increased again to 1194 vph after the traffic enters from University Boulevard entrance ramp. Capacities immediately following the plaza are more than adequate enough, 6950 vph. Even after the capacities decrease to 4604 vph, they are still quite accommodating for the 1194 vph approaching traffic volumes.

Central Florida Greeneway 417 South – Refers to Table 12

Traveling south on the 417, the Central Florida Greeneway, approaching the University Boulevard entrances and exits, approaching volumes decreased and then increased from 2926 to 2604 to 3371 vph. Segment capacities are quite adequate and steadily increase from 4587 to 6925 vph. At the University Main Plaza south, all five lanes were opened resulting in a computed capacity of 4006 vph, sufficient to satisfy the 3371 vph demand. There are no extra lanes that could be opened in the future to accommodate growth and this is a *potential* bottleneck due to the higher highway segment capacities prior to the plaza.

Approaching volumes to the segments following the plaza continued to be high until the 408 interchange, in the range between 3200 and 3650 vph. Capacities are somewhat larger than 4500 vph, which is sufficient but does not leave much room for future volume increases. Capacities jump to a slightly higher value of 6900 vph in the segments just prior to the 408 interchange to accommodate entering traffic volumes from Colonial Drive.

At the interchange the traffic splits. Somewhat more than half of the traffic volumes took the 408 west toward downtown Orlando or exited the 417 into Valencia College Lane. Somewhat less than half of the traffic continued on the 417 south or exited onto the 408 east. Highway segments in either direction have sufficient capacities, over 4500 vph, to accommodate traffic. Only one segment, ID number 417S-14.0-#NA#-2-65-NP, was operating nearly at capacity and is a *near* bottleneck situation. It is the one left merge lane from the 417 south onto the 408 west. Volumes in this one lane reached 2258 vph between 7:00 and 8:00 a.m. on October 10, 2001.

Continuing on the 417 south, after the 408 interchange, all segments leading up to the Curry Ford Main Plaza have capacities larger than 4500 vph, sufficient to meet traffic volume demands. These volumes were increasingly high as the plaza was approached: 2331 vph leaving the 408 interchange and 3275 vph after the Curry Ford Road entrance ramp. The capacity of the five-lane Curry Ford Main Plaza is only 4022 vph. This is a *potential* bottleneck because the segment prior to the plaza has a higher capacity than the plaza itself. It will also be a *near* bottleneck situation if volumes increase in the future.

After the plaza, traffic splits again at the interchange with the 528. Most traffic exits onto the 528 leaving low volumes on the 417 southbound, less than 1000 vph. Capacities of segments serving these low volumes maintain their high values above 4500 vph.

Traffic volumes remained low after the interchange. Traffic exiting and traffic entering Narcoossee Road, exit 22, were approximately the same numbers, so that volumes on the 417 southbound remained approximately the same, below 1000 vph. Traffic then approaches the Boggy

Creek Main Plaza, which has a capacity of 2107 vph, very adequate to serve the arriving volumes. Only three of the five toll lanes were in use and therefore this plaza has much more potential for growth.

After the plaza, approach volumes remained around 1000 vph and then gradually increased as traffic entered from Landstar Boulevard, exit 14, Orange Blossom Trail, exit 11, and John Young Parkway, exit 10. It reached a maximum of 1417 vph approaching the John Young Parkway Main Plaza. Segments along this route have larger capacities, all over 4600 vph, some reaching 7000 vph.

The John Young Parkway Main Plaza south has a capacity of 1767 vph, sufficient for the approaching traffic, 1417 vph. One lane was not being utilized so that this plaza can reach higher capacities whenever future approach volumes increase. After the plaza, much of the traffic was lost at the International Drive exit 6, so that volumes again resumed values smaller than 1000 vph.

East-West Expressway 408 East – Refers to Table 13

Traveling east on the 408, the East-West Expressway, from exit 1, Colonial Drive and Clarke Road, traffic volumes reached a total of approximately 2400 vph. Highway segment capacity is 4492 vph, sufficient to meet traffic demand. An additional 700 vph entered from Good Home Road. Capacity is still sufficient. This total of approximately 3100 vph entered the Hiawassee Main Plaza eastbound, which has a capacity of 3023 vph. This is a bottleneck situation during a typical week day morning rush hour, 7:00 to 8:00 a.m.

After the plaza, volumes gradually increased again, this time to 3454 vph, due to entering traffic from Hiawassee Road, exit 4. Capacity increases temporarily to 6781 vph to accommodate this surge; soon capacity returns to 4491 vph and this value is maintained as traffic approaches the Holland West Main Plaza east. Volumes on this same leg, however, continued to increase and by the time the Holland West Main Plaza was reached, approach volumes were close to 4000 vph. The six-lane Holland West Main Plaza eastbound has a capacity of 3864 vph. This is another bottleneck situation during a typical weekday morning rush hour.

In addition, there were several *near* bottleneck situations on the eastbound 408. The exit ramp to Interstate 4 from the 408 eastbound and the entrance ramp from the Interstate 4 onto the 408 eastbound were both *near* bottleneck situations. There were 1047 vph traveling eastbound on the 408 that exited onto the one lane ramp to I-4 and there were 1350 vph entering the 408 eastbound traffic from I-4. Four segments prior to the HWP contained approach volumes very near the maximum service flow rates and were therefore *near* bottleneck situations: segments with ID numbers beginning with 408E-12.0, 408E-13.0, 408E-14.0 and 408E-16.0. Vehicles entering the highway from Pine Hills Road, exit 6, and Mercy Drive, exit 7, added to the eastbound traffic volumes. Incoming traffic from two other entrances along this route, Kirkman Road, exit 5, and John Young Parkway, exit 8A, did not contribute much added traffic because the number of vehicles exiting equaled the number of vehicles entering.

After the plaza, approach volumes continued to be high until exit 10A, the Interstate-4 exit, just under 3500 vph. Capacities of highway segments also increases to 6791 vph to accommodate traffic volumes in these segments just prior to the interchange with I-4. Traffic volume exiting the 408 eastbound onto the I-4 is measured at 1047 vph, a *near* bottleneck on the off ramp. The number of vehicles entering from I-4, 1350 vph, is also a *near* bottleneck on the entrance ramp.

Traffic volumes after the I-4 interchange reached 3651 vph. Capacities of the segments are first enlarged to 6795 vph and then to 9122 vph to accommodate this increase. However, traffic volumes decreased once again to 2729 vph after losing traffic to Orange Avenue, exit 10B, into downtown

Orlando. Through the rest of downtown Orlando on the 408 eastbound and approaching the Holland East Main Plaza, volumes fluctuated between 2700 and 3200 vph. Capacities also fluctuate between 6800 and 9150 vph, sufficient to accommodate morning traffic. Along this route, the ideal Free Flow Speed, FFS, is reduced by the interchange density factor as well as the factor for the number of lanes (anything less than 5 lanes requires a reduction to the ideal FFS). This in turn, reduces the computed capacity of the segments. However, lanes are added and the capacity is never less than adequate.

At the five-lane Holland East Main Plaza eastbound, the approach volumes have reached 2917 vph. The plaza's capacity is 3777 vph, which is adequate to serve demand. After the plaza, capacities maintain values above 6800 vph on segments leading up to the 417 interchange. This adequately serves the approach volumes that ranged in value from 2100 to 3400 vph.

At the interchange the traffic splits. Most traffic stays on the 408 east or exits to the 417 south, exit 18. About one third of the traffic exits to the 417 north, where some may opt to exit onto Valencia College Lane, exit 1. Highway segments in either direction have sufficient capacities, approximately 4500 vph, to accommodate traffic. However, segment ID number 408E-43.0-18AX-3-65-NP-6807-2503-03 may be classified as a *near* bottleneck situation. It is the segment just prior to the 408/417 interchange. It is categorized as a *near* bottleneck situation because although its approach volume is only 2503 vph, the majority of its traffic volume, 1722 vph, is concentrated in just one of its three lanes. This lane is the outermost right lane leading to a diverging segment of highway leading either to the 417 south or a continuation of the 408 east. The innermost left two lanes serve traffic directed onto the 417 north, which serves well the evening rush hour.

Capacities of the 408 eastbound highway segments, immediately after the interchange, increase to 6790 vph to adequately serve incoming vehicles exiting off of the 417, although these volumes are relatively low in the morning rush hour. The eastbound traffic on the 408 then proceeds to approach the four-lane Dean Main Plaza, which has a capacity of 2304 vph. This is a bottleneck because volumes reached 3036 vph on the approach highway segment.

Following the plaza, volumes were reduced. This is due in part by vehicles exiting onto Rouse Road, exit 20, but it is also due to the small capacity of the Dean Main Plaza eastbound. Capacities in the segments after the plaza maintain a 4491-vph value, adequate to serve traffic volumes that did not exceed 1550 vph.

East-West Expressway 408 West – Refers to Table 14

Traveling west on the 408, the East-West Expressway, from exit 23, Challenger Drive, volumes were low, approximately 1500 vph. Volumes doubled with the incoming vehicles from Alafaya Trail, exit 21, and a few hundred more added to this from Rouse Road, exit 20. Capacities of the highway segments along this route are sufficiently maintained at 4481 vph until the Rouse Road exit where capacities are increased to 6766 vph.

Traffic then enters the four-lane Dean Main Plaza, which has a capacity of 3159 vph, scarcely adequate to meet the measured arrivals, 3083 vph. This is a *near* bottleneck situation.

After the plaza, traffic was lost to the Dean Road exit reducing volumes to 1725 vph. To increase capacity for incoming vehicles from Dean Road, a lane is added. Volumes surged to 2481 vph. Capacity is more than adequate, 6775 vph.

Traffic proceeds to split at the interchange 417, exit 18. Much traffic exits onto the 417, however approximately three fourth of the traffic continued on the 408 west. Highway ramp segments at this interchange have enough capacity to adequately serve traffic volumes.

After the interchange, highway segments on the 408 westbound have increasingly higher and higher capacities, from 4494 to 9133 vph, because volumes also increased along this route, from approximately 3000 to 6300 vph. There are five additional *near* bottleneck situations before reaching the Holland East Main Plaza. Approaching traffic volumes were near the maximum service flow rate in segment ID numbers beginning with 408W-18.0, 408W-19.0, 408W-20.0, 408W-22.0 and 408W-23.0, see maps number 3 and 17. These volumes are swollen due to the traffic entering from the 417, exit 18, and Goldenrod Road, exit 16. Typically 1245 vph entered onto the 408 west from the Goldenrod Road entrance ramp, a *near* bottleneck in itself.

After these segments, some traffic was lost at the Semoran Boulevard exit immediately resulting in slightly lower volumes of 5749 vph. However, volumes entering from the Semoran Boulevard entrance ramp resulted in volumes increasing once again to higher levels, 6295 vph. These volumes entered the Holland East Main Plaza segment. The plaza has adequate capacity, 6777 vph, to serve the 6295 vph approaching traffic; however, this is also a *near* bottleneck situation.

The segment immediately following the plaza is also a *near* bottleneck situation. Volumes were measured to be 6530 vph and the segments capacity is at most only 6806 vph. A lane is subsequently added in the following highway segment to accommodate a volume increase, 7241 vph, due to the entering traffic from Conway Road, exit 13. The fourth segment after the HEP westbound on the 408, immediately after the Crystal Lake Drive exit ramp, however, is a *near* bottleneck situation, segment 408W-31.0-#NA#-3-55-NP-6798-6053-17. The lane number on the mainline decreases from four to three, however, exiting traffic is only typically 496 vph and approach volumes are 6053 vph which is very near the maximum service flow rate of 6798 vph.

Volumes then gradually decreased from 7241 to 2239, due to volumes exiting at Rosalind Avenue, exit 11A, and the Interstate-4, exit 10A. Capacities gradually drop to 4491 vph and easily accommodate demand. There are bottleneck situations, however, on exit ramps 10A and 11A, I-4 exit and Rosalind Avenue exit. Volumes reached 1903 vph on the one-lane exit ramp to I-4 and volumes reached 1483 vph on the one-lane exit ramp to Rosalind Avenue.

Volumes then surged slightly with traffic entering from Orange Avenue, I-4 entrance ramp, Orange Blossom Trail and Tampa Avenue. By the time the Holland West Main Plaza was reached, approaching traffic volumes were 2239 vph. The capacity of this plaza is 4353 vph, more than adequate to serve the traffic arrivals in the morning rush hour.

Between the Holland West Main Plaza and the next plaza, Hiawassee Main, volumes continued to decrease. This is due to more vehicles exiting than entering the highway at the John Young Parkway, exit 8A, Mercy Drive, exit 7, Pine Hill Road, exit 6, Kirkman Road, exit 5, and Hiawassee Road, exit 4. Traffic entering the Hiawassee Main Plaza westbound was a low 1243 vph. Capacities of these same segments are high, between 4481 and 6767 vph. This high capacity is necessary to serve evening rush hour traffic. During the morning, however, volumes are much lower than capacities.

The Hiawassee Main Plaza west has a capacity of 1714 vph, but only 3 of the 4 lanes were in use during the morning from 7:00 to 8:00 a.m. This was sufficient to serve the 1243 vph morning traffic arrivals. Hiawassee Main Plaza west is a *potential* bottleneck due to the sudden decrease in mainline capacity without a possibility for vehicles to exit. Even if all four lanes are opened, this plaza segment is still a *potential* bottleneck.

Volumes dropped below 1000 vph after the plaza due to exiting vehicles at Good Home Road, exit 2, and West Colonial Drive and Clarke Road, exit 1. Capacities of segments following the plaza, however, maintain values of 4482 vph.

Bee Line Expressway 528 East – Refers to Table 15

Traveling east on the 528, the Bee Line Expressway, the segments prior to the Boggy Creek Road interchange, exit 8, capacities of the highway segments are high, 6740 vph. This easily meets approaching traffic volume demands of a little more than 1000 vph. Volumes were 1721 vph after the Boggy creek Road entrance but then decreased to 1272 vph after exiting to Tradeport Drive, exit 9. Segment capacities also increase to 9045 vph to accommodate traffic entering from Boggy Creek Road and then returns to 6740 vph just after losing traffic at Tradeport Drive exit 9.

Volumes approaching the segment just prior to the Airport Plaza segment increased to 1355 vph due to traffic entering from Tradeport Drive. Capacity of this same segment just prior to the Airport Plaza segment is 6740 vph and meets traffic demands.

Capacity of the six-lane Airport Plaza eastbound, 3723 vph, is also sufficient to meet these demands of 1355 vph. However, this is a *potential* bottleneck situation because of the sudden decrease in capacity, from 6740 to 3723 vph, without the possibility for vehicles to exit. The segment after the plaza, has a capacity of 6706 however, this drops to 4420 vph. This drop in capacity is not a problem because volumes also dropped, from 1203 to 341 vph, due to traffic exiting to the airport, exit 11.

Capacity continues to drop slightly between segments 11 and 23 from 4420 to 4228 vph. However, traffic volumes were at the most 1646 vph on this portion of highway and then steadily decreased to 587. The volumes decreased due to exiting traffic onto Narcoossee Road and interchange 417.

After segment 23, just after the interchange, there is a sudden capacity increase to 6322 vph just before the Bee Line Main Plaza east. This is necessary to meet demand for entering traffic from the 417, which is actually small in the morning peak rush hour traffic, only 964 vph on these segments approaching the Bee Line Main Plaza. Four lanes were opened at the plaza; the capacity is 2763 vph, which easily meets demand. The eastbound side of the plaza was still categorized as a *potential* bottleneck even if it had two lanes that were not in use. The capacity could be increased when required in the future, but it would still be a *potential* bottleneck.

After the plaza, the capacities of the highway segments are a steady 4168 vph, which meets demands of less than 1000 vph.

Bee Line Expressway 528 West – Refers to Table 16

Beginning at the International Corporate Park entrance traveling west on 528, the four-lane Bee Line Expressway, capacities of the four highway segments prior to the Bee Line Plaza are 4168 vph and meet actual traffic volume demands which had values between 1200 and 1400 vph. This is true also at the Bee Line Plaza. Typical arriving traffic volumes were 1286 vph but its capacity is 2689 vph. Again, the westbound side of the plaza was categorized as a *potential* bottleneck even though it had two lanes that were not in use. The capacity could be increased when required in the future but the situation would still be a *potential* bottleneck.

Traffic volumes entering the segment immediately following the plaza were 1427 vph but the highway segment has a capacity of 6318 vph, also more than sufficient to meet traffic demands. Traffic volumes were further lost due to exiting vehicles at the 417 Interchange reducing volumes to values below 1000 vph. However, entering vehicles from the 417 soon increased volumes back up to 2454 vph. Capacity reaches a maximum of 6426 vph in segment number 12 to accommodate this surge. However, there is a *potential* bottleneck situation at segment number 13 because of the sudden capacity drop to 4274 vph without a possibility for vehicles to exit.

Volumes then steadily rose up to 3115 vph in the segments leading up to the Airport Plaza. This is due to entering traffic at the Narcoossee Road entrance and the airport traffic also entering from Semoran Boulevard. This 3115 vph is typical volumes for the 7-8 a.m. morning hourly traffic entering the Airport Plaza west on the 528. Capacities of these segments are sufficiently high enough to meet demand; all are slightly above 4300 vph, except the segment just prior to the plaza, which has an elevated capacity of 6710 vph.

The plaza has six lanes serving the traffic in the westerly direction and a capacity of 4123 vph. Although this meets the approaching traffic volumes of 3115 vph, the plaza is a *potential* bottleneck in the future if volumes increase. This is also possible because the capacity of the highway segment prior to the plaza has a high capacity of 6710 vph.

Continuing to travel west on the 528, volumes again increased to a total of 3161 vph. This is due to the entrance ramp from Conway Road. Capacity, however, is sufficiently high, 9045 vph, to accommodate these demands. Approach volumes did not decrease until after the Sand Lake Road, exit 8, decreasing to 1905 vph. Capacity also decreases to 6740 vph at the following segment on the highway.

Appendix B: Vita Dr. Marguerite Zarrillo

Dr. Marguerite Zarrillo received her Bachelor of Science degree from Purdue University in December 1978, a Master of Science Degree from the University of Illinois at Urbana-Champaign in May 1981, and a Doctor of Philosophy degree, Ph.D., from the University of Central Florida in August 1998, in Civil Engineering focusing on Transportation Engineering. Her expertise is in the field of Intelligent Transportation Systems (ITS).

Her work experience includes 13 years of teaching and research at the university level: Bradley University, Brandeis University and the University of Massachusetts Dartmouth. Dr. Zarrillo also has 3 years of research experience at the Transportation Systems Institute in Orlando, Florida. Currently, she is an Assistant Professor at the University of Massachusetts Dartmouth.

Dr. Marguerite L. Zarrillo is very active in her professional societies. October 2001, she constructed a book review for ITE of the *Traffic Engineering Handbook 2001*. The review was published in the March 2001 issue of *ASCE's Journal of Transportation Engineering.* She is currently the Secretary of ITS-Massachusetts, www.itsmass.org, Massachusetts Chapter of ITS America. She has also been Vice Chair of the ITS-MA Technical Committee and a member of the ITS-MA Coordinating Committee whose responsibility is to organize the annual ITS-MA Cnference. Dr. Zarrillo has had two refereed papers published in the proceedings of ITS-America's Annual Meeting, in April 1999. October 2001, she presented her paper at the 8th World ITS Congress in Sydney Australia. The paper was entitled *Modeling the OOCEA's Toll Network of Highways Using Plaza Capacity Analyses.* In the past, Dr. Zarrillo has served as an officer in the Sigma Xi Society, the Institute for Transportation Engineers, ITE, and the Women's Transportation Seminar, WTS.

In January 2002, Dr. Zarrillo presented a paper at the 81st Annual Meeting of the Transportation Research Board, TRB, in Washington D.C. The paper is entitled *TNCC: Operations Management & Assessment Tool for Toll Network Operators*. The paper is sponsored by the TRB Committee on Transportation Systems Management and has been published in TRB RECORDS #1781. Dr. Zarrillo is also an active friend of the TRB Freeway Operations Committee and attends their midyear Conferences. She presided over the Committee's technical session on *Ramp Metering*, at TRB 81st Annual Meeting, 2002.

Dr. Zarrillo has also been active in ASCE's International Conferences on Applications of Advanced Technology in Transportation Engineering, AATTE. She presented her paper entitled *Traffic Operations During Electronic Toll Collection: Case Study of the Holland East Plaza* at the ASCE's 5th International Conference on AATTE in April 1998, Newport Beach, California. She presented her paper entitled *Recommended Lane Configuration for ETC Implementation: Case Study of the MassPike-90 Interchange 11A* at the ASCE's 6th International Conference on AATTE in June 2000, Singapore. This paper resulted from a sponsored research study funded by the UMD Foundation / Healey Grant. Dr. Zarrillo also presented two papers with her Master's Degree student in ASCE's 7th International Conference on AATTE in July 2002 in Boston, Massachusetts. These two papers resulted from a FDOT sponsored research study of the OOCEA's toll network. Much of the research work proposed in this project will be an expansion of that study.

Dr. Zarrillo's research has also been presented at the WCTR, World Conference on Transport Research, held in Antwerp, Belgium, in July 1998. Her Toll Plaza Queuing Model Software was demonstrated at the IBTTA, International Bridge, Tunnels and Turnpike Association, the Toll Industry's Annual Technology Workshop, held in Washington D.C., in June 1998. She has had two peer reviewed papers published in the area of highway capacity. One paper was presented in a poster session at the Transportation Research Board 79th Annual Meeting, held in Washington D.C., in

January 2000, and another was presented at the ASCE 6th International Conference on Applications of Advanced Technologies in Transportation Engineering, held in Singapore, in June 2000.

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Appendix C: Plaza Capacities & Morning Hourly Traffic Volume Data

TABLE 1 Capacities for 20 Plazas Situated on the Network using TNCC

Lane Configuration	Name	C *(vph)*
Central Florida Greeneway S.R. 417		
MTE-MTE-MTE(closed)**-E** **E-MTE-**MTE(closed)**-MTE**	**John Young Pkwy.** **Main Plaza**	N-1394 S-1767
MTE-MTE(closed)**-MTE-**MTE(closed)**-E** **E-**MTE(close)**-MTE-**MTE(closed)**-MTE**	**Boggy Creek** **Main Plaza**	N-1529 S-2107
AE(functions as E)**-MTE-MTE** **MTE-MTE-AE-E-E**	**Curry Ford** **Main Plaza**	N-1966 S-4022
MTE-MTE-E **E-E-AE-MTE-MTE**	**University** **Main Plaza**	N-1960 S-4006
East-West Expressway S.R. 408		
MTE-AE-MTE-E **E-**MTE(closed)**-AE-MTE**	**Hiawassee** **Main Plaza**	E-3023 W-1714
MTE-MTE-AE-AE-E-MTE **MTE-E-AE-AE-MTE-MTE**	**Holland West** **Main Plaza**	E-3864 W-4353
E-AE-AE-MTE-MTE **MTE-MTE-AE-AE-MTE-E-E-MTE-MTE**	**Holland East** **Main Plaza**	E-3777 W-6777
E-MTE-AE-MTE **MTE-AE-MTE-E**	**Dean Main** **Plaza**	E-2304 W-3159
Bee Line Expressway S.R. 528		
E-AE-MTE-MTE-MTE-MTE **MTE-MTE-MTE-MTE-AE-E**	**Airport** **Plaza**	E-3723 W-4123
MTE-MTE-MTE-E **E-MTE-MTE-MTE**	**Bee Line** **Main Plaza**	E-2763 W-2689

TABLE 2 Capacities for 38 Plazas Situated on Exit/Entrance Ramps using TNCC

Lane Configuration	**Name & Entrance or Exit #**	**C** ***(vph)***
Central Florida Greenway S.R. 417		
ME-E	John Young Pkwy on #10	929
ME-E	John Young Pkwy off #10	1081
ME-E	Orange Blossom Trail on #11	816
ME-E	Orange Blossom Trail off #11	1093
AE-E	Landstar Blvd on #14	909
AE-E	Landstar Blvd off #14	1060
ME-E	Boggy Creek Rd. on #17	852
ME-E	Boggy Creek Rd off #17	820
AE-E	Narcoosee Rd on #22	1518
AE-E	Narcoosee Rd off #22	1913
AE	Curry Ford Rd on #30	976
AE	Curry Ford Rd off #30	771
AE-E	Valencia College Lane on #1	1252
AE-E	East Colonial Drive on #34	1293
AE-E	East Colonial Drive off #34	1150
AE	University Blvd on #37	836
AE	University Blvd off #37	830
East-West Expressway S.R. 408		
ME-E	Hiawassee on #4	1061
AE-E	Hiawassee off #4	1301
AE-E	John Young Pkwy on #8A	1346
AE-E	John Young Pkwy off #8A	1260
ME-AE	Orange Blossom Trail on #9	1178
ME-AE	Orange Blossom Trail off #9	1452
AE	Mills Ave on #11B	751
AE	Mills Ave off #11B	921
ME-AE	Bumby Ave on #12A	1203
ME-AE	Bumby Ave off #12A	1276
ME-AE	Conway Rd on #13	1257
ME-AE	Conway Rd off #13	1173
AE-E	Semoran Blvd on #14	1236
AE-E	Semoran Blvd off #14	1395
AE	Valencia College Lane off #1	699
ME	Dean Rd on #19	606
ME	Dean Rd off #19	616
AE	Rouse Rd on #20	915
AE	Rouse Rd off #20	743
Bee Line Expressway S.R. 528		
AE	International Corp Park on #20	959
AE	International Corp Park off #20	788

TABLE 3 Morning Hourly Total Traffic Volumes Processed at 20 Plazas

Lane Configuration	Name	V *(vph)*
Central Florida Greeneway S.R. 417		
MTE-MTE-MTE(closed)**-E** **E-MTE-**MTE(closed)**-MTE**	**John Young Pkwy. Main Plaza**	N-411 S-1528
MTE-MTE(closed)**-MTE-**MTE(closed)**-E** **E-**MTE(close)**-MTE-**MTE(closed)**-MTE**	**Boggy Creek Main Plaza**	N-623 S-934
AE(functions as E)**-MTE-MTE** **MTE-MTE-AE-E-E**	**Curry Ford Main Plaza**	N-1181 S-2929
MTE-MTE-E **E-E-AE-MTE-MTE**	**University Main Plaza**	N-1326 S-3517
East – West Expressway S.R. 408		
MTE-AE-MTE-E **E-**MTE(closed)**-AE-MTE**	**Hiawassee Main Plaza**	E-2594 W-1074
MTE-MTE-AE-AE-E-MTE **MTE-E-AE-AE-MTE-MTE**	**Holland West Main Plaza**	E-3473 W-2289
E-AE-AE-MTE-MTE **MTE-MTE-AE-AE-MTE-E-E-MTE-MTE**	**Holland East Main Plaza**	E-3371 W-6530
E-MTE-AE-MTE **MTE-AE-MTE-E**	**Dean Main Plaza**	E-1494 W-3083
Bee Line Expressway S.R. 528		
E-AE-MTE-MTE-MTE-MTE **MTE-MTE-MTE-MTE-AE-E**	**Airport Plaza**	E-1203 W-2881
MTE-MTE-MTE-E **E-MTE-MTE-MTE**	**Bee Line Main Plaza**	E-840 W-1427

TABLE 4 Morning Hourly Total Traffic Volumes Processed at 38 Plazas

Lane Configuration	**Name & Entrance or Exit #**	**V** ***(vph)***
Central Florida Greenway S.R. 417		
ME-E	John Young Pkwy on #10	161
ME-E	John Young Pkwy off #10	193
ME-E	Orange Blossom Trail on #11	102
ME-E	Orange Blossom Trail off #11	141
AE-E	Landstar Blvd on #14	293
AE-E	Landstar Blvd off #14	51
ME-E	Boggy Creek Rd. on #17	95
ME-E	Boggy Creek Rd off #17	91
AE-E	Narcoosee Rd on #22	206
AE-E	Narcoosee Rd off #22	104
AE	Curry Ford Rd on #30	304
AE	Curry Ford Rd off #30	101
AE-E	Valencia College Lane on #1	244
AE-E	East Colonial Drive on #34	413
AE-E	East Colonial Drive off #34	152
AE	University Blvd on #37	241
AE	University Blvd off #37	322
East-West Expressway S.R. 408		
ME-E	Hiawassee on #4	736
AE-E	Hiawassee off #4	299
AE-E	John Young Pkwy on #8A	122
AE-E	John Young Pkwy off #8A	396
ME-AE	Orange Blossom Trail on #9	156
ME-AE	Orange Blossom Trail off #9	691
AE	Mills Ave on #11B	49
AE	Mills Ave off #11B	79
ME-AE	Bumby Ave on #12A	225
ME-AE	Bumby Ave off #12A	300
ME-AE	Conway Rd on #13	711
ME-AE	Conway Rd off #13	186
AE-E	Semoran Blvd on #14	218
AE-E	Semoran Blvd off #14	360
AE	Valencia College Lane off #1	107
ME	Dean Rd on #19	756
ME	Dean Rd off #19	208
AE	Rouse Rd on #20	55
AE	Rouse Rd off #20	77
Bee Line Expressway S.R. 528		
AE	International Corp Park on #20	5
AE	International Corp Park off #20	54

TABLE 5 Morning Hourly Non-ETC Semi-Truck Volumes Processed at 20 Plazas

Lane Configuration	Name	V *(vph)*
Central Florida Greeneway S.R. 417		
MTE-MTE-MTE(closed)**-E** **E-MTE-**MTE(closed)**-MTE**	**John Young Pkwy. Main Plaza**	14
MTE-MTE(closed)**-MTE-**MTE(closed)**-E** **E-**MTE(close)**-MTE-**MTE(closed)**-MTE**	**Boggy Creek Main Plaza**	17
AE(functions as E)**-MTE-MTE** **MTE-MTE-AE-E-E**	**Curry Ford Main Plaza**	22
MTE-MTE-E **E-E-AE-MTE-MTE**	**University Main Plaza**	32
East – West Expressway S.R. 408		
MTE-AE-MTE-E **E-**MTE(closed)**-AE-MTE**	**Hiawassee Main Plaza**	31
MTE-MTE-AE-AE-E-MTE **MTE-E-AE-AE-MTE-MTE**	**Holland West Main Plaza**	49
E-AE-AE-MTE-MTE **MTE-MTE-AE-AE-MTE-E-E-MTE-MTE**	**Holland East Main Plaza**	56
E-MTE-AE-MTE **MTE-AE-MTE-E**	**Dean Main Plaza**	26
Bee Line Expressway S.R. 528		
E-AE-MTE-MTE-MTE-MTE **MTE-MTE-MTE-MTE-AE-E**	**Airport Plaza**	44
MTE-MTE-MTE-E **E-MTE-MTE-MTE**	**Bee Line Main Plaza**	30

TABLE 6 Morning Hourly Non-ETC Semi-Truck Volumes Processed at 38 Plazas

Lane Configuration	Name & Entrance or Exit #	V *(vph)*
Central Florida Greenway S.R. 417		
ME-E	John Young Pkwy on #10	1
ME-E	John Young Pkwy off #10	1
ME-E	Orange Blossom Trail on #11	2
ME-E	Orange Blossom Trail off #11	0
AE-E	Landstar Blvd on #14	0
AE-E	Landstar Blvd off #14	0
ME-E	Boggy Creek Rd. on #17	1
ME-E	Boggy Creek Rd off #17	1
AE-E	Narcoosee Rd on #22	0
AE-E	Narcoosee Rd off #22	0
AE	Curry Ford Rd on #30	0
AE	Curry Ford Rd off #30	0
AE-E	Valencia College Lane on #1	0
AE-E	East Colonial Drive on #34	0
AE-E	East Colonial Drive off #34	0
AE	University Blvd on #37	0
AE	University Blvd off #37	0
East-West Expressway S.R. 408		
ME-E	Hiawassee on #4	2
AE-E	Hiawassee off #4	0
AE-E	John Young Pkwy on #8A	0
AE-E	John Young Pkwy off #8A	0
ME-AE	Orange Blossom Trail on #9	3
ME-AE	Orange Blossom Trail off #9	2
AE	Mills Ave on #11B	0
AE	Mills Ave off #11B	0
ME-AE	Bumby Ave on #12A	2
ME-AE	Bumby Ave off #12A	5
ME-AE	Conway Rd on #13	3
ME-AE	Conway Rd off #13	3
AE-E	Semoran Blvd on #14	0
AE-E	Semoran Blvd off #14	0
AE	Valencia College Lane off #1	0
ME	Dean Rd on #19	6
ME	Dean Rd off #19	3
AE	Rouse Rd on #20	0
AE	Rouse Rd off #20	0
Bee Line Expressway S.R. 528		
AE	International Corp Park on #20	0
AE	International Corp Park off #20	0

TABLE 7 Morning Hourly ETC & ACM Traffic Volumes Processed at 20 Plazas

Lane Configuration	Name	ETC (vph)	ACM (vph)
Central Florida Greeneway S.R. 417			
MTE-MTE-MTE(closed)**-E** **E-MTE-**MTE(closed)**-MTE**	**John Young Pkwy. Main Plaza**	N-125 S-696	0 0
MTE-MTE(closed)**-MTE-**MTE(closed)**-E** **E-**MTE(close)**-MTE-**MTE(closed)**-MTE**	**Boggy Creek Main Plaza**	N-235 S-519	0 0
AE(functions as E)**-MTE-MTE** **MTE-MTE-AE-E-E**	**Curry Ford Main Plaza**	N-600 S-1803	0 442
MTE-MTE-E **E-E-AE-MTE-MTE**	**University Main Plaza**	N-675 S-2243	0 459
East – West Expressway S.R. 408			
MTE-AE-MTE-E **E-**MTE(closed)**-AE-MTE**	**Hiawassee Main Plaza**	E-1408 W-510	449 275
MTE-MTE-AE-AE-E-MTE **MTE-E-AE-AE-MTE-MTE**	**Holland West Main Plaza**	E-1765 W-1136	783 418
E-AE-AE-MTE-MTE **MTE-MTE-AE-AE-MTE-E-E-MTE-MTE**	**Holland East Main Plaza**	E-1173 W-3458	608 1008
E-MTE-AE-MTE **MTE-AE-MTE-E**	**Dean Main Plaza**	E-767 W-1777	401 489
Bee Line Expressway S.R. 528			
E-AE-MTE-MTE-MTE-MTE **MTE-MTE-MTE-MTE-AE-E**	**Airport Plaza**	E-435 W-1345	158 309
MTE-MTE-MTE-E **E-MTE-MTE-MTE**	**Bee Line Main Plaza**	E-415 W-684	0 0

TABLE 8 Morning Hourly ETC & ACM Traffic Volumes Processed at 38 Plazas

Lane Configuration	Name & Entrance or Exit #	ETC *(vph)*	ACM *(vph)*
Central Florida Greenway S.R. 417			
ME-E	John Young Pkwy on #10	75	0
ME-E	John Young Pkwy off #10	103	0
ME-E	Orange Blossom Trail on #11	44	0
ME-E	Orange Blossom Trail off #11	74	0
AE-E	Landstar Blvd on #14	89	189
AE-E	Landstar Blvd off #14	20	28
ME-E	Boggy Creek Rd. on #17	37	0
ME-E	Boggy Creek Rd off #17	37	0
AE-E	Narcoosee Rd on #22	115	79
AE-E	Narcoosee Rd off #22	67	32
AE	Curry Ford Rd on #30	190	89
AE	Curry Ford Rd off #30	44	48
AE-E	Valencia College Lane on #1	119	116
AE-E	East Colonial Drive on #34	204	187
AE-E	East Colonial Drive off #34	68	79
AE	University Blvd on #37	130	105
AE	University Blvd off #37	172	142
East-West Expressway S.R. 408			
ME-E	Hiawassee on #4	384	0
AE-E	Hiawassee off #4	148	134
AE-E	John Young Pkwy on #8A	60	51
AE-E	John Young Pkwy off #8A	195	188
ME-AE	Orange Blossom Trail on #9	67	26
ME-AE	Orange Blossom Trail off #9	336	155
AE	Mills Ave on #11B	19	23
AE	Mills Ave off #11B	47	27
ME-AE	Bumby Ave on #12A	110	47
ME-AE	Bumby Ave off #12A	133	62
ME-AE	Conway Rd on #13	253	174
ME-AE	Conway Rd off #13	60	53
AE-E	Semoran Blvd on #14	103	103
AE-E	Semoran Blvd off #14	186	148
AE	Valencia College Lane off #1	34	58
ME	Dean Rd on #19	323	0
ME	Dean Rd off #19	96	0
AE	Rouse Rd on #20	34	20
AE	Rouse Rd off #20	33	42
Bee Line Expressway S.R. 528			
AE	International Corp Park on #20	2	1
AE	International Corp Park off #20	10	10

TABLE 9 Morning Hourly Semi-Truck Volumes Processed at 20 Plazas

Lane Configuration	Name	V *(vph)*
Central Florida Greeneway S.R. 417		
MTE-MTE-MTE(closed)**-E** **E-MTE-**MTE(closed)**-MTE**	**John Young Pkwy. Main Plaza**	42
MTE-MTE(closed)**-MTE-**MTE(closed)**-E** **E-**MTE(close)**-MTE-**MTE(closed)**-MTE**	**Boggy Creek Main Plaza**	57
AE(functions as E)**-MTE-MTE** **MTE-MTE-AE-E-E**	**Curry Ford Main Plaza**	108
MTE-MTE-E **E-E-AE-MTE-MTE**	**University Main Plaza**	75
East – West Expressway S.R. 408		
MTE-AE-MTE-E **E-**MTE(closed)**-AE-MTE**	**Hiawassee Main Plaza**	71
MTE-MTE-AE-AE-E-MTE **MTE-E-AE-AE-MTE-MTE**	**Holland West Main Plaza**	113
E-AE-AE-MTE-MTE **MTE-MTE-AE-AE-MTE-E-E-MTE-MTE**	**Holland East Main Plaza**	119
E-MTE-AE-MTE **MTE-AE-MTE-E**	**Dean Main Plaza**	89
Bee Line Expressway S.R. 528		
E-AE-MTE-MTE-MTE-MTE **MTE-MTE-MTE-MTE-AE-E**	**Airport Plaza**	149
MTE-MTE-MTE-E **E-MTE-MTE-MTE**	**Bee Line Main Plaza**	245

TABLE 10 Morning Hourly Semi-Truck Volumes Processed at 38 Plazas

Lane Configuration	Name & Entrance or Exit #	V *(vph)*
Central Florida Greenway S.R. 417		
ME-E	John Young Pkwy on #10	5
ME-E	John Young Pkwy off #10	9
ME-E	Orange Blossom Trail on #11	4
ME-E	Orange Blossom Trail off #11	1
AE-E	Landstar Blvd on #14	2
AE-E	Landstar Blvd off #14	3
ME-E	Boggy Creek Rd. on #17	6
ME-E	Boggy Creek Rd off #17	5
AE-E	Narcoosee Rd on #22	2
AE-E	Narcoosee Rd off #22	4
AE	Curry Ford Rd on #30	9
AE	Curry Ford Rd off #30	5
AE-E	Valencia College Lane on #1	1
AE-E	East Colonial Drive on #34	6
AE-E	East Colonial Drive off #34	4
AE	University Blvd on #37	0
AE	University Blvd off #37	0
East-West Expressway S.R. 408		
ME-E	Hiawassee on #4	3
AE-E	Hiawassee off #4	6
AE-E	John Young Pkwy on #8A	1
AE-E	John Young Pkwy off #8A	1
ME-AE	Orange Blossom Trail on #9	7
ME-AE	Orange Blossom Trail off #9	10
AE	Mills Ave on #11B	1
AE	Mills Ave off #11B	4
ME-AE	Bumby Ave on #12A	8
ME-AE	Bumby Ave off #12A	8
ME-AE	Conway Rd on #13	4
ME-AE	Conway Rd off #13	5
AE-E	Semoran Blvd on #14	2
AE-E	Semoran Blvd off #14	1
AE	Valencia College Lane off #1	0
ME	Dean Rd on #19	8
ME	Dean Rd off #19	17
AE	Rouse Rd on #20	1
AE	Rouse Rd off #20	0
Bee Line Expressway S.R. 528		
AE	International Corp Park on #20	1
AE	International Corp Park off #20	1

Appendix D: Segment-Approach-Volumes & Maximum Service-Flow-Rates

Results of the Capacity Calculations for the segments located between plazas as well as the plaza segments are listed in the following tables. An expanded version of the calculation details is included on a CD accompanying this report.

Table 11: the Central Florida Greeneway 417 eastbound

Table 12: the Central Florida Greeneway 417 westbound

Table 13: the East-West Expressway 408 eastbound

Table 14: the East-West Expressway 408 westbound

Table 15: the Bee Line Expressway 528 eastbound

Table 16: the Bee Line Expressway 528 westbound

Color Coded Legend describing the Highway Segments:

Color	Description
Green	**Bottlenecks**
Light green	**Near Bottlenecks**
Light cyan	**Potential Bottlenecks**
Yellow	**Tues' data rather than Wed**
Gray	**Segment not on the Mainline**
Peach	**Volume and SF columns**
Light blue	**Volumes are uncertain**

Table 11: Traveling North on the 417, Central FL Greeneway

SECTION NAME - highway name & direction - segment number - exit number X, entrance N - no. of lanes in segment - speed limit on segment - plaza PP or no plaza NP - map number on which it is located	SF is the service flow rate during pk 15 min.for LOS E $FFS=FFS_{ideal}-f_{id}-f_n-f_{lc}-f_{lw}$ f_{id}=5*(ipm)-2.5 f_n=7.5-1.5N $f_{lc} = f_{lw} = 0.0$ MSF=10*FFS+1700 $SF=N*MSF*f_{HV}*f_p$ $SF=Capacity*f_{HV}*f_p$ $f_p = 1.00$ $f_{HV}=1/(1+P_T(E_T-1.0))$ (vph)	from TNCC Plaza SF (vph)	PBS&J Enterning Volumes (vph) TOTAL	Ramp Plaza Capacity (vph)	Bottlenecks Near Bottlenecks Potential Bottlenecks Tues' data rather than Wed Segment not on the Mainline Volume and SF columns Volumes are uncertain
417N-01.0-#NA#-2-65-NP-13	4682		327		
417N-02.0-06#N-3-65-NP-13	7067		469		International Dr. (entrance #6)
417N-03.0-#NA#-2-65-NP-13	4682		469		
417N-04.0-#NA#-3-30-PP-13		1394	469		John Young Parkway Main Plaza (north)
417N-05.0-#NA#-2-65-NP-13	4677		411		
417N-06.0-10#X-2-65-NP-12	4671		411		John Young Parkway (SR 423) (exit #10)
417N-07.0-#NA#-2-65-NP-12	4666		388		
417N-08.0-10#N-2-65-PP-12	4661		549	929	John Young Parkway (SR 423) (entrance #10)
417N-09.0-11#X-2-65-NP-12	4655		549		Orange Blossom Trail (exit #11)
417N-10.0-#NA#-2-65-NP-11	4650		510		
417N-11.0-11#N-3-65-PP-11	7011		612	816	Orange Blossom Trail (entrance #11)
417N-12.0-#NA#-2-65-NP-11	4639		612		in future - Florida's Turnpike (exit 12) ?
417N-13.0-14#X-2-65-PP-11	4634		612	1060	Landstar Blvd. (exit #14)
417N-14.0-#NA#-2-65-NP-11	4629		561		
417N-15.0-14#N-2-65-NP-10	4624		988		Landstar Blvd. (entrance #14)
417N-16.0-#NA#-2-65-NP-10	4618		988		
417N-17.0-#NA#-3-30-PP-10		1529	988		Boggy Creek Main Plaza (north)
417N-18.0-#NA#-2-65-NP-10	4616		623		
417N-19.0-17#X-2-65-NP-09	4619		623		Boggy Creek Rd. (exit #17)
417N-20.0-#NA#-2-65-NP-09	4623		660		
417N-21.0-17#N-2-65-PP-09	4626		755	852	Boggy Creek Rd. (entrance #17)
417N-22.0-#NA#-2-65-NP-08	4629		755		
417N-23.0-22#X-2-65-NP-08	4632		755		Narcoosee Rd. (exit #22)
417N-24.0-#NA#-2-65-NP-08	4635		523		
417N-25.0-22#N-2-65-PP-08	4638		729	1518	Narcoosee Rd. (entrance #22)
417N-26.0-#NA#-2-65-NP-07	4536		729		
417N-27.0-26#X-2-65-NP-06	4539		729		Interchange 528 (exit #26 to EB & WB)
417N-27.1-26EX-1-45-NP-06	2255		123		to 528 EB
417N-28.0-26WX-1-45-NP-06	2255		5		to 528 WB
417N-28.1-#NA#-1-45-NP-06	2255		5		to 528 WB
417N-29.0-#NA#-2-65-NP-06	4542		606		
417N-30.0-26#N-2-65-NP-05	4545		1281		Interchange 528 (entrance #26 from EB & WB)
417N-31.0-#NA#-2-65-NP-05	4548		1281		
417N-32.0-####-3-65-NP-05	6871		1307		in future-Lee Vista Blvd. (exit #27) ?
417N-33.0-#NA#-3-30-PP-05		1966	1307		Curry Ford Main Plaza (north)
417N-34.0-#NA#-2-65-NP-05	4557		1181		
417N-35.0-30#X-2-65-NP-04	4560		1181		Curry Ford Rd. (SR552) (exit #30)
417N-36.0-#NA#-2-65-NP-04	4563		1159		
417N-37.0-30#N-2-65-PP-04	4565		1463	976	Curry Ford Rd. (SR552) (entrance #30)
417N-38.0-#NA#-2-65-NP-04	4568		1463		
417N-39.0-33AX-2-65-NP-03	4571		1463		Interchange 408 (exit 33A to EB)
417N-40.0-33BX-2-65-NP-03	4574		1115		Interchange 408 (exit 33A to WB)
417N-41.0-#NA#-2-65-NP-03	4576		629		
417N-42.0-18#N-2-65-NP-03	4579		858		Interchange 408 (entrance 33A from WB)
417N-43.0-#NA#-2-65-NP-03	4582		858		
417N-44.0-#NA#-4-65-NP-03	9287		1616		Interchange 408 (merge entrance from EB)
417N-45.0-34#X-4-65-PP-03	9292		1616	1150	East Colonial Drive (exit #34)
417N-46.0-#NA#-3-65-NP-03	6929		1464		
417N-47.0-#NA#-2-65-NP-02	4593		1356		
417N-48.0-34#N-3-65-NP-02	6938		1462		East Colonial Drive (entrance #34)
417N-49.0-#NA#-3-65-NP-02	6942		1462		
417N-50.0-#NA#-2-65-NP-02	4601		1462		
417N-51.0-#NA#-3-30-PP-02		1960	1462		University Main Plaza (north)
417N-52.0-37AX-3-65-NP-02	6950		1326		University Blvd. (exit #37A to EB)
417N-53.0-37BX-3-65-NP-02	6950		1077		University Blvd. (exit #37B to WB)
417N-54.0-#NA#-2-65-NP-02	4604		953		
417N-55.0-37#N-2-65-PP-01	4604		1194	836	University Blvd. (entrance #37)

Table 12: Traveling South on the 417, Central FL Greeneway

Legend (cell colours):
- Bottlenecks
- Near Bottlenecks
- Potential Bottlenecks
- Tues' data rather than Wed
- Segment not on the Mainline
- Volume and SF columns
- Volumes are uncertain

SECTION NAME - highway name & direction - segment number - exit number X, entrance N - no. of lanes in segment - speed limit on segment - plaza PP or no plaza NP - map number on which it is located	SF is the service flow rate during pk 15 min.for LOS E $FFS=FFS_{ideal}-f_{id}-f_n-f_{lc}-f_{lw}$ $f_{id}=5*(ipm)-2.5$ $f_n=7.5-1.5N$ $f_{lc} = f_{lw} = 0.0$ $MSF=10*FFS+1700$ $SF=N*MSF*f_{HV}*f_p$ $SF=Capacity*f_{HV}*f_p$ $f_p = 1.00$ $f_{HV}=1/(1+P_T(E_T-1.0))$ (vph)	from TNCC Plaza SF (vph)	PBS&J Enterning Volumes (vph) TOTAL	Ramp Plaza Capacity (vph)	
417S-01.0-37#X-2-65-PP-01	4587		2926	830	University Blvd. (exit #37)
417S-02.0-#NA#-2-65-NP-02	4587		2604		
417S-03.0-37AN-3-65-NP-02	6925		3237		University Blvd. (entrance #37 from WB)
417S-04.0-37BN-3-65-NP-02	6925		3371		University Blvd. (entrance #37 from EB)
417S-05.0-#NA#-5-30-PP-02		4006	3371		University Main Plaza (south)
417S-06.0-#NA#-2-65-NP-02	4584		3517		
417S-07.0-34#X-2-65-NP-02	4581		3517		East Colonial Drive (exit #34)
417S-08.0-#NA#-2-65-NP-02	4578		3204		
417S-09.0-34#N-3-65-PP-02	6906		3617	1293	East Colonial Drive (entrance#34)
417S-10.0-33BX-3-65-NP-03	6901		3617		Interchange 408 (diverge exit to WB)
417S-11.0-01#X-2-65-NP-03	4571		2147		Valencia College Lane (exit #1)
417S-12.0-#NA#-2-65-NP-03	4571		1438		
417S-13.0-01#N-2-65-PP-03	4571		1682	1252	Valencia College Lane (entrance #1)
417S-14.0-#NA#-1-65-NP-03	2271		2258		single left merge lane onto 408 WB from 417 SB
417S-15.0-#NA#-2-65-NP-03	4568		1733		
417S-16.0-33AX-2-65-NP-03	4564		1733		Interchange 408 (exit #33A to EB)
417S-17.0-#NA#-2-65-NP-03	4561		1484		
417S-18.0-33AN-2-65-NP-03	4558		2331		Interchange 408
417S-19.0-#NA#-2-65-NP-03	4555		2331		(entrance #33A from EB & WB)
417S-20.0-30#X-2-65-PP-04	4551		2331	771	Curry Ford Road (SR552) (exit #30)
417S-21.0-#NA#-2-65-NP-04	4548		2230		
417S-22.0-30#N-2-65-NP-04	4545		3275		Curry Ford Road (entrance #30)
417S-23.0-#NA#-2-65-NP-04	4542		3275		
417S-24.0-#NA#-5-30-PP-05		4022	3275		Curry Ford Main Plaza (south)
417S-25.0-#NA#-2-65-NP-05	4535		2929		in future-Lee Vista Blvd. (entrance #27)
417S-26.0-26#X-2-65-NP-05	4532		2533		Interchange 528 (exit #26 to EB & WB)
417S-27.0-26WX-1-45-NP-06	2252		1794		to 528 WB
417S-28.0-26EX-1-45-NP-06	2252		283		to 528 EB
417S-29.0-#NA#-2-65-NP-06	4529		739		
417S-30.0-26#N-2-65-NP-06	6833		955		Interchange 528
417S-31.0-#NA#-3-65-NP-07	7028		955		(entrance #26 from EB & WB)
417S-32.0-#NA#-2-65-NP-07	4653		955		
417S-33.0-22#X-2-65-PP-07	4650		955	1913	Narcoossee Rd. (exit #22)
417S-34.0-#NA#-2-65-NP-08	4647		851		
417S-35.0-22#N-2-65-NP-08	4644		966		Narcoossee Rd. (entrance #22)
417S-36.0-#NA#-2-65-NP-08	4641		966		
417S-37.0-17#X-2-65-PP-09	4638		966	820	Boggy Creek Rd. (exit #17)
417S-38.0-#NA#-2-65-NP-09	4637		875		
417S-39.0-17#N-2-65-NP-09	4634		1028		Boggy Creek Rd. (entrance #17)
417S-40.0-#NA#-2-65-NP-10	4630		1028		
417S-41.0-#NA#-3-30-PP-10		2107	1028		Boggy Creek Main Plaza (south)
417S-42.0-#NA#-2-65-NP-10	4631		934		
417S-43.0-14#X-2-65-NP-10	4636		934		Landstar Blvd. (exit #14)
417S-44.0-#NA#-2-65-NP-10	4641		858		
417S-45.0-14#N-3-65-PP-11	7013		1151	909	Landstar Blvd. (entrance #14)
417S-46.0-#NA#-2-65-NP-11	4652		1151		in future - Florida's Turnpike (exit 12)
417S-47.0-11#X-3-65-PP-11	7029		1151	1093	Orange Blossom Trail (exit #11)
417S-48.0-#NA#-3-65-NP-11	7037		1010		
417S-49.0-11#N-3-65-NP-12	7045		1233		Orange Blossom Trail (entrance #11)
417S-50.0-10#X-3-65-PP-12	7053		1233	1081	John Young Parkway (SR423) (exit #10)
417S-51.0-#NA#-2-65-NP-12	4678		1040		
417S-52.0-10#N-2-65-NP-12	4683		1417		John Young Parkway (entrance #10)
417S-53.0-#NA#-2-65-NP-12	4689		1417		
417S-54.0-#NA#-3-30-PP-13		1767	1417		John Young Parkway Main Plaza (south)
417S-55.0-#NA#-2-65-NP-13	4694		1528		
417S-56.0-06#X-3-65-NP-13	7085		1528		International Dr. (exit #6)
417S-57.0-#NA#-2-65-NP-13	4694		656		

Table 13: Traveling East on the 408, East-West Expressway

SECTION NAME - highway name & direction - segment number - exit number X, entrance N - no. of lanes in segment - speed limit on segment - plaza PP or no plaza NP - map number on which it is located	SF is the service flow rate during pk 15 min.for LOS E $FFS=FFS_{ideal}-f_{id}-f_n-f_{lc}-f_{lw}$ f_{id}=5*(ipm)-2.5 f_n=7.5-1.5N $f_{lc} = f_{lw}$ = 0.0 MSF=10*FFS+1700 SF=N*MSF*f_{HV}*f_p SF=Capacity*f_{HV}*f_p f_p = 1.00 f_{HV}=1/(1+P_T(E_T-1.0)) (vph)	from TNCC Plaza SF (vph)	PBS&J Enterning Volumes (vph) TOTAL	Ramp Plaza Capacity (vph)	Bottlenecks (green) Near Bottlenecks (light green) Potential Bottlenecks (light cyan) Tues' data rather than Wed (yellow) Segment not on the Mainline (grey) Volume and SF columns (orange) Volumes are uncertain (blue)
408E-02.0-01#N-1-##-NP-14	2231				West Colonial Dr./Clarke Rd. (entrance #1)
408E-03.0-#NA#-2-65-NP-14	4492		2431		
408E-04.0-02#N-2-65-NP-14	4492		3068		Good Homes Rd. (entrance #2)
408E-05.0-#NA#-4-30-PP-14		3023	3068	Hiawassee Main Plaza (east)	
408E-06.0-04#X-2-65-NP-14	4492		2594		Hiawassee Road (exit #4)
408E-07.0-#NA#-2-65-NP-14	4492		2718		
408E-08.0-04#N-3-65-PP-14	6781		3454	1061	Hiawassee Road (entrance #4)
408E-09.0-05#X-3-65-NP-15	6781		3454		Kirkman Rd. (exit #5)
408E-10.0-#NA#-2-55-NP-15	4491		2837		
408E-11.0-05#N-2-55-NP-15	4491		3303		Kirkman Rd. (entrance #5)
408E-12.0-06#N-2-55-NP-15	4491		3695		Pine Hill Rd. (entrance #6)
408E-13.0-07#N-2-45-NP-15	4491		3982		Mercy Dr. (entrance #7)
408E-14.0-08AX-2-45-PP-15	4491		3982	1260	John Young Parkway (SR423) (exit #8A)
408E-15.0-#NA#-2-45-NP-15	4490		3586		
408E-16.0-08AN-2-45-NP-15	4490		3901		John Young Parkway (SR423) (entrance #
408E-17.0-#NA#-6-30-PP-15		3864	3901	Holland West Main Plaza (east)	
408E-18.0-08BX-2-55-NP-16	4492		3473		Tampa Ave. (exit #8B)
408E-19.0-09#X-2-55-NP-16	4493		3475		Orange Blossom Trail (exit #9)
408E-20.0-#NA#-2-55-NP-16	4495		3268		
408E-21.0-09#N-3-55-PP-16	6788		3424	1178	Orange Blossom Trail (entrance #9)
408E-22.0-10AX-3-55-NP-16	6791		3424		Interstate-4 (exit #10A)
408E-23.0-#NA#-2-55-NP-16	4499		2412		
408E-24.0-10AN-3-55-NP-16	6795		3651		Interstate-4 (entrance #10A)
408E-25.0-10BX-4-55-NP-16	9122		3651		Orange Ave. (exit 10B)
408E-26.0-#NA#-3-55-NP-16	6800		2729		
408E-27.0-11AN-4-55-NP-16	9129		2779		Orange Ave. (entrance 10B)
408E-28.0-11BX-4-55-PP-16	9132		2779	921	Mills Avenue (exit #11B)
408E-29.0-#NA#-3-55-NP-16	6807		2700		
408E-30.0-11BN-4-55-NP-16	9138		3196		Mills Avenue (entrance #11B)
408E-31.0-12AX-4-55-PP-16	9141		3196	1276	Bumby Avenue (exit #12A)
408E-32.0-#NA#-3-55-NP-17	6814		2896		
408E-33.0-12BN-4-55-NP-17	9147		3103		Crystal Lake Dr. (entrance #12B)
408E-34.0-13#X-4-55-PP-17	9150		3103	1173	Conway Road (exit #13)
408E-35.0-#NA#-3-55-NP-17	6821		2917		
408E-36.0-#NA#-5-30-PP-17		3777	2917	Holland East Main Plaza (east)	
408E-37.0-14#X-3-55-NP-17	6821		3371		Semoran Blvd. (SR436) (exit #14)
408E-38.0-#NA#-3-55-NP-17	6818		2663		
408E-39.0-14#N-3-55-PP-17	6816		2881	1236	Semoran Blvd. (SR436) (entrance #14)
408E-40.0-16#X-3-55-NP-03	6814		2881		Goldenrod Rd. (exit #16)
408E-41.0-#NA#-3-55-NP-03	6811		2155		
408E-42.0-16#N-3-65-NP-03	6809		2503		Goldenrod Rd. (entrance #16)
408E-43.0-18AX-3-65-NP-03	6807		2503		Interchange 417 (diverge exit 18A to NB)
408E-44.0-01#X-2-65-PP-03	4507		983	699	Valencia College Lane (exit #1)
408E-45.0-#NA#-2-65-NP-03	4505		876		
408E-46.0-01#N-2-65-NP-03	4504		934		Valencia College Lane (entrance #1)
408E-47.0-18BX-2-65-NP-03	4502		1722		Interchange 417 (exit 18A to SB)
408E-48.0-#NA#-2-65-NP-03	4500		1511		
408E-49.0-33AN-2-65-NP-03	4499		1639		Interchange 417 (entrance 18A from NB)
408E-50.0-33AN-3-65-NP-03	6790		1567		Interchange 417 (entrance 18A from SB)
408E-51.0-19#X-3-65-PP-03	6788		1567	616	Dean Road (exit #19)
408E-52.0-#NA#-2-65-NP-03	4494		1359		
408E-53.0-19#N-2-65-NP-03	4493		3036		Dean Road (entrance #19)
408E-54.0-#NA#-4-30-PP-03		2304	3036	Dean Main Plaza (east)	
408E-55.0-20#X-2-55-NP-18	4491		1494		Rouse Road (exit #20)
408E-56.0-#NA#-2-55-NP-18	4491		1463		
408E-57.0-20#N-2-55-PP-18	4491		1518	915	Rouse Road (entrance #20)
408E-58.0-21#X-2-55-NP-18	4491		1518		Alafaya Trail (exit #21)
408E-59.0-#NA#-2-55-NP-18	4491		1046		
408E-60.0-23#X-2-55-NP-18	4491		1046		Colonial Dr. (exit #23)
408E-61.0-#NA#-2-55-NP-18	4491		503		
408E-62.0-#NA#-2-45-NP-19	4491		503		

Table 14: Traveling West on the 408, East-West Expressway

SECTION NAME - highway name & direction - segment number - exit number X, entrance N - no. of lanes in segment - speed limit on segment - plaza PP or no plaza NP - map number on which it is located	SF is the service flow rate during pk 15 min.for LOS E $FFS=FFS_{ideal}-f_{id}-f_n-f_{lc}-f_{lw}$ f_{id}=5*(ipm)-2.5 f_n=7.5-1.5N $f_{lc}=f_{lw}=0.0$ MSF=10*FFS+1700 $SF=N*MSF*f_{HV}*f_p$ $SF=Capacity*f_{HV}*f_p$ $f_p = 1.00$ $f_{HV}=1/(1+P_T(E_T-1.0))$ (vph)	from TNCC Plaza SF (vph)	PBS&J Enterning Volumes (vph) TOTAL	Ramp Plaza Capacity (vph)	Bottlenecks Near Bottlenecks Potential Bottlenecks Tues' data rather than Wed Segment not on the Mainline Volume and SF columns Volumes are uncertain
408W-01.0-#NA#-2-45-NP-19	4481		84		
408W-02.0-23AN-2-55-NP-18	4481		1266		Colonial Dr. (entrance #23 from WB)
408W-03.0-23BN-2-65-NP-18	4481		1506		Colonial Dr. (entrance #23 from EB)
408W-04.0-#NA#-2-65-NP-18	4481		1506		
408W-05.0-21#N-2-65-NP-18	4481		2954		Alafaya Trail (entrance #21)
408W-06.0-#NA#-2-65-NP-18	4481		2954		
408W-07.0-20#N-3-65-NP-18	6766		3115		Rouse Road (entrance #20)
408W-08.0-20#X-3-65-PP-18	6766		3115	743	Rouse Road (exit #20)
408W-09.0-#NA#-3-65-NP-18	6766		3083		
408W-10.0-#NA#-4-30-PP-03		3159	3083	Dean Main Plaza (west)	
408W-11.0-19#X-2-65-NP-03	4483		3083		Dean Road (exit #19)
408W-12.0-#NA#-2-65-NP-03	4485		1725		
408W-13.0-19#N-3-65-PP-03	6775		2481	606	Dean Road (entrance #19)
408W-14.0-18#X-3-65-NP-03	6777		2481		Interchange 417 (exit #18 to NB & SB)
408W-14.1-18#X-3-45-NP-03	2230		801		Interch'ge 417 (diverge lane to NB & SB)
408W-15.0-18NX-1-35-NP-03	2230		229		Interchange 417 (lane to NB)
408W-16.0-18SX-1-35-NP-03	2230		572		Interchange 417 (lane to SB)
408W-17.0-#NA#-2-65-NP-03	4491		1680		
408W-18.0-18#N-2-65-NP-03	4492		3488		Interchange 417 (entrance #18 from NB)
408W-19.0-#NA#-2-65-NP-03	4494		3488		Interchange 417 (entrance #18 from SB)
408W-20.0-16#X-3-65-NP-03	6788		6293		Goldenrod Rd. (exit #16)
408W-21.0-#NA#-3-55-NP-03	6791		4902		
408W-22.0-16#N-3-55-NP-03	6794		6323		Goldenrod Rd. (entrance #16)
408W-23.0-14#X-3-55-PP-17	6797		6323	1395	Semoran Boulevard (exit #14)
408W-24.0-#NA#-3-55-NP-17	6800		5963		
408W-25.0-14NN-4-55-NP-17	9129		5749		Semoran Blvd. (entance #14 from NB)
408W-26.0-14SN-4-55-NP-17	9133		6295		Semoran Blvd. (entance #14 from SB)
408W-27.0-#NA#-9-30-PP-17		6777	6295	Holland East Main Plaza (west)	
408W-28.0-#NA#-3-55-NP-17	6806		6530		
408W-29.0-13#N-4-55-PP-17	9130		7241	1257	Conway Road (entrance #13)
408W-30.0-12BX-4-55-NP-17	9127		7241		Crystal Lake Dr. (exit 12B)
408W-31.0-#NA#-3-55-NP-17	6798		6053		
408W-32.0-12AN-4-55-PP-16	9120		6278	1203	Bumby Avenue (entrance #12A)
408W-33.0-11BX-4-55-NP-16	9117		6278		Mills Avenue (exit #11B)
408W-34.0-#NA#-3-55-NP-16	6791		5544		
408W-35.0-11BN-4-55-PP-16	9111		5593	751	Mills Avenue (entrance #11B)
408W-36.0-11AX-4-55-NP-16	9107		5593		Rosalind Ave. (exit #11A)
408W-37.0-10AX-3-55-NP-16	6784		4069		Interstate-4 (exit #10A)
408W-38.0-#NA#-2-55-NP-16	4491		2239		
408W-39.0-10LN-2-55-NP-16	4490		2406		Orange Ave. (entrance)
408W-40.0-10AN-2-55-NP-16	4488		2782		Interstate-4 (entrance #10A)
408W-41.0-09#X-2-55-PP-16	4487		2782	1452	Orange Blossom Trail (exit #9)
408W-42.0-#NA#-2-55-NP-16	4485		2091		
408W-43.0-09#N-2-45-NP-16	4484		2413		Orange Blossom Trail (entrance #9)
408W-44.0-08BN-2-45-NP-16	4482		2239		Tampa Ave. (entrance #8B)
408W-45.0-#NA#-6-30-PP-16		4353	2239	Holland West Main Plaza (west)	
408W-46.0-08AX-3-55-NP-16	6765		2289		John Young Parkway (exit #8A)
408W-47.0-#NA#-3-55-NP-15	6765		1904		
408W-48.0-#NA#-2-55-NP-15	4481		1904		
408W-49.0-08AN-2-55-PP-15	4481		2026	1346	John Young Parkway (entrance #8A)
408W-50.0-07#X-2-55-NP-15	4481		2026		
408W-51.0-06#X-2-55-NP-15	4481		1818		Mercy Dr. (exit #7)
408W-52.0-05#X-2-55-NP-15	4481		1626		Pine Hill Rd. (exit #6)
408W-53.0-#NA#-2-65-NP-15	4481		1237		Kirkman (exit #5)
408W-54.0-05#N-3-65-NP-15	6766		1362		Kirkman (entrance #5)
408W-55.0-04#X-3-65-PP-14	6767		1362	1301	Hiawassee Road (exit #4)
408W-56.0-#NA#-2-65-NP-14	4482		1063		
408W-57.0-04#N-2-65-NP-14	4482		1243		Hiawassee Road (entrance #4)
408W-58.0-#NA#-3-30-PP-14		1714	1243	Hiawassee Main Plaza (west)	
408W-59.0-02#X-2-65-NP-14	4482		1074		Good Home Rs. (exit #2)
408W-60.0-01#X-2-65-NP-14	4482		1201		West Colonial Dr./Clarke Rd. (exit #1)
408W-61.0-#NA#-2-65-NP-14	4482		752		

Table 15: Traveling East on the 528, Bee Line Expressway

SECTION NAME - highway name & direction - segment number - exit number X, entrance N - no. of lanes in segment - speed limit on segment - plaza PP or no plaza NP - map number on which it is located	SF is the service flow rate during pk 15 min.for LOS E $FFS=FFS_{ideal}-f_{id}-f_n-f_{lc}-f_{lw}$ $f_{id}=5*(ipm)-2.5$ $f_n=7.5-1.5N$ $f_{lc} = f_{lw} = 0.0$ $MSF=10*FFS+1700$ $SF=N*MSF*f_{HV}*f_p$ $SF=Capacity*f_{HV}*f_p$ $f_p = 1.00$ $f_{HV}=1/(1+P_T(E_T-1.0))$ (vph)	from TNCC Plaza SF (vph)	PBS&J Enterning Volumes (vph) TOTAL	Ramp Plaza Capacity (vph)	Bottlenecks Near Bottlenecks Potential Bottlenecks Tues' data rather than Wed Segment not on the Mainline Volume and SF columns Volumes are uncertain Mistake in PBS&J Volume Study 1193 should be at least 1646 Both: March 21,'01, 7-8a.m.
528E-01.0-08#X-3-55-NP-20	6740				Sand Lake Rd. (exit #8)
528E-02.0-#NA#-3-55-NP-20	6740		1096		
528E-03.0-08#N-4-55-NP-20	9045		1721		Boggy Creek Rd. (entrance #8)
528E-04.0-09#X-4-55-NP-20	9045		1721		Tradeport Rd. (exit #9)
528E-05.0-#NA#-3-55-NP-20	6740		1272		
528E-06.0-09#N-3-55-NP-20	6740		1355		Tradeport Rd. (entrance #9)
528E-07.0-#NA#-6-30-PP-20		3723	1355		Airport Plaza (east)
528E-08.0-11#X-3-55-NP-20	6706		1203		Semoran Blvd. (exit #11)
528E-09.0-11AX-1-30-NP-20	2207		862		Semoran Blvd. (exit #11 to SB)
528E-10.0-11BX-1-30-NP-20	2207		261		Semoran Blvd. (exit #11 to NB)
528E-11.0-#NA#-2-55-NP-20	4420		341		
528E-12.0-11#N-2-55-NP-20	4397		1646		Semoran Blvd. (entrance #11 from SB)
528E-13.0-11AN-2-55-NP-20	4375		1193		Semoran Blvd. (entrance #11 from NB)
528E-14.0-#NA#-2-65-NP-21	4354		1193		
528E-15.0-13#X-2-65-NP-21	4332		1193		Narcoossee Rd. (exit #13)
528E-16.0-#NA#-2-70-NP-21	4311		790		
528E-17.0-13#N-2-70-NP-21	4290		972		Narcoossee Rd. (entrance #13)
528E-18.0-#NA#-2-70-NP-21	4269		972		
528E-19.0-16#X-2-70-NP-06	4248		972		Interchange 417 (exit # 16 to NB & SB)
528E-20.0-16NX-1-45-NP-06	2110		385		Interchange 417 (exit lane to NB)
528E-21.0-16SX-1-45-NP-06	2110		7		Interchange 417 (exit lane to SB)
528E-22.0-16SN-1-45-NP-06	2110		216		Interchange 417 (merge lane to SB)
528E-23.0-#NA#-2-70-NP-06	4228		587		
528E-24.0-16#N-3-70-NP-06	6352		964		Interchange 417(entrance from NB & SB)
528E-24.1-#NA#-3-70-NP-06	6322		964		
528E-25.0-#NA#-4-30-PP-06		2763	964		Bee Line Main Plaza (east)
528E-26.0-#NA#-2-70-NP-22	4168		840		
528E-27.0-20#X-2-70-NP-22	4168		840		International Corporate Park (exit #20)
528E-28.0-#NA#-2-70-NP-22	4168		755		
528E-29.0-20#N-2-70-PP-22	4168		760	959	Intern'l Corporate Park (entrance #20)

Table 16: Traveling West on the 528, Bee Line Expressway

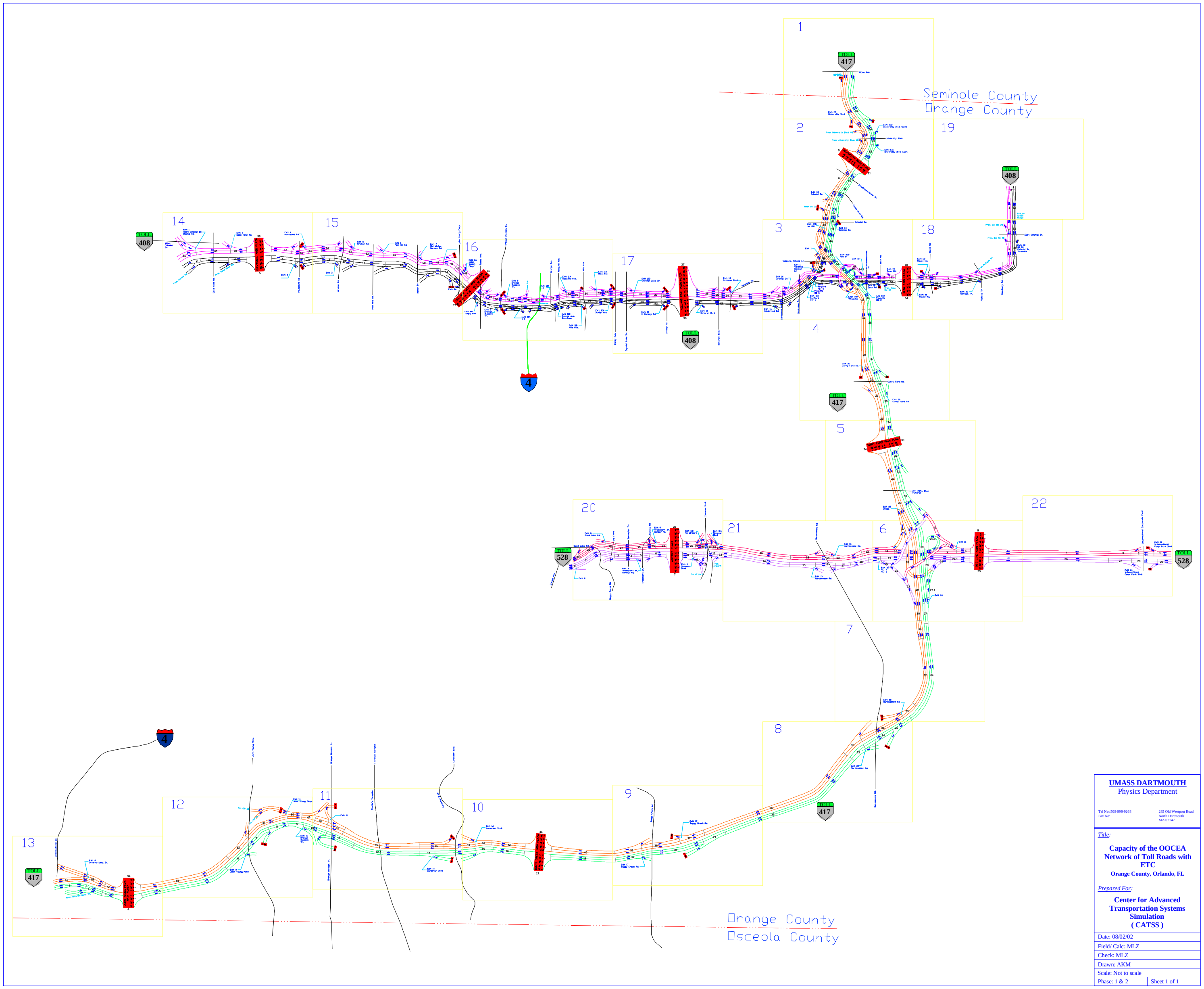
SECTION NAME - highway name & direction - segment number - exit number X, entrance N - no. of lanes in segment - speed limit on segment - plaza PP or no plaza NP - map number on which it is located	SF is the service flow rate during pk 15 min.for LOS E $FFS=FFS_{ideal}-f_{id}-f_n-f_{lc}-f_{lw}$ f_{id}=5*(ipm)-2.5 f_n=7.5-1.5N $f_{lc}=f_{lw}=0.0$ MSF=10*FFS+1700 SF=N*MSF*f_{HV}*f_p SF=Capacity*f_{HV}*f_p $f_p=1.00$ $f_{HV}=1/(1+P_T(E_T-1.0))$ (vph)	from TNCC Plaza SF (vph)	PBS&J Enterning Volumes (vph) TOTAL	Ramp Plaza Capacity (vph)	Bottlenecks (green) Near Bottlenecks (light green) Potential Bottlenecks (light cyan) Tues' data rather than Wed (yellow) Segment not on the Mainline (grey) Volume and SF columns (orange) Volumes are uncertain (blue)
528W-01.0-20#X-2-70-PP-22	4168		1323	788	International Corporate Park (exit #20)
528W-02.0-#NA#-2-70-NP-22	4168		1269		
528W-03.0-20#N-2-70-NP-22	4168		1286		Intern'l Corporate Park (entrance #20)
528W-04.0-#NA#-2-70-NP-22	4168		1286		
528W-05.0-#NA#-4-30-PP-06		2689	1286	Bee Line Main Plaza (west)	
528W-06.0-16#X-3-70-NP-06	6318		1427		Interchange 417 (exit # 16 to NB & SB)
528W-07.0-16SX-1-45-NP-06	2079		209		
528W-08.0-16NX-1-45-NP-06	2079		297		
528W-09.0-#NA#-2-70-NP-06	4203		921		
528W-10.0-16NN-2-70-NP-06	4220		943		Interchange 417 (entrance # 16 from NB)
528W-11.0-16SN-3-70-NP-06	6398		2454		Interchange 417 (entrance # 16 from SB)
528W-12.0-#NA#-3-70-NP-21	6426		2454		
528W-13.0-13#X-2-70-NP-21	4274		2454		Narcoossee Rd. (exit #13)
528W-14.0-#NA#-2-70-NP-21	4293		2138		
528W-15.0-13#N-2-65-NP-21	4311		2632		Narcoossee Rd. (entrance #13)
528W-16.0-#NA#-2-65-NP-21	4330		2632		
528W-17.0-11AX-2-65-NP-20	4348		2632		Semoran Blvd. (exit #11A to NB)
528W-18.0-#NA#-2-65-NP-20	4367		2681		
528W-19.0-11AN-2-65-NP-20	4386		3011		Semoran Blvd. (entrance #11 from NB)
528W-20.0-11BX-2-65-NP-20	4406		3011		Semoran Blvd. (exit #11 to SB)
528W-21.0-#NA#-2-65-NP-20	4425		2489		
528W-22.0-11BN-3-65-NP-20	6710		3115		Semoran Blvd. (entrance #11 from SB)
528W-23.0-#NA#-6-30-PP-20		4123	3115	Airport Plaza (west)	
528W-24.0-09#X-3-55-NP-20	6740		2881		Tradeport Dr./Conway Rd. (exit #9)
528W-25.0-#NA#-3-55-NP-20	6740		2407		
528W-26.0-09#N-4-55-NP-20	9045		3161		Tradep't Dr./Conway Rd. (entrance #9)
528W-27.0-#NA#-4-55-NP-20	9045		3161		
528W-28.0-08#X-4-55-NP-20	9045		3161		Sand Lake Rd. (exit #8)
528W-29.0-#NA#-3-55-NP-20	6740		1905		
528W-30.0-08#N-3-55-NP-20	6740				Sand Lake Rd. (entrance #8)

Appendix E: Processing Rates

TABLE 17 Description of the customer-groups at the toll facilities

Customer-Group **X**	**Processing Rates** ***(vphpl)*** S_X	Description
M	498 ± 48	The **M**anual services are services in which drivers of vehicles other than semi-trucks pay a toll collector cash based upon the number of axles.
A	618 ± 30	The **A**utomatic Coin-Machine Services are services, in which the driver must pay the toll by tossing the exact change into a basket, (no semi-trucks permitted).
T	138 ± 78	These are manual services in which the drivers of semi-**T**rucks pay a toll collector cash.
E	1560 ± 120	The **E**TC Services are services in which drivers' accounts are automatically debited the toll. This rate is only for dedicated ETC lanes with 35-mph speed limits with headways of 2.3 seconds.

Appendix F: Maps
23 Maps with ID Numbers of the 295 highway segments


1
2
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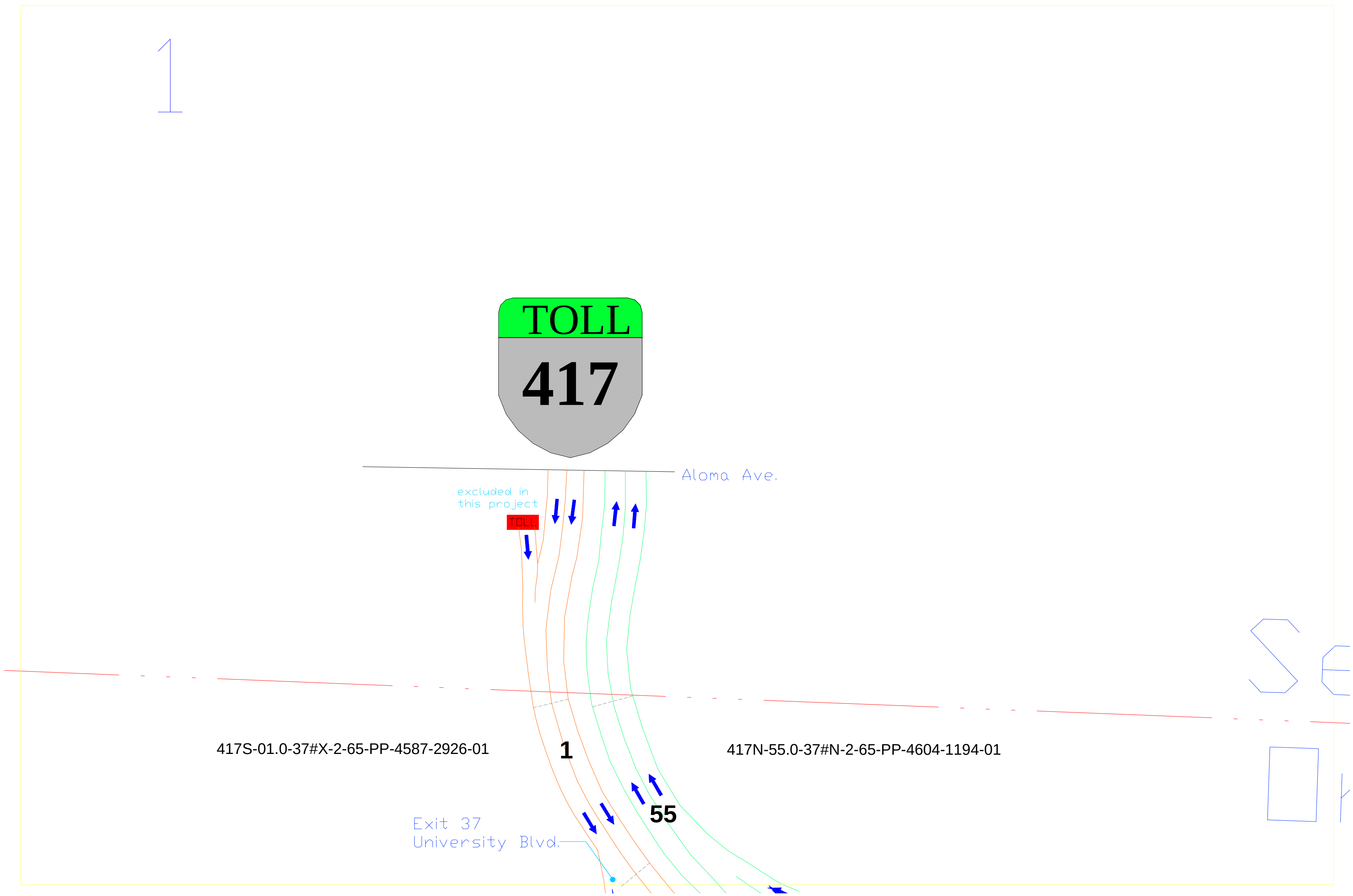
17
18
19
20
21
22
Seminole County
Orange County
Osceola County
417
408
528
4
UMASS DARTMOUTH
Physics Department
Tel No: 508-999-9268
Fax No:
285 Old Westport Road
North Dartmouth
MA 02747
Title:
Capacity of the OOCEA Network of Toll Roads with ETC
Orange County, Orlando, FL
Prepared For:
Center for Advanced Transportation Systems Simulation (CATSS)
Date: 08/02/02
Field/ Calc: MLZ
Check: MLZ
Drawn: AKM
Scale: Not to scale
Phase: 1 & 2
Sheet 1 of 1


1
TOLL
417
Aloma Ave.
excluded in
this project
TOLL
417S-01.0-37#X-2-65-PP-4587-2926-01
1
417N-55.0-37#N-2-65-PP-4604-1194-01
55
Exit 37
University Blvd.

2

417S-02.0-#NA#-2-65-NP-4587-2604-02
417S-03.0-37AN-3-65-NP-6925-3237-02
417S-04.0-37BN-3-65-NP-6925-3371-02
417S-05.0-#NA#-5-30-PP-4006-3371-02
417S-06.0-#NA#-2-65-NP-4584-3517-02
417S-07.0-34#X-2-65-NP-4581-3517-02
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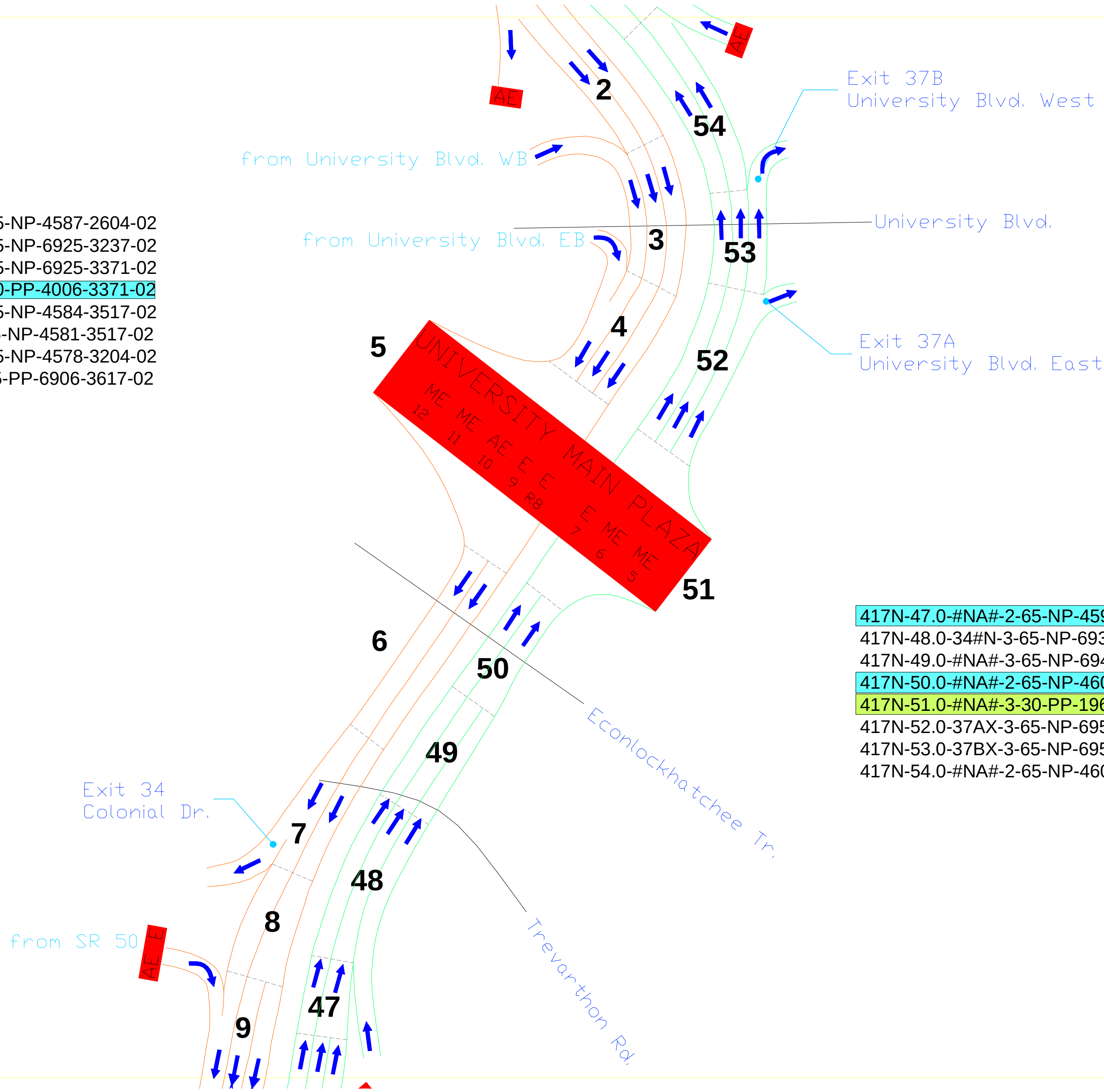

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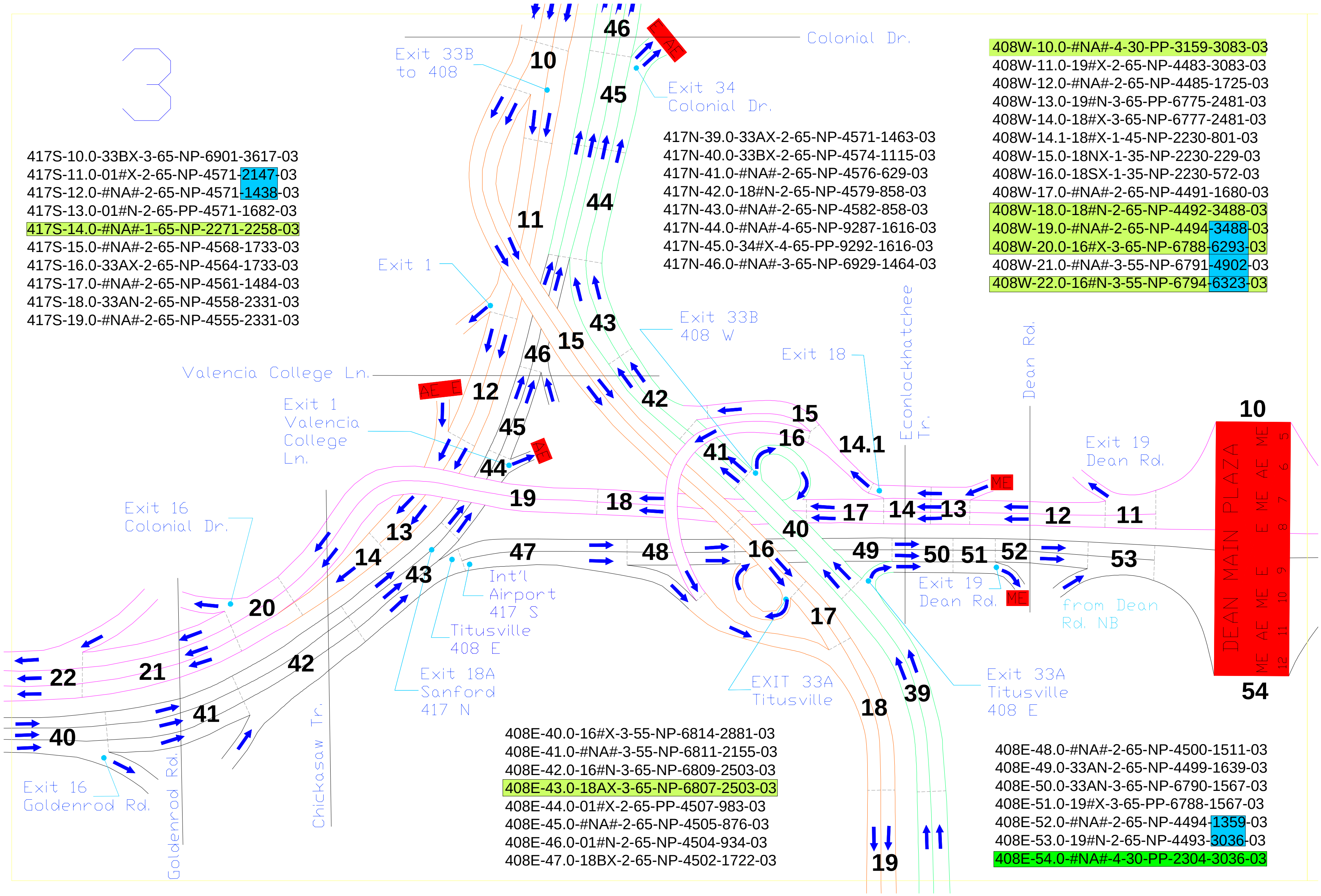
417N-48.0-34#N-3-65-NP-6938-1462-02
417N-49.0-#NA#-3-65-NP-6942-1462-02
417N-50.0-#NA#-2-65-NP-4601-1462-02
417N-51.0-#NA#-3-30-PP-1960-1462-02
417N-52.0-37AX-3-65-NP-6950-1326-02
417N-53.0-37BX-3-65-NP-6950-1077-02
417N-54.0-#NA#-2-65-NP-4604-953-02


3
Colonial Dr.
Exit 33B
to 408
Exit 34
Colonial Dr.
417S-10.0-33BX-3-65-NP-6901-3617-03
417S-11.0-01#X-2-65-NP-4571-2147-03
417S-12.0-#NA#-2-65-NP-4571-1438-03
417S-13.0-01#N-2-65-PP-4571-1682-03
417S-14.0-#NA#-1-65-NP-2271-2258-03
417S-15.0-#NA#-2-65-NP-4568-1733-03
417S-16.0-33AX-2-65-NP-4564-1733-03
417S-17.0-#NA#-2-65-NP-4561-1484-03
417S-18.0-33AN-2-65-NP-4558-2331-03
417S-19.0-#NA#-2-65-NP-4555-2331-03
417N-39.0-33AX-2-65-NP-4571-1463-03
417N-40.0-33BX-2-65-NP-4574-1115-03
417N-41.0-#NA#-2-65-NP-4576-629-03
417N-42.0-18#N-2-65-NP-4579-858-03
417N-43.0-#NA#-2-65-NP-4582-858-03
417N-44.0-#NA#-4-65-NP-9287-1616-03
417N-45.0-34#X-4-65-PP-9292-1616-03
417N-46.0-#NA#-3-65-NP-6929-1464-03
408W-10.0-#NA#-4-30-PP-3159-3083-03
408W-11.0-19#X-2-65-NP-4483-3083-03
408W-12.0-#NA#-2-65-NP-4485-1725-03
408W-13.0-19#N-3-65-PP-6775-2481-03
408W-14.0-18#X-3-65-NP-6777-2481-03
408W-14.1-18#X-1-45-NP-2230-801-03
408W-15.0-18NX-1-35-NP-2230-229-03
408W-16.0-18SX-1-35-NP-2230-572-03
408W-17.0-#NA#-2-65-NP-4491-1680-03
408W-18.0-18#N-2-65-NP-4492-3488-03
408W-19.0-#NA#-2-65-NP-4494-3488-03
408W-20.0-16#X-3-65-NP-6788-6293-03
408W-21.0-#NA#-3-55-NP-6791-4902-03
408W-22.0-16#N-3-55-NP-6794-6323-03
Exit 1
Exit 33B
408 W
Exit 18
Econlockhatchee
Tr.
Dean Rd.
Valencia College Ln.
Exit 1
Valencia
College
Ln.
Exit 19
Dean Rd.
DEAN MAIN PLAZA
Exit 16
Colonial Dr.
Int'l
Airport
417 S
Titusville
408 E
Exit 19
Dean Rd.
from Dean
Rd. NB
Exit 18A
Sanford
417 N
EXIT 33A
Titusville
Exit 33A
Titusville
408 E
Exit 16
Goldenrod Rd.
Goldenrod Rd.
Chickasaw Tr.
408E-40.0-16#X-3-55-NP-6814-2881-03
408E-41.0-#NA#-3-55-NP-6811-2155-03
408E-42.0-16#N-3-65-NP-6809-2503-03
408E-43.0-18AX-3-65-NP-6807-2503-03
408E-44.0-01#X-2-65-PP-4507-983-03
408E-45.0-#NA#-2-65-NP-4505-876-03
408E-46.0-01#N-2-65-NP-4504-934-03
408E-47.0-18BX-2-65-NP-4502-1722-03
408E-48.0-#NA#-2-65-NP-4500-1511-03
408E-49.0-33AN-2-65-NP-4499-1639-03
408E-50.0-33AN-3-65-NP-6790-1567-03
408E-51.0-19#X-3-65-PP-6788-1567-03
408E-52.0-#NA#-2-65-NP-4494-1359-03
408E-53.0-19#N-2-65-NP-4493-3036-03
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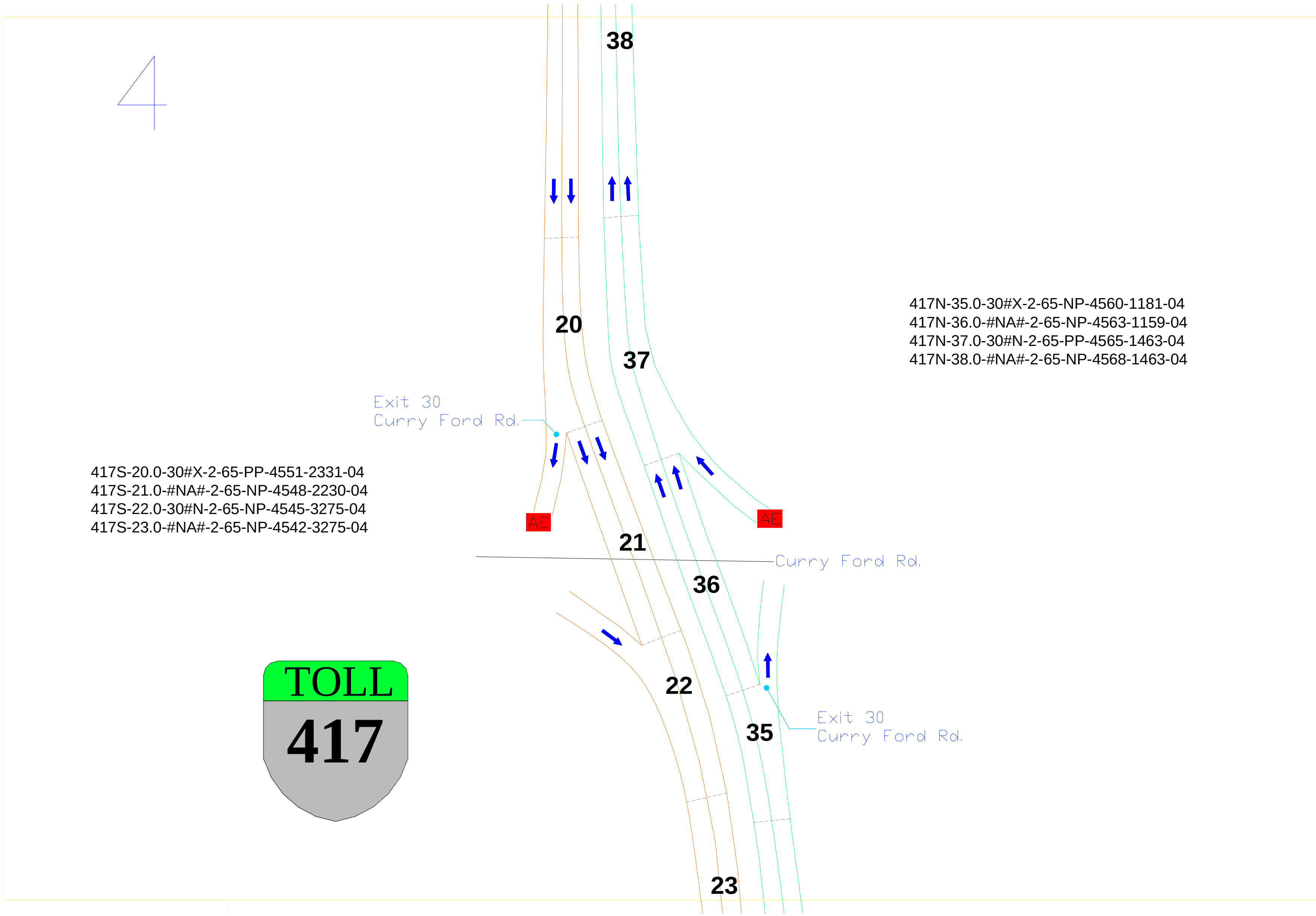
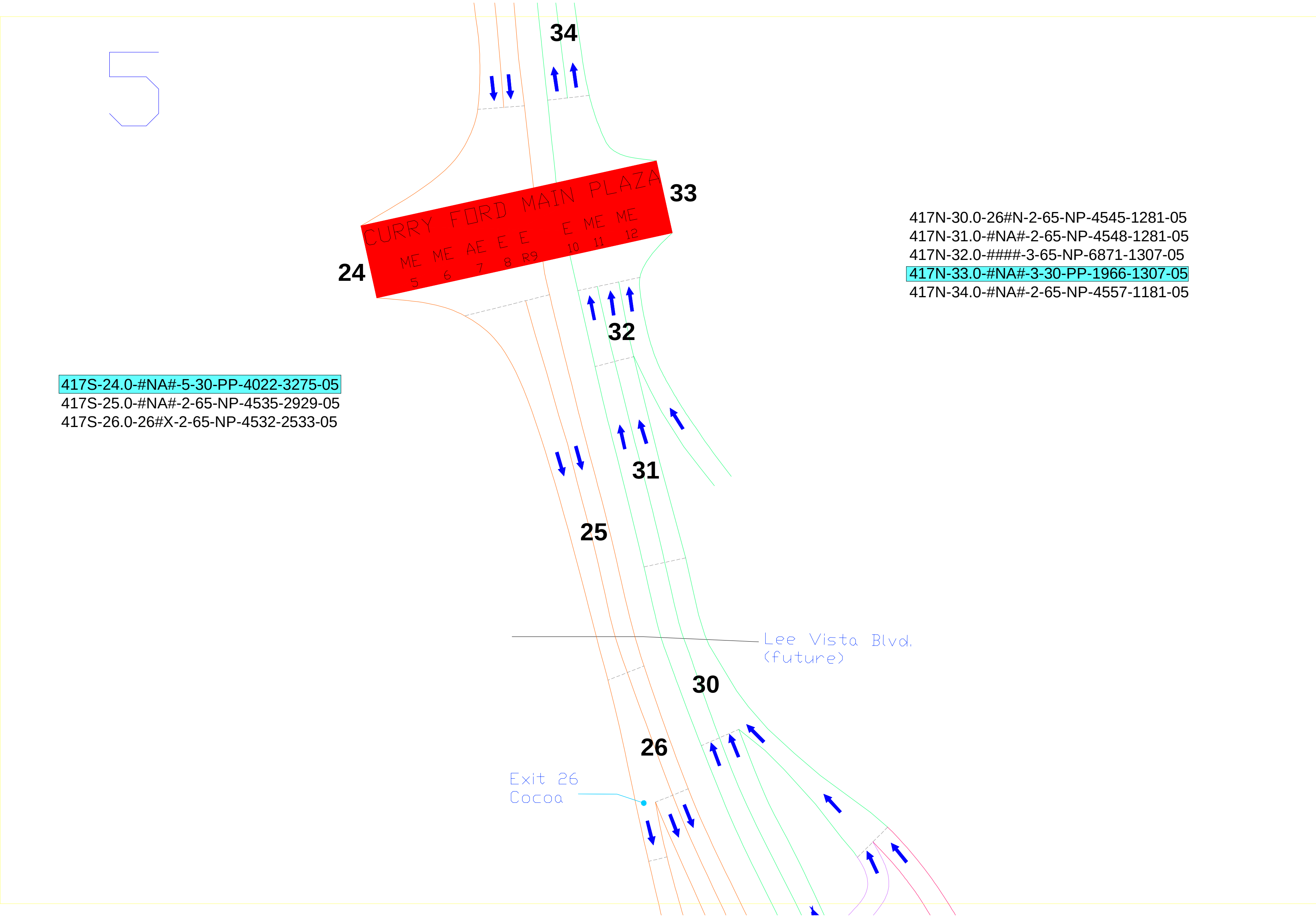
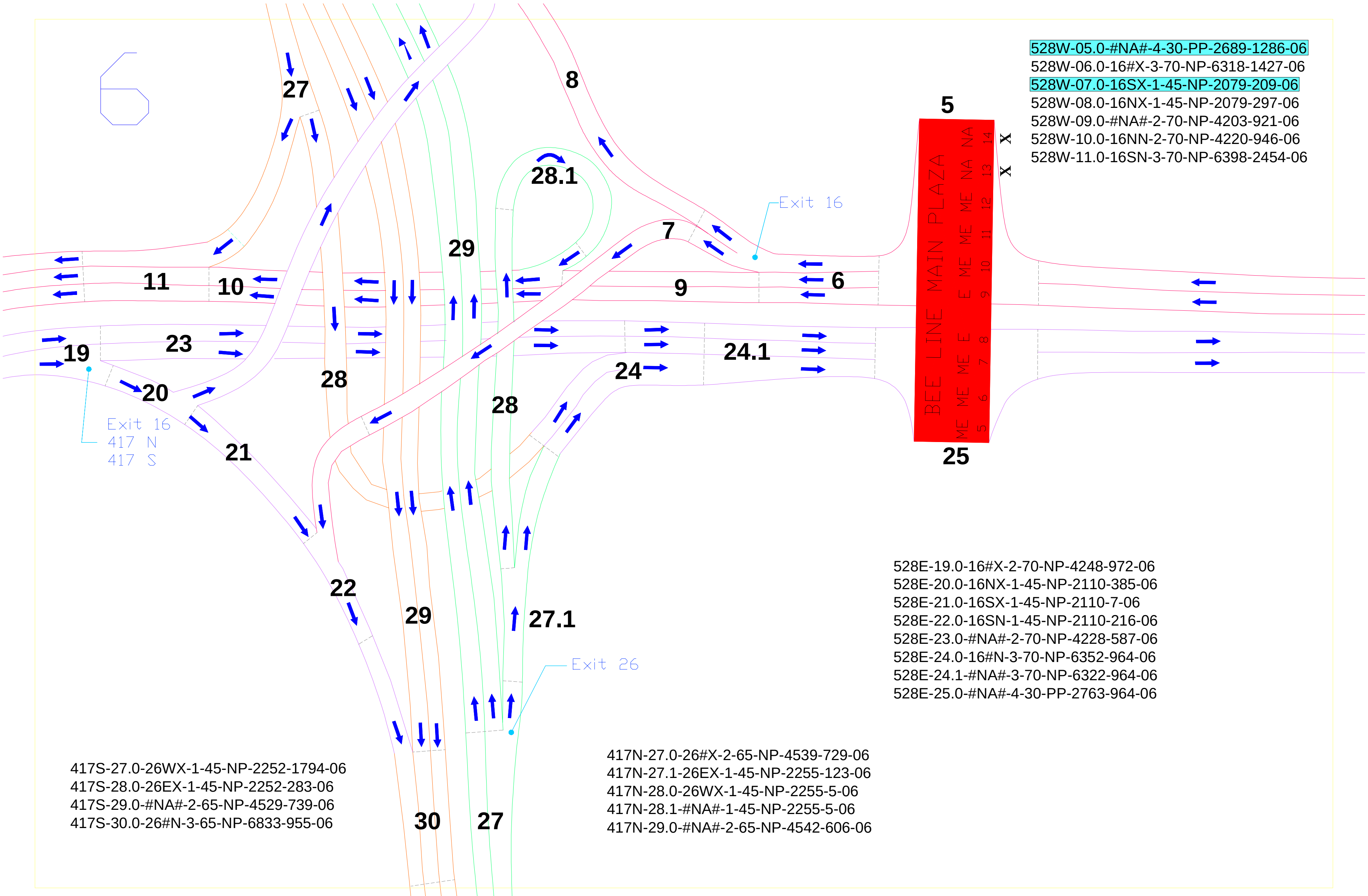

4
38
20
37
417N-35.0-30#X-2-65-NP-4560-1181-04
417N-36.0-#NA#-2-65-NP-4563-1159-04
417N-37.0-30#N-2-65-PP-4565-1463-04
417N-38.0-#NA#-2-65-NP-4568-1463-04
Exit 30
Curry Ford Rd.
417S-20.0-30#X-2-65-PP-4551-2331-04
417S-21.0-#NA#-2-65-NP-4548-2230-04
417S-22.0-30#N-2-65-NP-4545-3275-04
417S-23.0-#NA#-2-65-NP-4542-3275-04
AE
AE
21
Curry Ford Rd.
36
TOLL
417
22
Exit 30
Curry Ford Rd.
35
23


5
34
33
CURRY FORD MAIN PLAZA
24
32
31
25
30
26
417N-30.0-26#N-2-65-NP-4545-1281-05
417N-31.0-#NA#-2-65-NP-4548-1281-05
417N-32.0-####-3-65-NP-6871-1307-05
417N-33.0-#NA#-3-30-PP-1966-1307-05
417N-34.0-#NA#-2-65-NP-4557-1181-05
417S-24.0-#NA#-5-30-PP-4022-3275-05
417S-25.0-#NA#-2-65-NP-4535-2929-05
417S-26.0-26#X-2-65-NP-4532-2533-05
Lee Vista Blvd.
(future)
Exit 26
Cocoa


6
528W-05.0-#NA#-4-30-PP-2689-1286-06
528W-06.0-16#X-3-70-NP-6318-1427-06
528W-07.0-16SX-1-45-NP-2079-209-06
528W-08.0-16NX-1-45-NP-2079-297-06
528W-09.0-#NA#-2-70-NP-4203-921-06
528W-10.0-16NN-2-70-NP-4220-946-06
528W-11.0-16SN-3-70-NP-6398-2454-06
BEE LINE MAIN PLAZA
5
25
Exit 16
Exit 16
417 N
417 S
Exit 26
27
8
28.1
29
7
6
9
11
10
23
19
20
21
28
28
24
24.1
22
29
27.1
30
27
528E-19.0-16#X-2-70-NP-4248-972-06
528E-20.0-16NX-1-45-NP-2110-385-06
528E-21.0-16SX-1-45-NP-2110-7-06
528E-22.0-16SN-1-45-NP-2110-216-06
528E-23.0-#NA#-2-70-NP-4228-587-06
528E-24.0-16#N-3-70-NP-6352-964-06
528E-24.1-#NA#-3-70-NP-6322-964-06
528E-25.0-#NA#-4-30-PP-2763-964-06
417S-27.0-26WX-1-45-NP-2252-1794-06
417S-28.0-26EX-1-45-NP-2252-283-06
417S-29.0-#NA#-2-65-NP-4529-739-06
417S-30.0-26#N-3-65-NP-6833-955-06
417N-27.0-26#X-2-65-NP-4539-729-06
417N-27.1-26EX-1-45-NP-2255-123-06
417N-28.0-26WX-1-45-NP-2255-5-06
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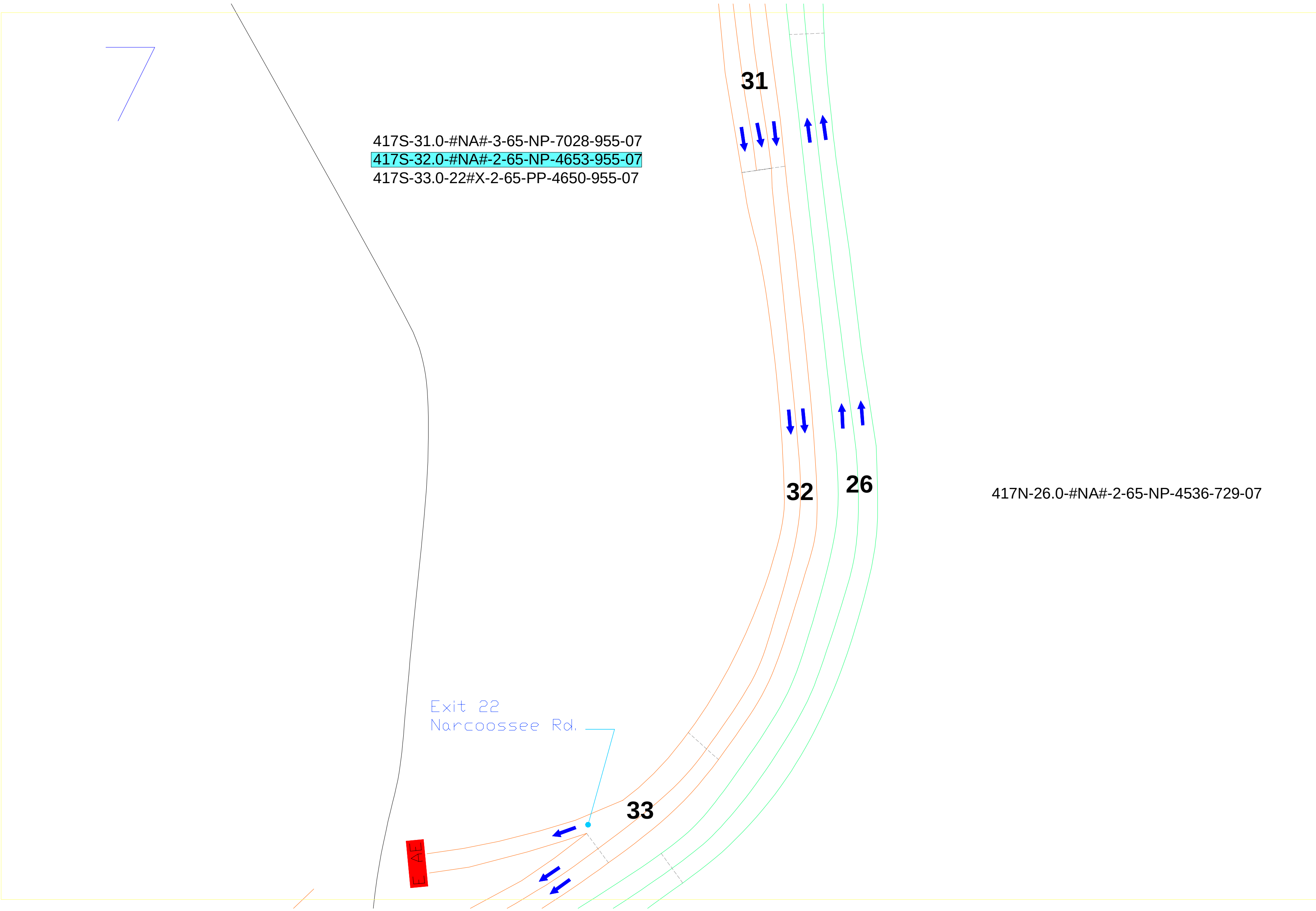
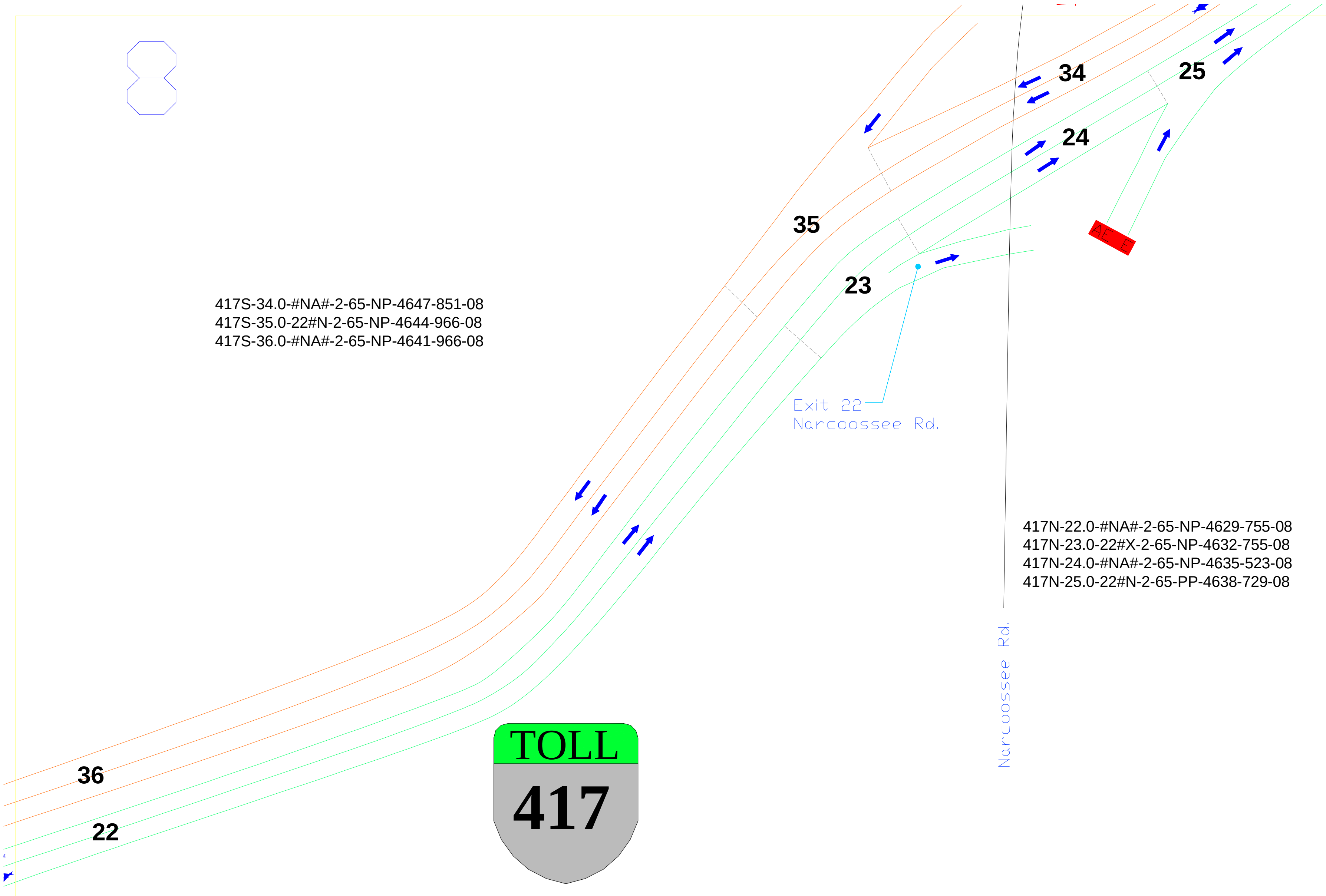
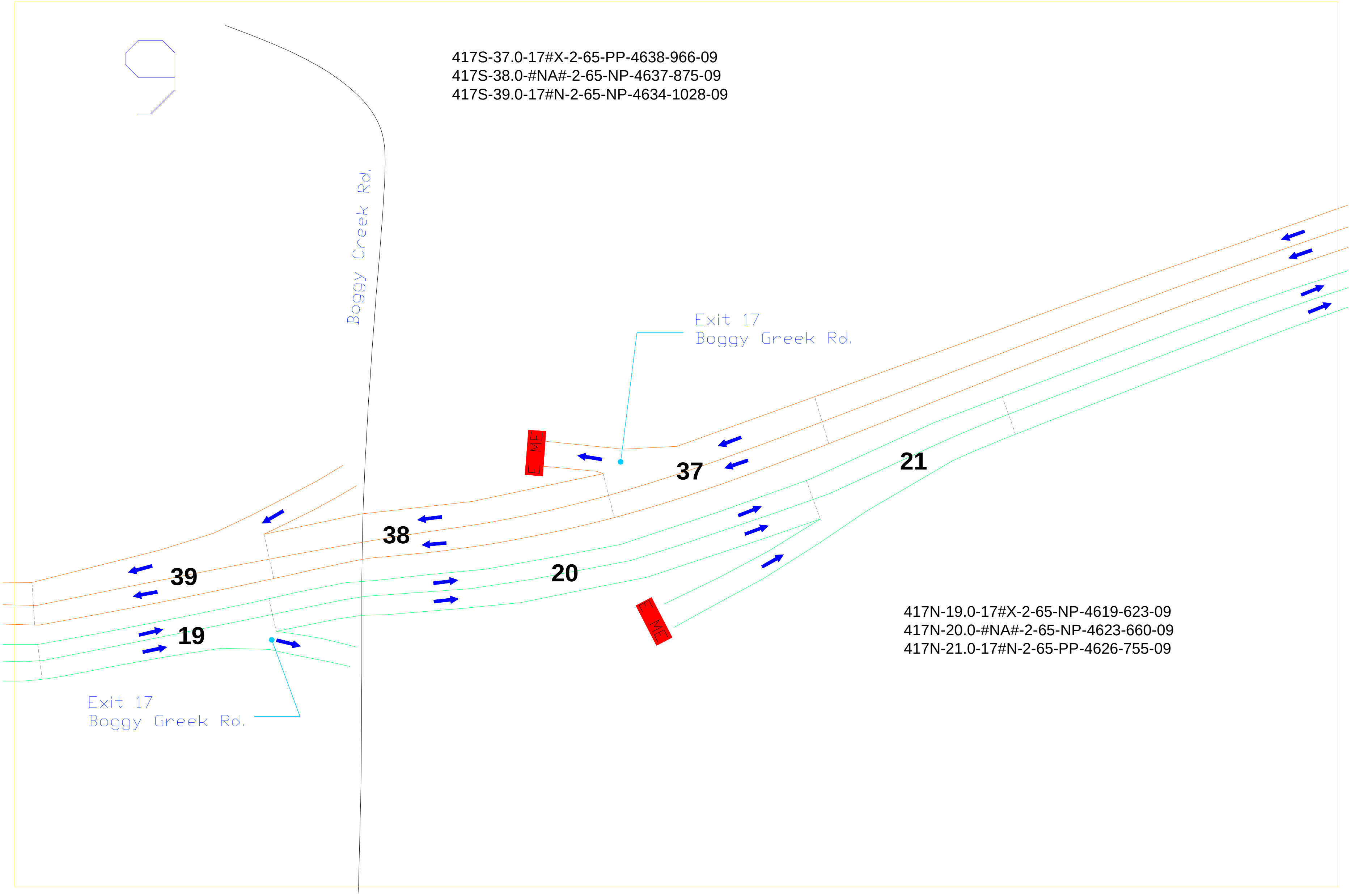
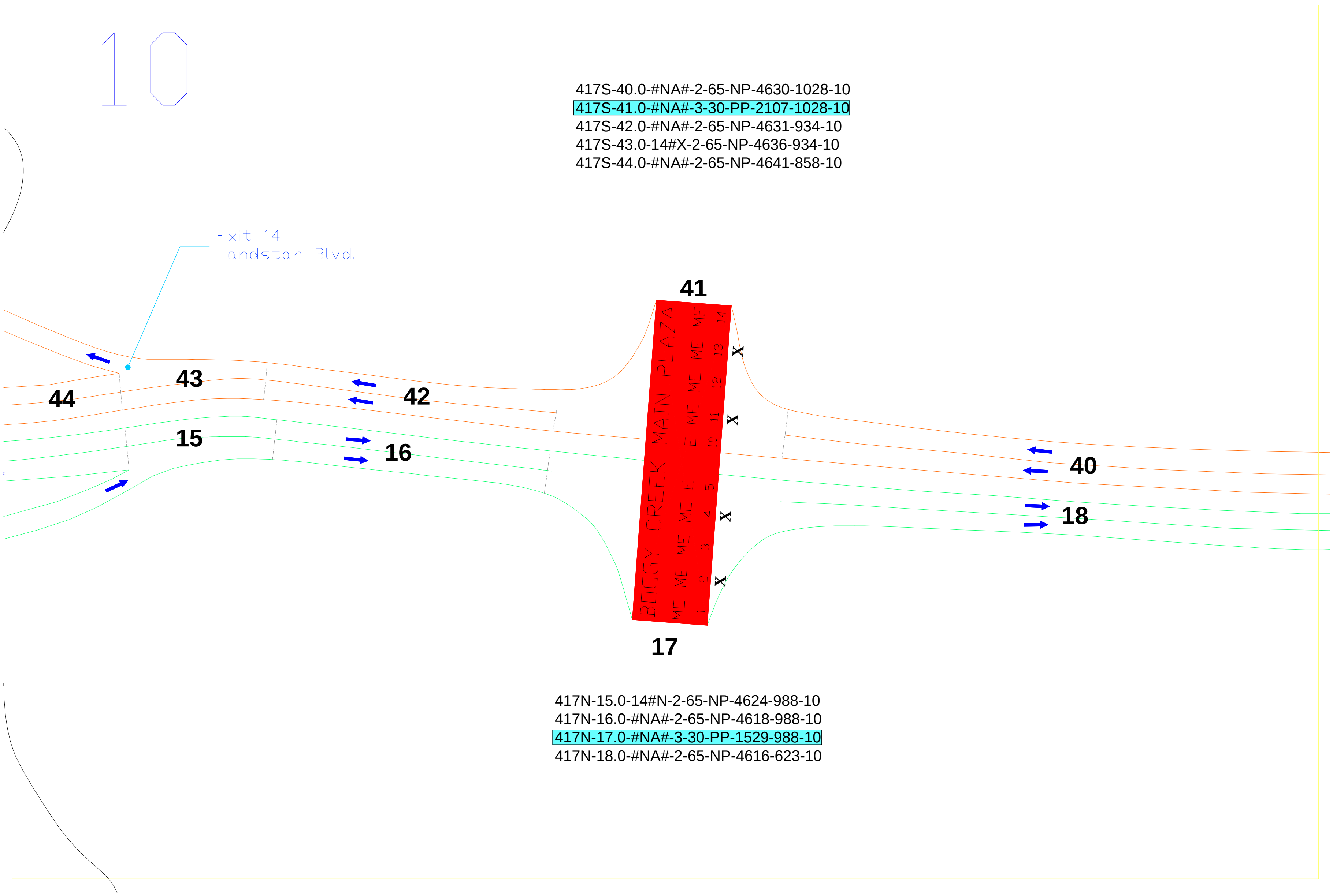


31
417S-31.0-#NA#-3-65-NP-7028-955-07
417S-32.0-#NA#-2-65-NP-4653-955-07
417S-33.0-22#X-2-65-PP-4650-955-07
32
26
417N-26.0-#NA#-2-65-NP-4536-729-07
Exit 22
Narcoossee Rd.
33
AE



8
34
25
24
35
23
417S-34.0-#NA#-2-65-NP-4647-851-08
417S-35.0-22#N-2-65-NP-4644-966-08
417S-36.0-#NA#-2-65-NP-4641-966-08
Exit 22
Narcoossee Rd.
417N-22.0-#NA#-2-65-NP-4629-755-08
417N-23.0-22#X-2-65-NP-4632-755-08
417N-24.0-#NA#-2-65-NP-4635-523-08
417N-25.0-22#N-2-65-PP-4638-729-08
Narcoossee Rd.
36
22
TOLL
417


9
417S-37.0-17#X-2-65-PP-4638-966-09
417S-38.0-#NA#-2-65-NP-4637-875-09
417S-39.0-17#N-2-65-NP-4634-1028-09
Boggy Creek Rd.
Exit 17
Boggy Greek Rd.
37
38
39
19
20
21
Exit 17
Boggy Greek Rd.
417N-19.0-17#X-2-65-NP-4619-623-09
417N-20.0-#NA#-2-65-NP-4623-660-09
417N-21.0-17#N-2-65-PP-4626-755-09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417S-40.0-#NA#-2-65-NP-4630-1028-10
417S-41.0-#NA#-3-30-PP-2107-1028-10
417S-42.0-#NA#-2-65-NP-4631-934-10
417S-43.0-14#X-2-65-NP-4636-934-10
417S-44.0-#NA#-2-65-NP-4641-858-10
Exit 14
Landstar Blvd.
41
43
42
44
15
16
40
18
BOGGY CREEK MAIN PLAZA
17
417N-15.0-14#N-2-65-NP-4624-988-10
417N-16.0-#NA#-2-65-NP-4618-988-10
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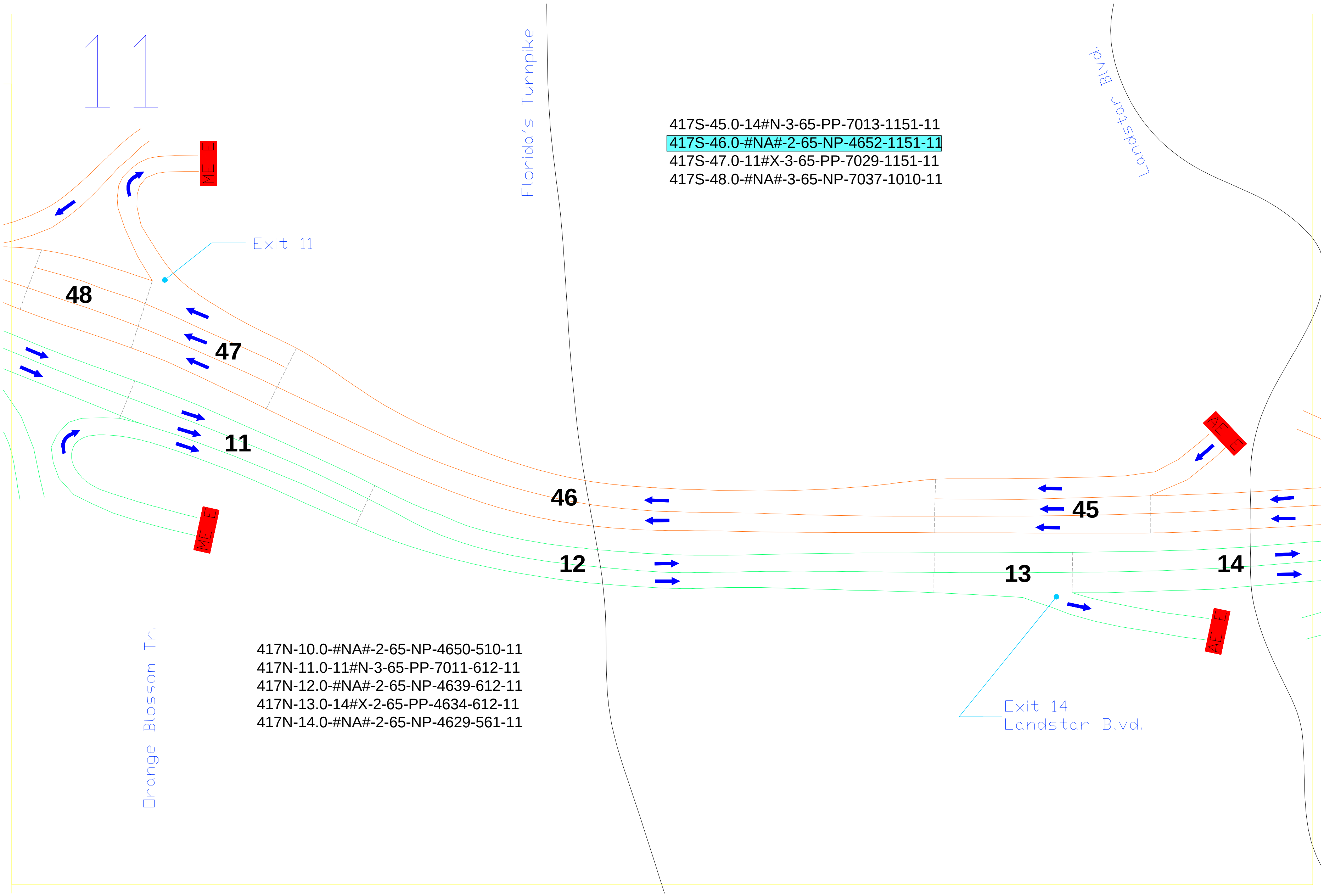
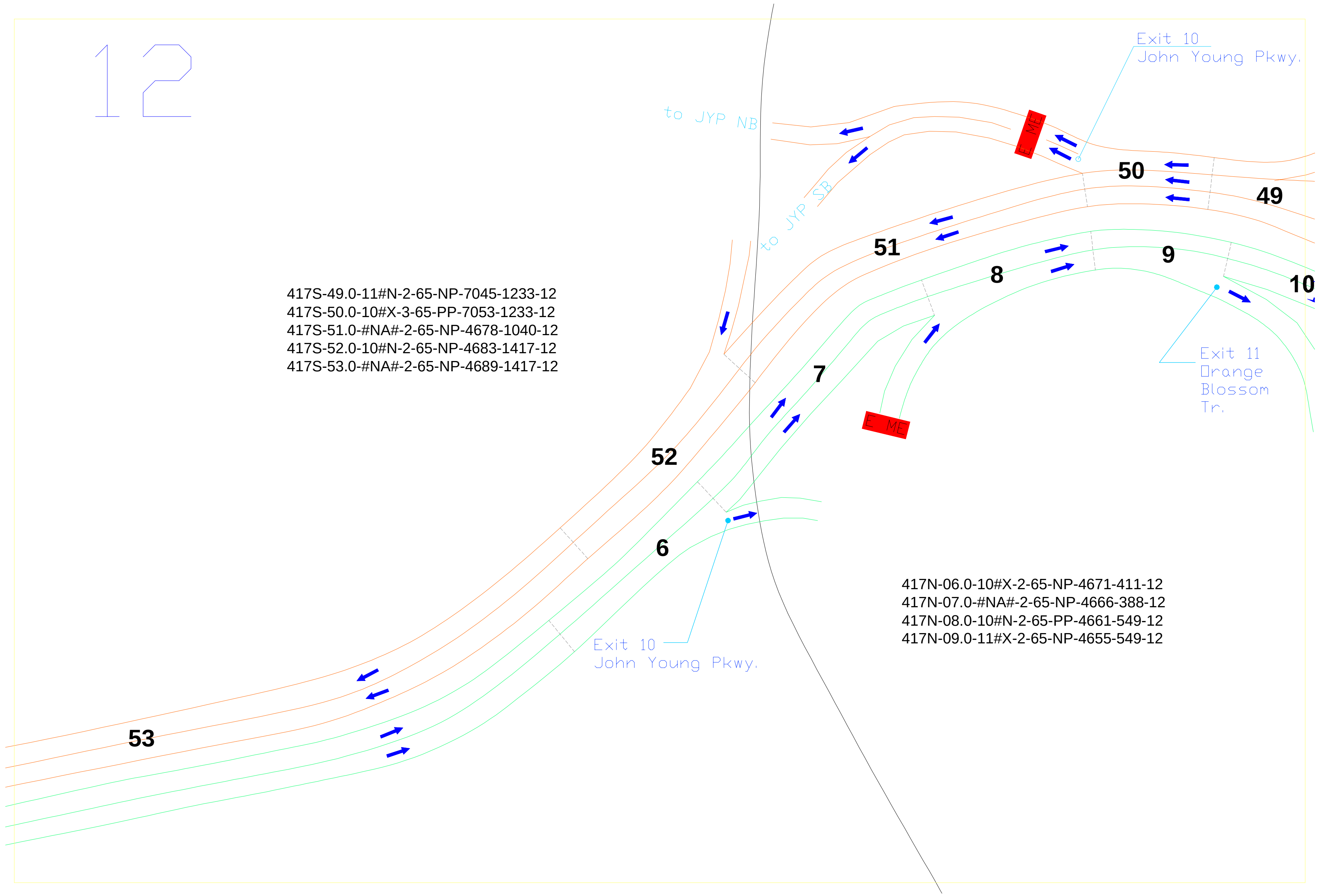
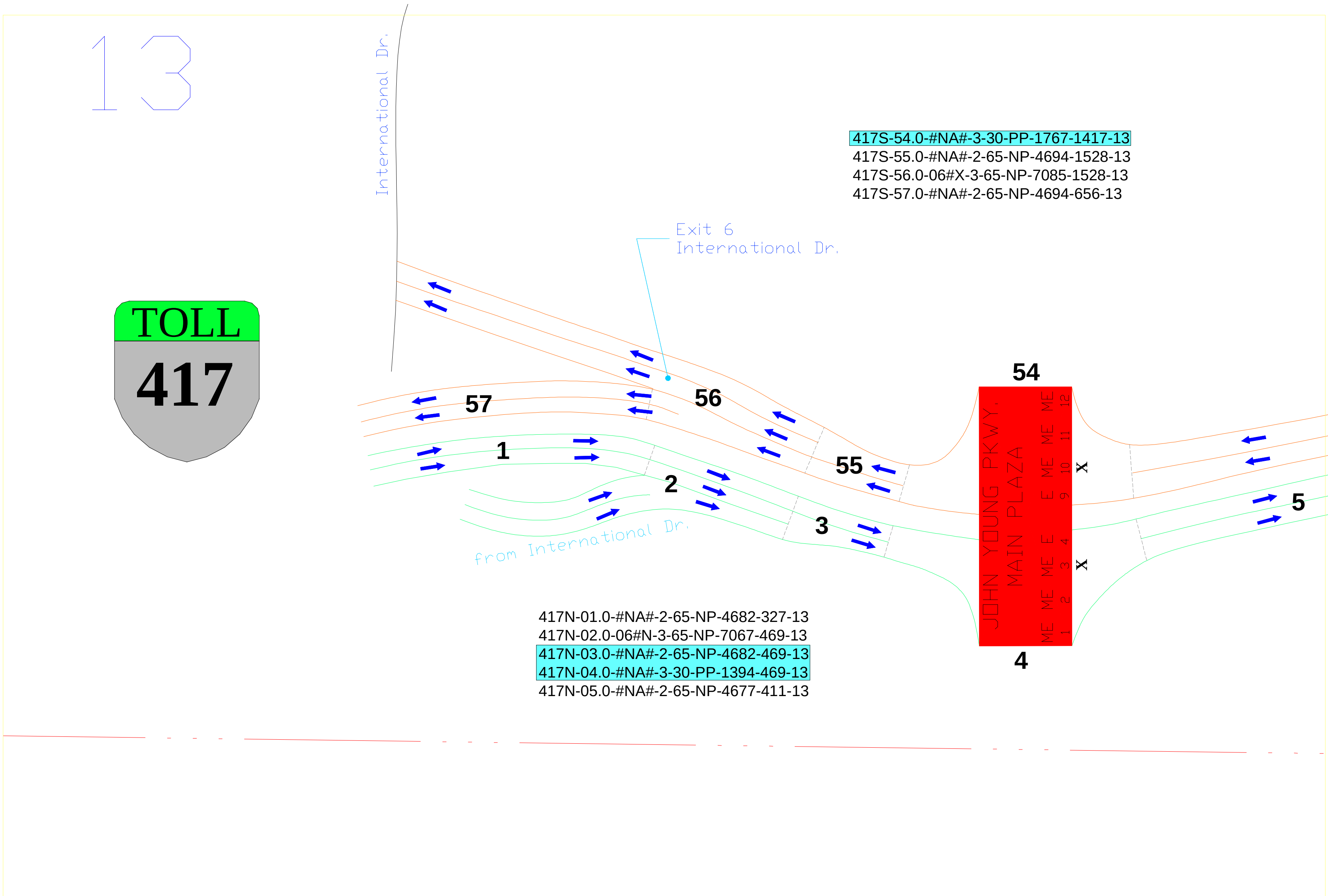
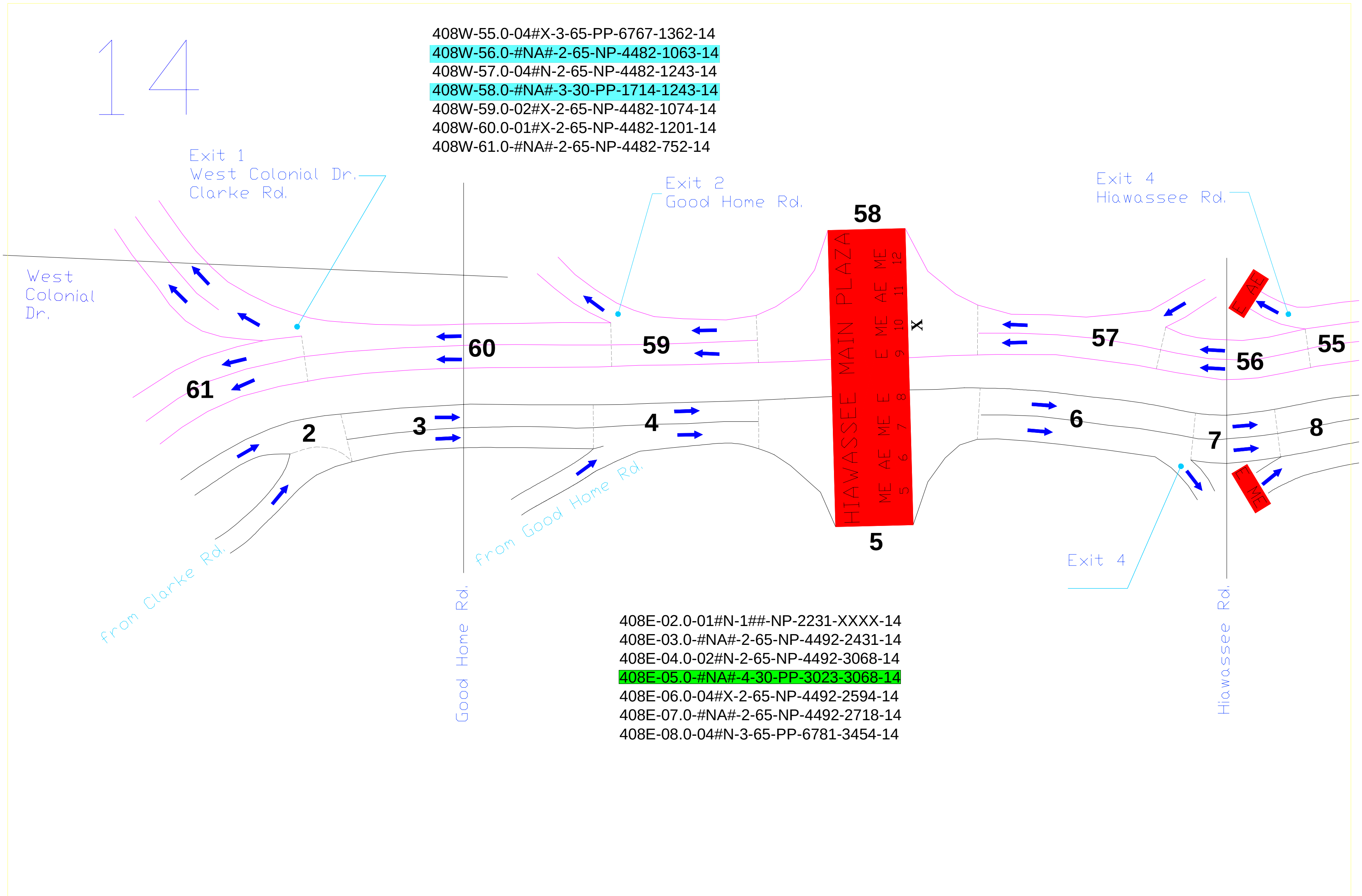
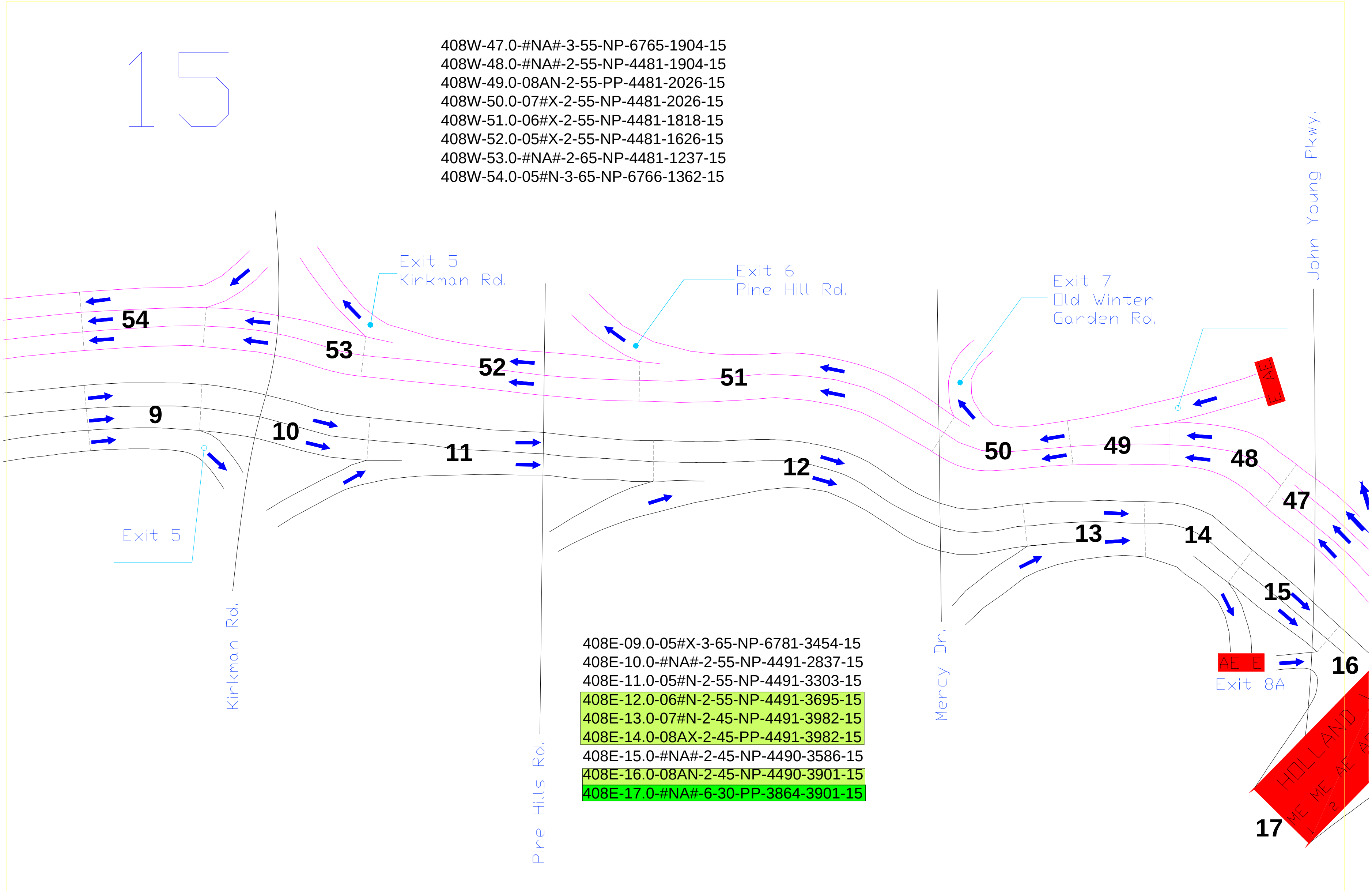

11
Florida's Turnpike
Landstar Blvd.
417S-45.0-14#N-3-65-PP-7013-1151-11
417S-46.0-#NA#-2-65-NP-4652-1151-11
417S-47.0-11#X-3-65-PP-7029-1151-11
417S-48.0-#NA#-3-65-NP-7037-1010-11
Exit 11
48
47
11
46
45
12
13
14
Orange Blossom Tr.
417N-10.0-#NA#-2-65-NP-4650-510-11
417N-11.0-11#N-3-65-PP-7011-612-11
417N-12.0-#NA#-2-65-NP-4639-612-11
417N-13.0-14#X-2-65-PP-4634-612-11
417N-14.0-#NA#-2-65-NP-4629-561-11
Exit 14
Landstar Blvd.


12
Exit 10
John Young Pkwy.
to JYP NB
to JYP SB
50
49
51
9
8
10
7
52
6
53
Exit 11
Orange
Blossom
Tr.
417S-49.0-11#N-2-65-NP-7045-1233-12
417S-50.0-10#X-3-65-PP-7053-1233-12
417S-51.0-#NA#-2-65-NP-4678-1040-12
417S-52.0-10#N-2-65-NP-4683-1417-12
417S-53.0-#NA#-2-65-NP-4689-1417-12
417N-06.0-10#X-2-65-NP-4671-411-12
417N-07.0-#NA#-2-65-NP-4666-388-12
417N-08.0-10#N-2-65-PP-4661-549-12
417N-09.0-11#X-2-65-NP-4655-549-12
Exit 10
John Young Pkwy.


13
International Dr.
TOLL
417
Exit 6
International Dr.
from International Dr.
417S-54.0-#NA#-3-30-PP-1767-1417-13
417S-55.0-#NA#-2-65-NP-4694-1528-13
417S-56.0-06#X-3-65-NP-7085-1528-13
417S-57.0-#NA#-2-65-NP-4694-656-13
54
57
56
55
1
2
3
5
4
JOHN YOUNG PKWY.
MAIN PLAZA
417N-01.0-#NA#-2-65-NP-4682-327-13
417N-02.0-06#N-3-65-NP-7067-469-13
417N-03.0-#NA#-2-65-NP-4682-469-13
417N-04.0-#NA#-3-30-PP-1394-469-13
417N-05.0-#NA#-2-65-NP-4677-411-13


14
408W-55.0-04#X-3-65-PP-6767-1362-14
408W-56.0-#NA#-2-65-NP-4482-1063-14
408W-57.0-04#N-2-65-NP-4482-1243-14
408W-58.0-#NA#-3-30-PP-1714-1243-14
408W-59.0-02#X-2-65-NP-4482-1074-14
408W-60.0-01#X-2-65-NP-4482-1201-14
408W-61.0-#NA#-2-65-NP-4482-752-14
Exit 1
West Colonial Dr.
Clarke Rd.
Exit 2
Good Home Rd.
Exit 4
Hiawassee Rd.
West
Colonial
Dr.
58
HIAWASSEE MAIN PLAZA
x
5
60
59
57
56
55
61
2
3
4
6
7
8
from Clarke Rd.
from Good Home Rd.
Good Home Rd.
Exit 4
Hiawassee Rd.
408E-02.0-01#N-1##-NP-2231-XXXX-14
408E-03.0-#NA#-2-65-NP-4492-2431-14
408E-04.0-02#N-2-65-NP-4492-3068-14
408E-05.0-#NA#-4-30-PP-3023-3068-14
408E-06.0-04#X-2-65-NP-4492-2594-14
408E-07.0-#NA#-2-65-NP-4492-2718-14
408E-08.0-04#N-3-65-PP-6781-3454-14


15
408W-47.0-#NA#-3-55-NP-6765-1904-15
408W-48.0-#NA#-2-55-NP-4481-1904-15
408W-49.0-08AN-2-55-PP-4481-2026-15
408W-50.0-07#X-2-55-NP-4481-2026-15
408W-51.0-06#X-2-55-NP-4481-1818-15
408W-52.0-05#X-2-55-NP-4481-1626-15
408W-53.0-#NA#-2-65-NP-4481-1237-15
408W-54.0-05#N-3-65-NP-6766-1362-15
Exit 5
Kirkman Rd.
Exit 6
Pine Hill Rd.
Exit 7
Old Winter
Garden Rd.
John Young Pkwy.
54
53
52
51
50
49
48
47
9
10
11
12
13
14
15
16
17
Exit 5
Exit 8A
Kirkman Rd.
Pine Hills Rd.
Mercy Dr.
HOLLAND
408E-09.0-05#X-3-65-NP-6781-3454-15
408E-10.0-#NA#-2-55-NP-4491-2837-15
408E-11.0-05#N-2-55-NP-4491-3303-15
408E-12.0-06#N-2-55-NP-4491-3695-15
408E-13.0-07#N-2-45-NP-4491-3982-15
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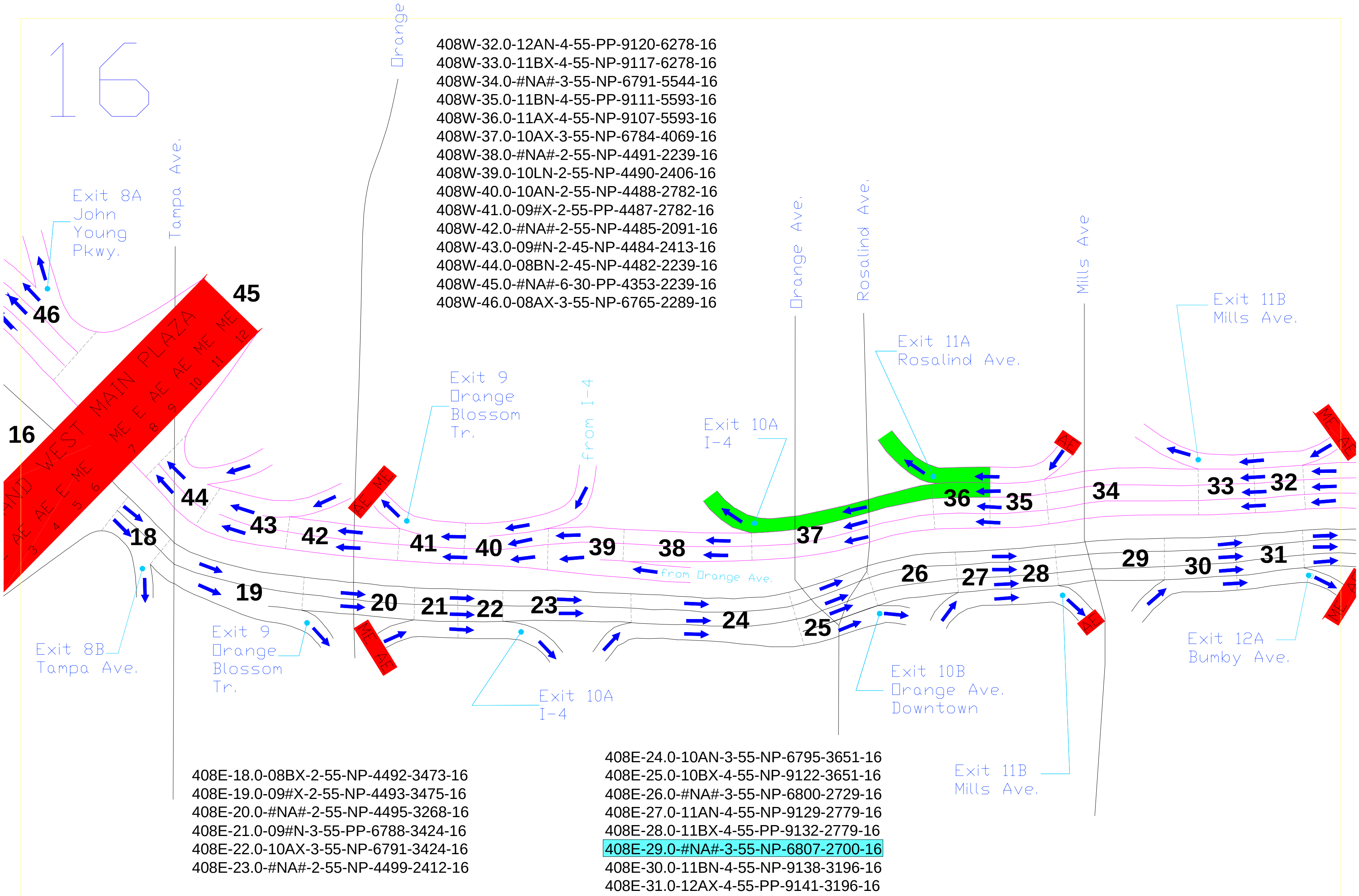
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Orange
Tampa Ave.
Exit 8A John Young Pkwy.
WEST MAIN PLAZA
Exit 9 Orange Blossom Tr.
from I-4
Exit 10A I-4
Orange Ave.
Rosalind Ave.
Mills Ave
Exit 11A Rosalind Ave.
Exit 11B Mills Ave.
from Orange Ave.
Exit 8B Tampa Ave.
Exit 9 Orange Blossom Tr.
Exit 10A I-4
Exit 10B Orange Ave. Downtown
Exit 11B Mills Ave.
Exit 12A Bumby Ave.
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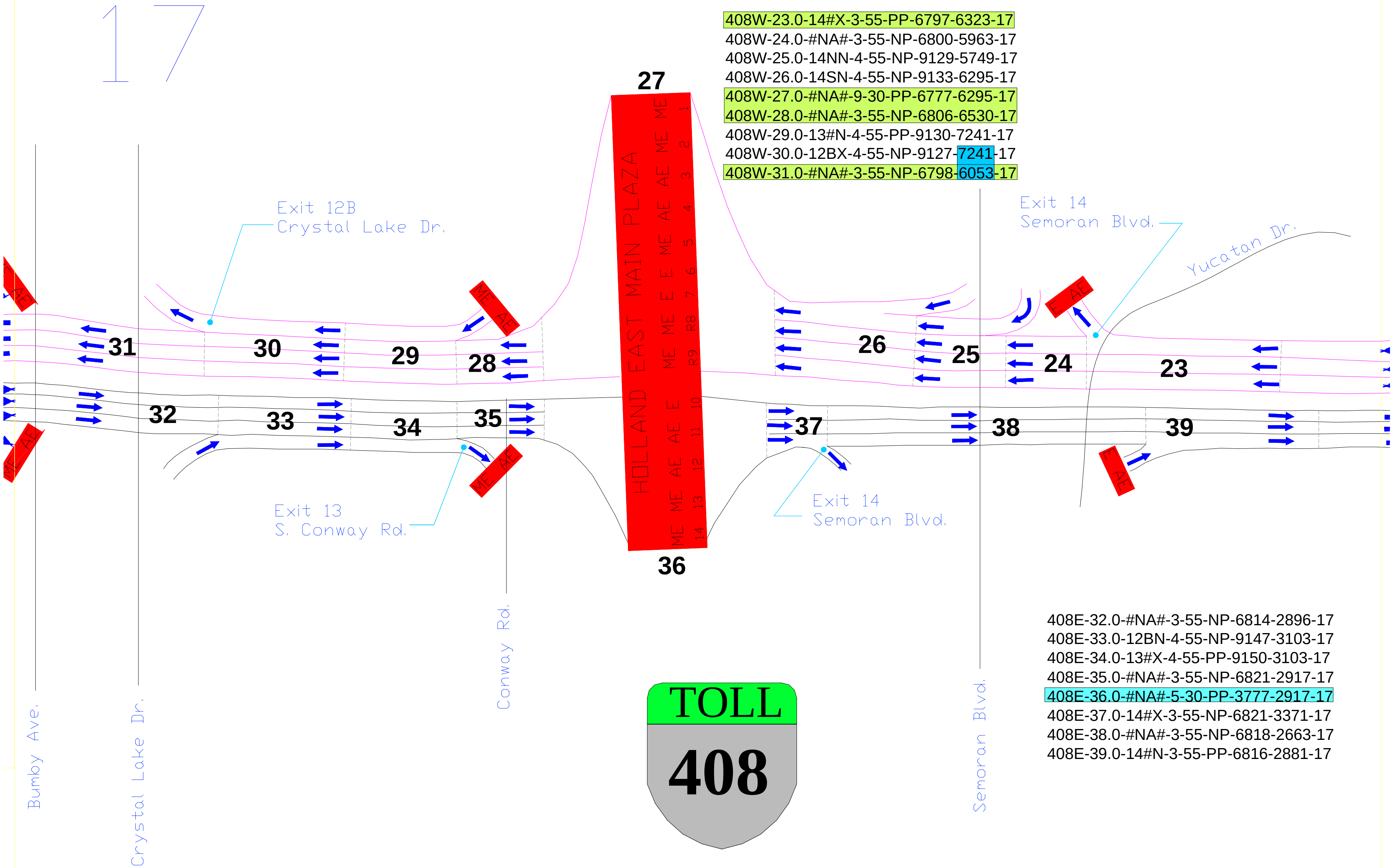
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Exit 12B
Crystal Lake Dr.
Exit 14
Semoran Blvd.
Yucatan Dr.
HOLLAND EAST MAIN PLAZA
27
36
31
30
29
28
26
25
24
23
32
33
34
35
37
38
39
Exit 13
S. Conway Rd.
Exit 14
Semoran Blvd.
Bumby Ave.
Crystal Lake Dr.
Conway Rd.
Semoran Blvd.
TOLL
408
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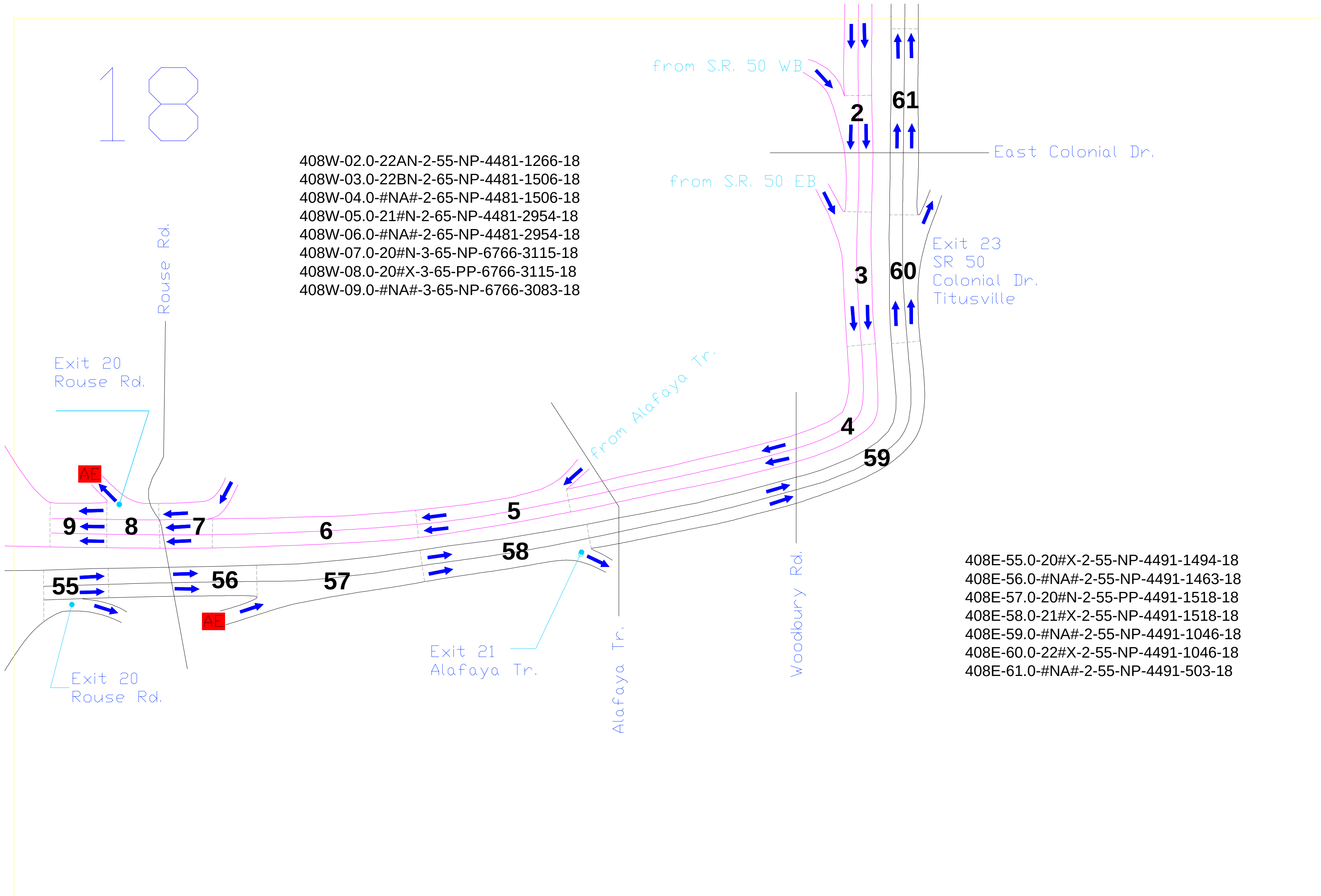
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from S.R. 50 WB
from S.R. 50 EB
East Colonial Dr.
Exit 23
SR 50
Colonial Dr.
Titusville
Rouse Rd.
Exit 20
Rouse Rd.
from Alafaya Tr.
Exit 21
Alafaya Tr.
Alafaya Tr.
Woodbury Rd.
Exit 20
Rouse Rd.
AE
AE
2
3
4
5
6
7
8
9
55
56
57
58
59
60
61
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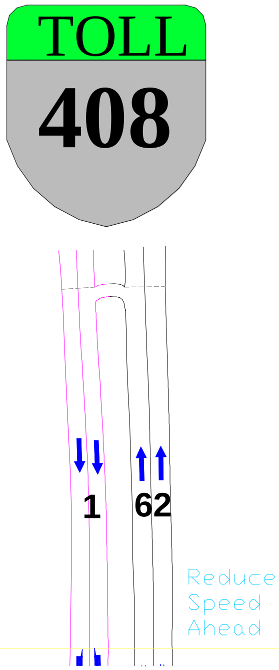

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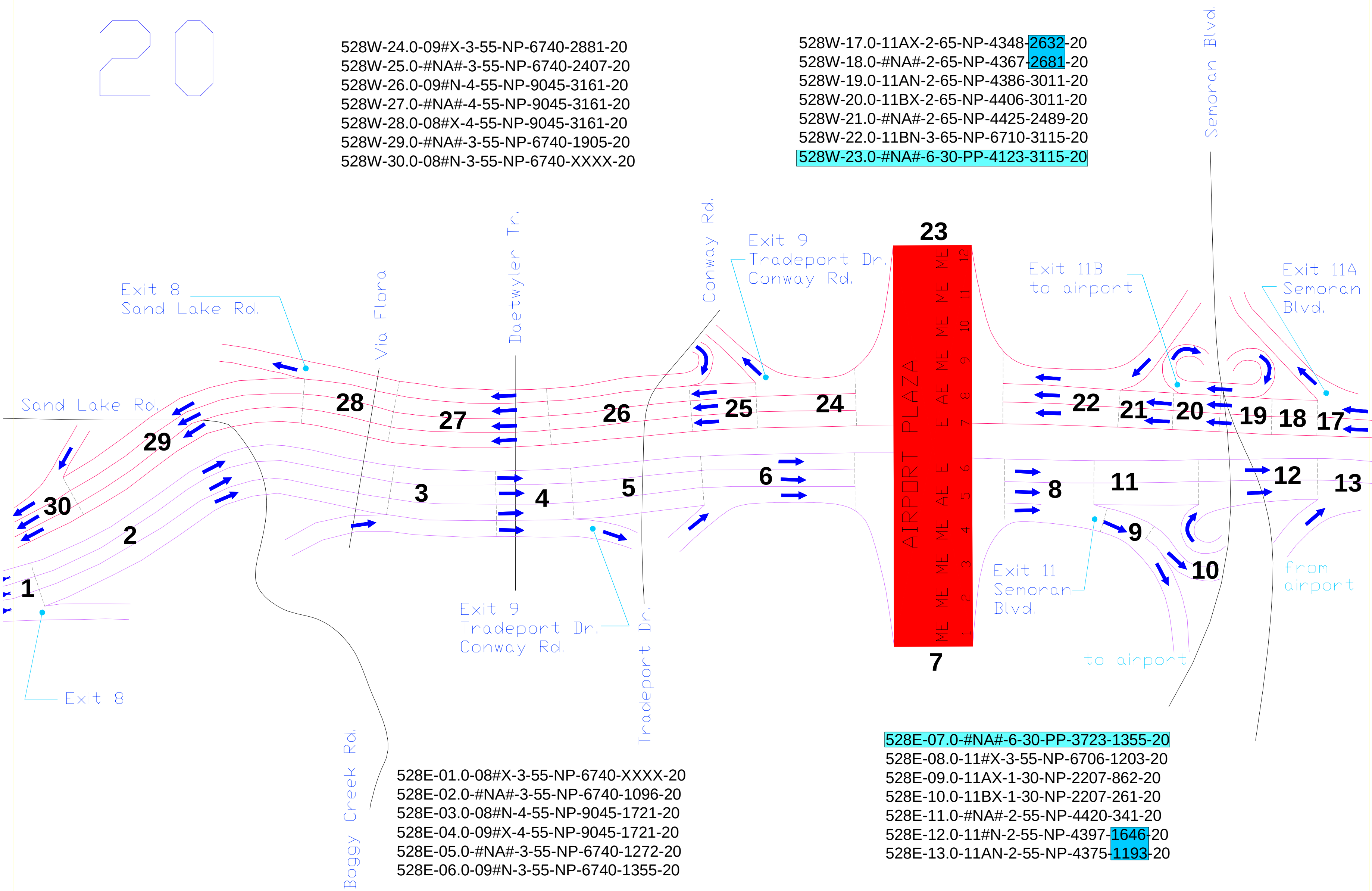

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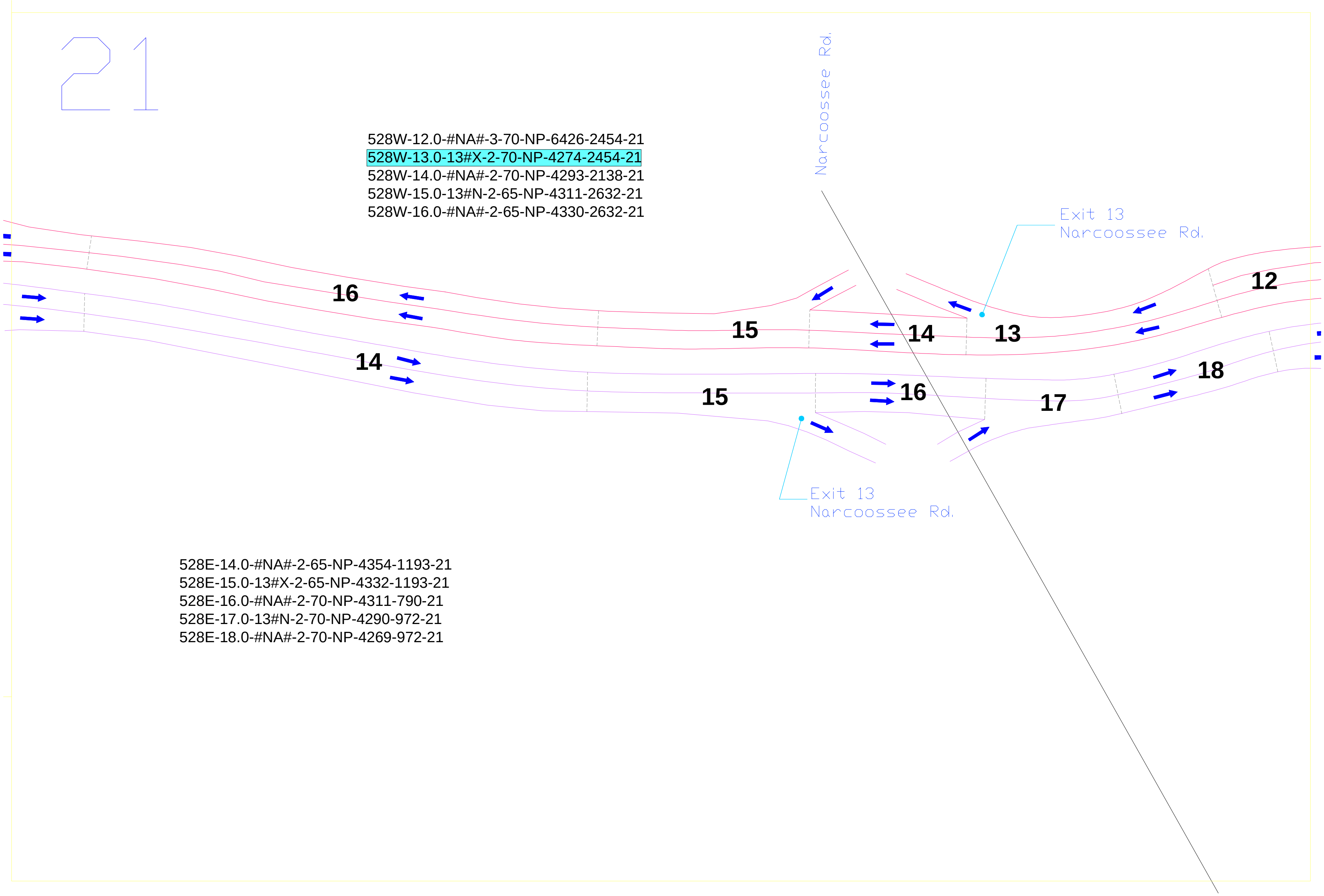
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Narcoossee Rd.
Exit 13
Narcoossee Rd.
16
15
14
13
12
14
15
16
17
18
Exit 13
Narcoossee Rd.
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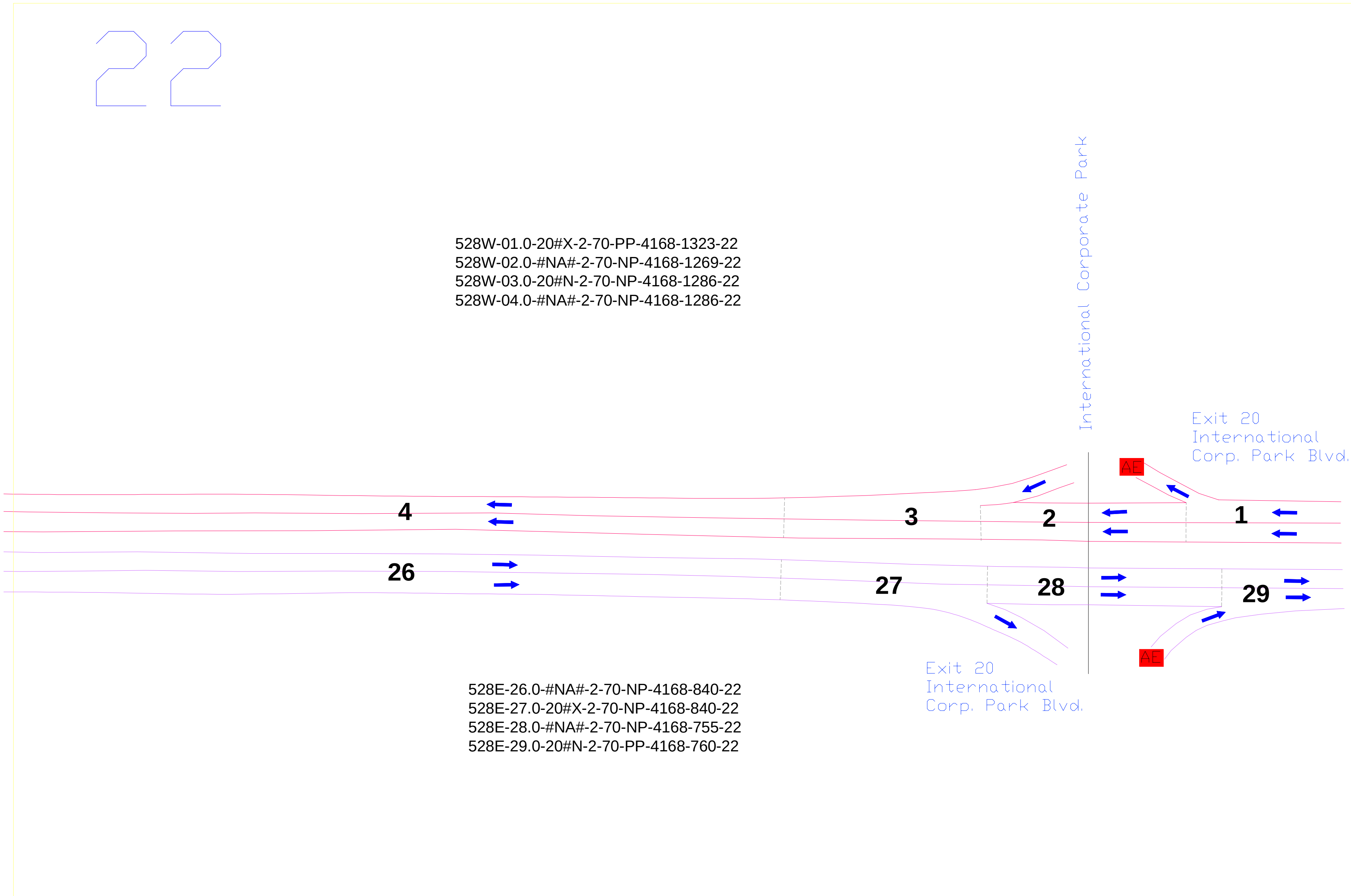
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528W-03.0-20#N-2-70-NP-4168-1286-22
528W-04.0-#NA#-2-70-NP-4168-1286-22
International Corporate Park
Exit 20
International
Corp. Park Blvd.
AE
4
3
2
1
26
27
28
29
AE
Exit 20
International
Corp. Park Blvd.
528E-26.0-#NA#-2-70-NP-4168-840-22
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Appendix G: Paper published in 2002 TRB RECORDS #1781 presented at the 81st Annual TRB Meeting 2002
TNCC : Operations Management & Assessment Tool for Toll Network Operators

Abstract

This research developed a performance assessment tool to assist managers and operators of highway networks containing toll collection facilities. Toll Network Capacity Calculator, TNCC, quantifies a toll facility's ability to process traffic. It can also assist engineers designing toll facilities to adequately serve highway systems. TNCC will determine the maximum amount of traffic that a collection facility can handle. In addition, TNCC may be employed for disruption management during lane closings, during incidents or during maintenance checks. Furthermore, TNCC may be employed as a planning tool and a performance assessment tool by predicting the impact of surging traffic volumes during special events.

The performance of a toll facility was determined from plaza characteristics such as lane number, lane type and processing rates. The results of the calculations met constraints set by the characteristics of the arriving traffic. For instance, variables such as the percentage of arrivals that were ETC patrons and the percentage of arrivals that were semi-trucks requiring non-ETC services influenced the plazas' performance outcome. Overflow of ETC users from the dedicated ETC lanes into the mixed lanes was also a factor. Performance was independent of hourly arrival volumes. Videotapes and transaction data at real plazas provided necessary input to TNCC in the evaluation of 32 plazas on the toll network of highways in Orange County, Florida.

Keywords -- Management Tool, Capacity, ETC, Toll Operations, Assessment Tool

Toll Network Capacity Calculator, TNCC

One way to calculate toll plaza performance is to determine the optimum number of vehicles and/or passenger car equivalents that can pass through all available lanes in one hour. Toll Network Capacity Calculator, TNCC, is a tool developed for this purpose. It can be applied to one toll collection plaza or to a system of successive toll collection facilities to locate bottlenecks on the network. The objective of this paper is to present a new methodology and tool for calculating the capacity of a toll facility, TNCC, and also to present the results of its application. Although TNCC has been computerized in Visual Basic 6.0, TNCC is actually an analytical method to calculate the capacity of a toll facility in which calculations, although tedious, do not require a computer.

When comparing capacities of different configurations for the same plaza, it is found that some lane configurations better meet the same traffic demands for the different customer-groups, and will have a higher capacity than other lane configurations. If a customer-group is not provided adequate service, due to the lack of lanes providing service to that particular customer-group, queues arise and the capacity of the entire plaza will become smaller. The calculated capacity of a plaza becomes an optimum value when the chosen configuration best matches the arrival-portions of all customer-groups.

While calculating a toll facility's best possible performance, the optimum capacity for a plaza is limited by two constraints. First, adequate service is required for all customer-groups, thus characteristics of the traffic arrivals and their required services is an important consideration. Just as the ideal capacity for highways must be reduced by heavy vehicle factors and other traffic characteristics, so shall the ideal capacity be reduced for toll facilities through the use of the processing rates for the different customer-groups. The portion of the arrival volumes that belong to each customer-group, such as the percent trucks, is a known quantity and considered a characteristic of the arriving traffic. Percentages of the different customer-groups used in the calculation must reflect true observed traffic characteristics at the plaza. Second, the rate at which the customer-groups are processed is a determining factor of the resulting calculated capacity and must be based on measured values in the field. For instance, only a limited number of semi-trucks using the manual service can be processed in one hour. Observations estimate this to be 138 vehicles per hour per lane, *vphpl. (1,2)*

Both constraints limit the optimum number of vehicles processed through the plaza in one hour. Given the traffic characteristics of the arrivals, or the portion of arrivals belonging to each customer-group, and given the processing rates for all customer-groups arriving at the plaza, the maximum number of vehicles that can be processed for the plaza's specific lane configuration can be determined.

TNCC's capacity calculation process is cyclic, in which the capacity is calculated during consecutive iterative cycles. At the end of each cycle the calculated capacity is a value closer to the correct optimum capacity of the facility. To determine whether or not another iterative step is necessary, a check on the queues in each of the individual lanes is made. If at the end of a calculation cycle there are no queues in all lanes, the calculation stops and the capacities in each of the lanes have converged to their final value. The percentages of all customer-groups in each of the lanes have also converged to their final value. The plaza capacity is the sum of all lane capacities.

In order to check the queues, the number of processed vehicles of each customer-group at the plaza is determined. This number is the product of the observed plaza percentage of vehicles belonging to that particular customer-group and the new capacity that was calculated during a cycle. The observed percentage is a traffic characteristic at the plaza, such as the percent ETC vehicles using the plaza or the percent vehicles that are semi-trucks using traditional collection services. Except for the ETC users, the vehicles are then split up evenly into the lanes that provide their required service. ETC users, however, are placed preferably into dedicated ETC lanes over lanes providing mixed types of services. The time it takes to process all vehicles in each of the individual lanes can then be determined. If it is less than one hour, there is no queue and the capacity for that lane is the number of vehicles processed in that lane. If it is greater than one hour, then there is a queue and the capacity of that lane is determined by mixed lane equations described in a later section of this paper *Application of TNCC and Case Study Reports*. The new capacity of the plaza is the sum of the individual calculated lane capacities. Finally, as long as there is at least one lane with a queue, the iterations continue, and when the queues are eliminated in all lanes, the true capacity has been reached.

Traffic and Plaza Characteristics as Input

The lane configuration for a plaza is described by the collection services provided in each of the lanes. To assist with lane configuration, four categories of vehicles or customer-groups, M, A, T and E, were identified. Each group has its own specific processing rate whose value measured in the field lies within a small definable range under queuing conditions. Definitions of the 4 customer-groups are given in Table 1. Videotapes of the plazas from the fall of 1995 until the summer of 1998, during data collection of previous studies determined these rates. In addition, as part of this study, these values were validated by videotapes taken in August 2000 of the same plazas as well as additional plazas on the network.

A lane providing the manual M toll collection service to all vehicles other than semi-trucks is an example of a single service lane. It has a processing rate of 498 *vphpl.* However, a lane providing the same manual service to both semi-trucks and vehicles other than semi-trucks is identified as a mixed service lane, MT. The processing rate in this mixed lane would range in value from 138 to 498 *vphpl.* This is because semi-trucks, on average, require much longer service times or have the lower manual processing rates of 138 *vphpl.* *(1,2)* Semi-trucks are thus placed separately into their own customer-group, T, whenever they utilized non-electronic toll collection, non-ETC services. The mixed lane MTE offers the traditional manual toll collection service in conjunction with ETC, thus MTE lanes provide service to three customer-groups, M, T and E, a common installation. *(3,4,5)* Finally, the mixed lane AE offers toll collection service to automatic coin machine, ACM, users and ETC users. Analytical queuing models that have previously addressed the issue of *mixed queues* have used similar definitions. *(6,7,8,9)*

The performance or capacity calculation makes assumptions concerning plaza geometry. Plaza geometry is assumed to contain enough buffer zone space to accommodate queues and it is assumed that there is no blocking of the dedicated ETC lanes due to lack of space. In the real world, dedicated ETC lanes are often blocked and drivers do not always have access to these lanes due to the queue spilling out of the buffer zone and into the highway. TNCC, however, will calculate the maximum number of vehicles that a plaza can process in one hour assuming that there is no blockage. Future research will include quantitative ways to set limitations on the plaza capacity set my inadequate buffer zones.

The performance or capacity calculation also makes assumptions concerning drivers' behavior. TNCC assumes that drivers utilizing ETC prefer a dedicated ETC lane to mixed lanes. These mixed lanes provide the traditional services, either the manual M service or the ACM service, as well as the ETC services. There are times, however, when the dedicated ETC lanes are fully utilized, when vehicles are being processed at the optimum observed rate of 1560 *vphpl* in the dedicated ETC lanes. Under these conditions, ETC drivers will divert to their second choice, the AE lanes. These AE lanes are preferred over the MTE lanes because of their faster processing rates and because semi-trucks are not permitted to use them. If however, the AE lanes are also fully utilized, ETC drivers will divert to their third choice, the MTE lanes. In addition to these behavioral assumptions, it is assumed that drivers utilizing ACM do not divert to other lanes. In other words, the observed percentages of arrivals utilizing ACM at the plaza is determined from data collected in the field and serve as data entry into TNCC. Thus, the drivers' preferences typical for that plaza are reflected in the resulting calculated plaza capacity.

The optimum processing rate for vehicles in the dedicated ETC lanes, S_E , varies with the speed limit in the ETC lane. For plazas evaluated in this project, TNCC used a fast processing rate of 1560 ± 120 *vphpl*. Previous studies indicate that processing rates are lower when speed limits are more restrictive. *(10,11)* Furthermore, this high processing rate of 1560 *vphpl* was not observed for ETC vehicles in the mixed lanes under queuing conditions. In mixed lanes, ETC vehicles found themselves waiting for the vehicles in front of them to be processed by traditional collection services and frequently had to reduce their speeds to values as low as 2.5 mph. A realistic 26-foot spacing and a 7-second headway computes to a processing rate of 514 *vphpl*. If the portion of ETC vehicles using the mixed lane was high, speeds were not reduced quite as much. Thus, it was observed in the mixed MTE manual lanes that the processing rate for vehicles using the ETC ranged from 514 *vphpl* to 1560 *vphpl*, depending upon the portion of ETC vehicles using the MTE lane. In other words, if the portion of ETC vehicles versus vehicles using the manual service was low, then the average hourly processing rates were closer to 514 *vphpl*. If, however, the portion of ETC vehicles versus vehicles using the manual service was high, then the average hourly processing rates were closer to 1560 *vphpl*. Similarly, in the AE lanes, the ETC processing rate ranged from 618 *vphpl* to 1560 *vphpl*. It was found that the ETC processing rate was adequately represented as an increasing cosine function of the variable P_E , the percent ETC usage. In other words, the portion of vehicles in the mixed lane utilizing ETC, P_E , may range from a value of 0 to 100 percent and yield mixed lane processing rates that increase as this percentage increases. The cosine functions describing the ETC processing rates in the mixed lanes, MTE and AE, are displayed by equations (1) and (2), respectively. The functions are displayed graphically in Figures 1 and 2. The argument of the cosine has units of degrees. The advantage of the cosine function is that it has smooth and continuous derivatives at the end points where the percentage of ETC usage is either 0% or 100%. Furthermore, the derivative approaches zero at the end points and this is reflective of field observations. In other words, the observed processing rates do not change considerably with the variable P_E near the two extreme end points.

$$S_E^{MTE}(P_E) = 1037 - 523\cos(1.80P_E) \quad (1)$$

$$S_E^{AE}(P_E) = 1089 - 471\cos(1.80P_E) \quad (2)$$

Application of TNCC and Case study reports

In order to test TNCC, this study determined capacities of 12 ramp plazas and capacities of 20 highway plazas, both sides of 10 plazas. The plazas are located on a network of three highways in Orlando, Florida: the 408 or East-West Expressway, the 528 or Bee Line Expressway, and the 417 or Central Florida Greenway. Input to the calculation was extracted from transaction data, which provided traffic characteristics such as volumes of the different customer-groups at the plazas for the morning rush hour of August 16, 2000. From the volumes, traffic charac-teristics were extracted: the percentage of arrivals using ETC at the plazas, the percentage of arrivals using automatic coin machine services, and the percentage of arrivals using the manual services (both semi-trucks and vehicles other than semi-trucks).

Videotapes taken at the plazas provided other input to the capacity calculation such as the plaza lane configurations. In other words, the customer-groups serviced in each of the lanes at the plazas were identified. In addition, processing rates for the four customer-groups were extracted from the tapes. Processing rates were somewhat typical to those reported in previous literature. *(4,12,13,14,15)* The highway plazas and ramp plazas, maintained and managed by the Orlando-Orange County Expressway Authority, OOCEA, are listed in Table 2 and Table 3, respectively. Lane configurations and the calculated capacities are also provided in the tables. The traffic directions are indicated along with the capacities: W-West, E-East, N-North and S-South. Table 2 also indicates whether there is overflow of ETC vehicles out of the dedicated ETC lanes and into the mixed lanes. Plazas on ramps having dedicated ETC lanes had no overflow because arrival volumes were low.

The processing rates, S_M, S_A, S_T, and S_E, extracted from the data, serve as initial input to the capacity calculation. The processing rates are in units of vehicles per hour. The contribution from single service lanes to the plaza's capacity is the product of the number of lanes providing that service and the processing rate for that single service. The N_X variables specify the number of lanes providing X service. The total contribution from all single service lanes is the sum, J, given by equation (3). In addition, the contribution from mixed lanes, MTE and AE, to the plaza's capacity is given by K in equations (4) and (5). The capacity of a lane providing mixed services is the number of processed vehicles utilizing the lane divided by the total time required to process all customer-groups using that lane. *(2,16,17)* The capacity, C, is the sum of all contributions, equation (6).

The percentages, P_M, P_A, P_T and P_E, in equations (4) and (5) are the portion of arrivals within an individual lane that belong to a particular customer group. These are different values than the percentages of the arrivals to the plaza as a whole. For example, the percentage of arrivals that are ETC users to a plaza as a whole may be 55%, but the percentage of arrivals in one of its MTE lanes, P_E, may only be 2%, due to a small overflow of ETC users from the plaza's dedicated ETC lanes. The percentages of arrivals in each of the individual lanes are determined by TNCC. Each of TNCC's iterative steps calculates these percentages. They converge to unique values; their final values decided when the maximum throughput at the plaza is determined. Their values must also be in accord with the observed values for the percentages of arrivals belonging to each of the customer groups to the plaza as a whole, which are observed field values and serve as a nonnegotiable data entry into TNCC. It is not possible, for example, to have 2% ETC usage in all lanes of the plaza when 55% of the plaza's arrivals are ETC users.

$$J = N_M S_M + N_T S_T + N_A S_A + N_E S_E \tag{3}$$

$$K\ \alpha\ \ K_{MTE} = N_{MTE} S_{MTE} = \quad N_{MTE} \frac{100\%}{\left(\frac{P_M}{S_M} + \frac{P_T}{S_T} + \frac{P_E}{S_E}\right)} \tag{4}$$

$$K\ \alpha\ \ K_{AE} = N_{AE} S_{AE} = \quad N_{AE} \frac{100\%}{\left(\frac{P_A}{S_A} + \frac{P_E}{S_E}\right)} \tag{5}$$

$$C = J + K \tag{6}$$

The Iterative Process

The capacity calculation is an iterative procedure in which the vehicles are shifted from one lane to another until an optimum capacity value is attained. The calculated capacities converge to their correct values after several iterations. The shifting of vehicles may not violate the rules already stated. In the final iteration, constraints on the traffic characteristics at the plaza and constraints on the processing rates must all be met. Processing rates for the single services, for instance, must be equivalent to those observed and described in Table 1 and processing rates for ETC vehicles in the mixed lanes must be equivalent to those calculated by equation (1) and (2). At the end of each iterative step, constraints on traffic characteristics are checked for consistency with observations and vehicles are shifted to correct discrepancies, thus facilitating the calculation of a new capacity in the next iteration. *(10,11,18,19)*

To initiate the iteration process, the percentages in the individual lanes have to be assigned. Percentages in any *single* service lane are always 100%. For example, in a dedicated ETC lane, the percentage of ETC, P_E , is 100% ETC. In any *mixed* lane the percentages P_M , P_T , P_A and P_E are assigned arbitrary values such that their sum total is 100%. Several initial assignments were tested. All resulted in the same optimum value for the final capacity. In other words, the final capacity calculated in the last iteration for a specific plaza was independent of the initial assignment. Each initial assignment, however, required a different number of iteration steps to meet convergence, some more and some less.

An example of an initial assignment for an MTE lane was to assign two of the three customer-groups, M and T, percentage values P_M and P_T in that lane such that they were equivalent to the observed percentages of the total arrivals in all lanes. The remaining percentage in that lane, P_E , was then derived from the other two such that the total was 100%. An example of an initial assignment for an AE lane was to assign one of the two customer-groups, E, a percentage P_E in that lane also equivalent to the observed percentage of the total arrivals in all lanes. The remaining unassigned percentage in that lane, P_A , was then derived such that the total was 100%.

In successive iterations, percentages, P_M , P_T , P_A and P_E in each of the lanes converge to more realistic values for each of the individual lanes. After several iterations, the percentages become very different from their initial assignment, and in the final iteration, their values vary widely from lane to lane. For instance, the percentage of ETC usage to a plaza may be 50% whereas in the MTE lane, this value P_E , may decrease to 6%. This occurs whenever there are dedicated lanes in the configuration that can handle most all the ETC arrival traffic. Also, the percentage of semi-trucks using non-ETC services in a plaza may be 5% whereas in the MTE lane, this value P_T , may increase to 12%. This occurs whenever non-ETC semi-trucks are forbidden to use other lanes such as the ACM lanes or the dedicated ETC lanes. Lastly, although percentages vary in value from lane to lane, the percentages of total arrivals to the plaza in all lanes that are ETC users, ACM users and Manual users remain constant throughout the iterative process and reflect the traffic characteristics at the plaza. In other words, they are consistent with the transaction data for the rush hour at the plaza.

TNCC: A disruption Management tool, BEST practices

Whenever lanes must close at a toll collection facility due to maintenance or incidents, disruption in traffic flow occurs due to a reduction in capacity. TNCC may assist in disruption management. It may determine the impact of a lane closure and assist operators in the adjustment of the remaining lane configuration. To help alleviate the disruption, TNCC may suggest opening up the remaining lanes to other services. Traffic characteristics such as the percent ETC usage, manual usage and ACM usage, serve as input to TNCC using a new lane configuration containing the closed lanes.

Suppose there is an incident in the morning rush hour at the Holland East Main Plaza, traveling west. The capacity of the Holland East Main Plaza is 6777 *vph* and has five MTE lanes, two AE lanes and two dedicated ETC lanes. According to TNCC, if there is an MTE lane closure due to an incident, the plaza's capacity is reduced to 5998 *vph*. To alleviate the disruption, operators may consider converting the other dedicated ETC lane to a manual service lane, MTE. TNCC would compute that this would further reduce the capacity to 5706 *vph*, thus this action should not be taken. Furthermore, TNCC can indicate the logic behind this decision. In this case, there is a high 53% ETC usage rate and taking away a dedicated ETC lane would not adequately serve the ETC customer-group. TNCC is designed to use these percentages, and other characteristics of the hourly arrival volumes, in conjunction with the new configuration to deduce a plaza's ability to perform.

TNCC also alleviates disruption due to scheduled maintenance. Suppose that there is required maintenance scheduled on the eastbound side of John Young Parkway Main Plaza, which requires closure of one lane. The configuration contains two MTE lanes and one dedicated ETC lane. In this case, if there is an MTE lane closure, the capacity is reduced drastically from 1394 to 697 *vph*. To alleviate the disruption, operators may again consider converting the dedicated ETC lane to a manual service lane, MTE. Unlike the previous example, TNCC would recommend this as a best practice choice because it would increase the capacity to 1081 *vph*. Therefore, during scheduled maintenance requiring one lane closure on the side of the John Young Parkway Main Plaza in which traffic is directed east, the configuration with the highest capacity would be an MTE-MTE rather than an E-MTE configuration.

TNCC: A planning tool and a Performance Assessment tool

Whenever a planned special event occurs in the region and heavy usage of the toll facilities is expected, increased volumes in manual usage may occur. The changes in the proportion of customer-groups arriving to the plaza will change the capacity. TNCC may serve as an assessment tool of the toll collection facility under these new conditions. For instance, there may be a special event requiring heavy traffic to flow westbound through the John Young Parkway Main Plaza, configuration E-MTE-MTE. The new traffic characteristics may not reflect the typical 46% ETC usage, but rather a lower 33% ETC usage rate. Special events often attract non-commuters that may or may not possess a transponder for ETC usage. TNCC predicts a capacity reduction from 1767 to 1448 *vph* due to the lower ETC usage rate. TNCC also predicts that the performance of the plaza could be improved by converting the dedicated ETC lane into a third MTE lane. This conversion could increase the capacity to 1656 *vph*.

TNCC also assists with planning plaza lane configuration patterns to meet future developments. At the Holland East Plaza, the early morning rush hour westbound traffic, on August 16, 2000, had a 53% ETC usage rate. The two dedicated ETC lanes adequately serviced ETC users. However, if the percentage of ETC users increases to 57% or more, TNCC indicates that a third dedicated ETC lane converted from one of the MTE lanes would be beneficial. However, until the 57% ETC usage is attained, a third dedicated ETC lane would reduce capacity and would probably take away from the performance of the plaza. According to TNCC, this action would specifically reduce the 6777 *vph* capacity to as much as 5999 *vph.*

Other Conclusions

As expected, TNCC calculates higher capacities for plazas with a large number of lanes. Also, traffic with a higher percentage of arrivals that are semi-trucks using non-ETC service results in lower calculated capacities. These vehicles have the lowest processing rates and should be encouraged to use ETC. In addition, capacities calculated by TNCC do not depend upon hourly arrival volumes, however, capacities depend upon the distribution of arrivals among the customer-groups and whether the lane configuration can meet these requirements.

TNCC correctly simulates the effects of the traffic characteristics. Consideration of some of the ramp plazas clearly demonstrates this result. For instance, ramp plazas containing a dedicated ETC lane, may actually have calculated capacities smaller than 1560 *vph*. At first glance this result may seem incorrect. However, the traffic characteristics determine the proportion of vehicles arriving to the plaza and therefore impact the capacity. Greater ETC usage resulted in larger calculated capacities. Keeping the percentage of ETC usage and manual usage consistent with the data requires an upper limit on the number of ETC users that can be serviced during the rush hour through the plaza. For example, through the John Young on-ramp AE-E plaza there is a 54% ETC usage and a 46% ACM usage rate. There is a capacity of 618 *vphpl* for the AE lane assuming all ETC users utilize the dedicated ETC lane. This is not a bad assumption because there are less than 1560 ETC users, proportionately, approaching the plaza in one hour; thus all ETC are using the dedicated ETC lane and no ETC drivers are using the mixed AE lane. If only 618 vehicles are processed in the AE lane, then there can only be an optimum value of 727 vehicles being processed in the dedicated ETC lane in one hour, or 618 times the ratio of 54 to 46. Keeping the portion of traffic volumes consistent with observation is a requirement by TNCC and restricts the resulting optimum calculated plaza capacity. In this case, the total capacity of this AE-E plaza is 1346 *vph*, smaller than 1560 *vph.*

TNCC also takes into account the shifting of ETC vehicles among the dedicated and mixed lanes. Configurations that provide enough dedicated ETC lanes for the approaching ETC traffic volumes all have an increase in capacity with an increase in ETC usage. In other words, if there is sufficient dedicated ETC lanes for the ETC volumes, then there is no overflow of ETC users into the mixed lanes and capacity becomes dependent on ETC usage rates. However, whenever there is overflow of ETC vehicles into the mixed MTE and AE lanes, then the ACM usage rate rather than ETC usage rate plays a large role in determining the capacity.

To illustrate an increase in capacity with an increase in ETC usage rate, six plazas all with the configuration E-MTE-MTE were considered. These plazas were the east and west side of John Young Main Plaza, the east and west side of Boggy Creek Main Plaza, Curry Ford Plaza northbound-side and University Main Plaza northbound-side. There is no ETC overflow from the dedicated ETC lane into the MTE lanes in any of these six plazas. Thus, capacities should increase with the ETC usage rates. Indeed, the rates, 30%, 38%, 46%, 50.8%, 50.9% and 56%, correlate well with the plazas' capacities of 1394, 1529, 1767, 1960, 1966 and 2107 *vph.* Another good comparison is the east and west side of the Bee Line Main Plaza. Both sides have the same configuration E-MTE-MTE-MTE and there is no overflow of ETC vehicles into the MTE lanes. The eastbound traffic volume has a slightly higher ETC usage rate, 49%, compared to the westbound traffic of 48%. Capacity is also slightly higher, 2763 rather than 2689 *vph.*

To illustrate how the ACM usage rate rather than the ETC usage rate plays a role in determining the capacity when ETC overflow occurs, both sides of the Holland West Plaza are considered. Both sides have the same configuration: 2 AE lanes, 3 MTE lanes and 1 dedicated E lane. Furthermore, the percentage of arrivals that are semi-trucks using non-ETC services are also the same on both sides, 0.9%. Only ETC and ACM usage are different. ETC usage is slightly higher for the eastbound traffic, 51% rather than 50%, and the ACM usage is significantly higher for the same eastbound traffic, 23% rather than 18%. In other words, there is less usage of the slow manual service in the eastbound direction, leading one to believe that the plaza with eastbound traffic would result in a higher capacity, 3882 *vph.* However, the calculation results in a higher capacity for the plaza with the westbound traffic, 4353 *vph*. To make sense of this, it can be observed that there is only one dedicated lane for ETC usage on either side. And with a high 50% or 51% ETC usage rate, ETC overflow will occur on both sides of the plaza. In the plaza with eastbound traffic, more of the ETC overflow is shifted into the MTE lanes because the AE lanes are already full, it has the higher 23% ACM usage. Thus, two observations can be made. In the plaza with eastbound traffic, the capacity of the AE lanes is smaller than that of the plaza with westbound traffic, there are less ETC vehicles proportionately using the AE lanes. Also in the plaza with the eastbound traffic, the capacity of the MTE lanes is higher than that of the plaza with the westbound traffic, there are more ETC vehicles proportionately using the MTE lanes. The higher MTE capacity, however, is not high enough to offset the lower AE capacity and therefore results in a lower total capacity for the eastbound direction.

A similar case can be made for Airport Main Plaza. Both sides have the same configuration and again the ACM usage, 13%, for the eastbound traffic is higher than the ACM usage, 11%, for the westbound traffic. However, in this case, there is no overflow of ETC vehicles out of the dedicated ETC lane in the eastbound direction, thus, ETC vehicles are not shifted into MTE lanes. Here, the difference in the capacity of the plaza that has eastbound traffic compared to the plaza that has westbound traffic, 4123 versus 3723 *vph*, is due to the large difference in ETC usage. In the westbound directed traffic, there is a large portion of the vehicles using ETC, 47%, rather than the 36% usage in the eastbound directed traffic.

Capacity calculations for 32 plazas were provided in this study using TNCC from which conclusions were drawn. For future research, a more comprehensive capacity analysis for the entire network of toll highways can be constructed. Capacities of additional segments between and not including plazas could be calculated using traditional techniques. Geometric considerations and traffic characteristics would be used. As a result, locations of the bottlenecks on the network could be identified from the comparison of adjacent segments on the network.

Acknowledgement

We would like to thank the Center for Transportation Systems Simulation, CATSS, for their financial support of this project. Furthermore, we would like to thank the Orlando-Orange County Expressway Authority, OOCEA, for providing assistance in the data acquisition and for their continuous support. Finally, we would like to thank our colleagues at the University of Central Florida and the University of Massachusetts Dartmouth.

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TABLE 1 Description of the customer-groups at the toll facilities

Customer-Group X	Processing Rates *(vphpl)* S_X	Description
M	498 ± 48	The **M**anual services are services in which drivers of vehicles other than semi-trucks pay a toll collector cash based upon the number of axles.
A	618 ± 30	The **A**utomatic Coin-Machine Services are services, in which the driver must pay the toll by tossing the exact change into a basket, (no semi-trucks permitted).
T	138 ± 78	These are manual services in which the drivers of semi-**T**rucks pay a toll collector cash.
E	1560 ± 120	The **E**TC Services are services in which drivers' accounts are automatically debited the toll. This rate is only for dedicated ETC lanes with 35-mph speed limits with headways of 2.3 seconds.

TABLE 2 Capacities of Plazas on the OOCEA toll network of highways

Lane Configuration **West/East and North/South**	**Name**	**Over -flow**	**C** ***(vph)***
E-MTE(closed)**-AE-MTE** **MTE-AE-MTE-E**	Hiawassee Main Plaza	**No** **Yes**	W-1714 E-3023
MTE-E-AE-AE-MTE-MTE **MTE-MTE-AE-AE-E-MTE**	Holland West Main Plaza	**Yes** **Yes**	W-4353 E-3882
MTE-MTE-AE-AE-MTE-E-E-MTE-MTE **E-AE-AE-MTE-MTE**	Holland East Main Plaza	**Yes** **Yes**	W-6777 E-3777
MTE-AE-MTE-E **E-MTE-AE-MTE**	Dean Main Plaza	**Yes** **No**	W-3159 E-2304
E-MTE-MTE(closed)**-MTE** **MTE-MTE-**MTE(closed)**-E**	John Young Main Plaza	**No** **No**	W-1767 E-1394
E-MTE(close)**-MTE-**MTE(closed)**-MTE** **MTE-**MTE(closed)**-MTE-**MTE(closed)**-E**	Boggy Creek Main Plaza	**No** **No**	W-2107 E-1529
MTE-MTE-AE-E-E **AE**(functions as E)**-MTE-MTE**	Curry Ford Main Plaza	**No** **No**	S-4022 N-1966
MTE-MTE-E **E-E-AE-MTE-MTE**	University Main Plaza	**No** **No**	N-1960 S-4006
MTE-MTE-MTE-MTE-AE-E **E-AE-MTE-MTE-MTE-MTE**	Airport Main Plaza	**Yes** **No**	W-4123 E-3723
E-MTE-MTE-MTE **MTE-MTE-MTE-E**	Bee Line Main Plaza	**No** **No**	W-2689 E-2763

TABLE 3 Capacities of Ramp Plazas on the OOCEA toll network of highways

Lane Configuration	Name & Entrance or Exit #	C *(vph)*
ME-E	Hiawassee on #4	1061
AE-E	Hiawassee off #4	1301
AE-E	John Young on #8	1346
AE-E	John Young off #8	1260
ME-AE	Orange Blossom Trail on #9	1178
ME-AE	Orange Blossom Trail off #9	1452
AE	Mills Ave on #11	751
AE	Mills Ave off #11	921
ME-AE	Bumby Ave on #12	1203
ME-AE	Bumby Ave off #12	1276
ME-AE	Conway Rd on #13	1257
ME-AE	Conway Rd off #13	1173

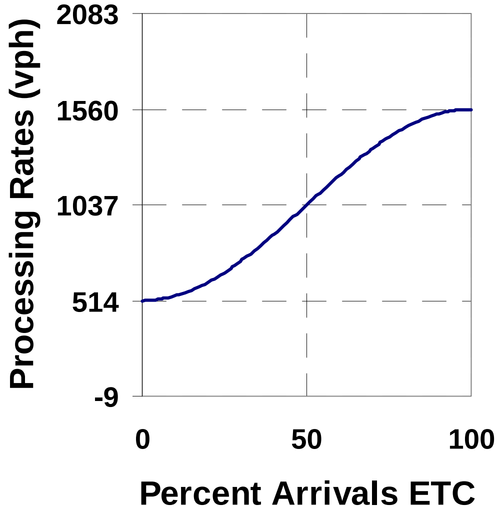

FIGURE 1 ETC Processing Rates, Manual lanes.

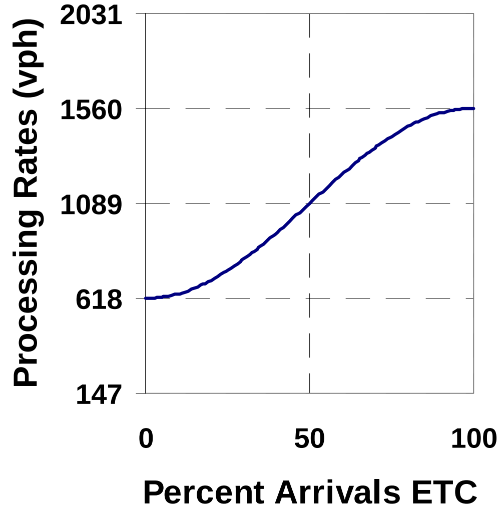

FIGURE 2 ETC Processing Rates, ACM lanes.

Appendix H: paper #1 presentation at ASCE's AATT 2002 Conference

Case Study Application of TNCC: a Simulation Tool to Identify Plaza Bottlenecks on a Toll Network of Highways

Joseph H. Dowd[6], Marguerite L. Zarrillo[7], A. Essam Radwan[8]

Abstract

Toll Network Capacity Calculator, TNCC, determines the optimum number of vehicles and/or passenger car equivalents that can pass through all available lanes at a toll collection facility in one hour. The capacity depends on the number of lanes available at the plaza and the processing rates for each of the customer-groups served in the lanes. The capacity also depends on the distribution of the arrival volumes among the customer-groups. In other words, the percentage of arrival volumes belonging to each of the customer-groups is an important factor in the determination of the maximum throughput.

TNCC was applied to 58 toll plazas on the toll network in Orange County, Florida, maintained by the Orlando Orange County Expressway Authority, OOCEA. Four categories of vehicles or customer-groups were identified in this study. Videotapes of the throughputs at the plazas provided the processing rates for the customer-groups. The distribution of the arrival volumes among the customer-groups was extracted from transaction data.

Once capacities were calculated throughout the toll network, potential bottlenecks were identified, generally centered around urban highway segments. At plaza bottlenecks, lane configurations were altered by TNCC and new capacities were determined. Through the software, it was possible to find the optimal lane configuration for maximum throughput at each of the 58 toll plazas.

Introduction

[6] Visiting Lecturer, Department of Physics, University of Massachusetts Dartmouth, 285 Old Westport Road, North Dartmouth, Massachusetts 02747-2300; phone 508-910-6647; u_jdowd@umassd.edu
[7] Ph.D., Assistant Professor, Department of Physics, University of Massachusetts Dartmouth, 285 Old Westport Road, North Dartmouth, Massachusetts 02747-2300; phone 508-999-9268; MZarrillo@UMassD.edu.
[8] P.E., Ph.D., Chair, Civil and Environmental Engineering Department, Director, Center for Advanced Transportation Systems Simulation, University of Central Florida, Orlando, Florida 32816-2450; phone 407-823-6340;AERadwan@mail.UCF.edu

Capacity determinations for a toll facility rely on many variables. Toll plaza characteristics such as lane number, customer group configuration and processing rates have to be weighed alongside traffic characteristics like vehicle type and percent distribution. Mathematically, the process of manipulating these variables can be tedious and often redundant. Toll Network Capacity Calculator (TNCC) is a software package that was developed to streamline the capacity calculation process and to make available comparative data to analyze a toll facility's efficiency and ability to adjust to different input traffic characteristics. (Zarrillo, et al. 2002)

Transaction data from Florida's Orlando-Orange County toll network provided the input for TNCC calculations. The data was provided through research supported by the Orlando Orange County Expressway Authority (OOCEA). Traffic volumes and distributions were gathered for August 16, 2000 through toll facility transaction data. A snapshot of traffic was culled for the morning rush hour, 7:00 to 8:00AM, to be used for analysis. The toll network under study consisted of 20 main toll plazas (10 plazas, separated by direction) and 38 ramps with toll facilities. TNCC could then be tested with a large sample of various configurations and input volumes.

The capacity calculation process differs according to traffic and plaza characteristics. (Zarrillo 1999) Customer-group overflow determines the appropriate set of equations TNCC employs, and percent distribution then guides the software decision process. Pre-defined processing rates are not all held constant throughout the calculation, but are instead determined by traffic distribution. (Zarrillo, 2000) Variable processing rates are employed for mixed configuration lanes and are explained in the "Input Variable Characteristic" section.

TNCC Decision Process

Microsoft® Visual Basic 6.0 was chosen as the programming language to develop TNCC. Transaction data from the toll facilities was inputted to spreadsheets using Microsoft® Excel and reports generated from the program are generated through Microsoft® Word.

The form-based nature of Visual Basic maximizes end-user utility by allowing for input directly from a spreadsheet and enabling button- or menu-based output to word processing and spreadsheet programs. A sample of the input screen is provided in Figure 1. The majority of data configuration and calculation is done from a single form.

The software decision processes involved in determining a capacity for any given toll facility are manifold. Initially, customer-groups separate the input volumes and the values generated provide an overestimation of the capacity. The initial capacity values are compared to initial customer percent distribution to determine validity. Checks for overflow and under-utilization per given volumes occur within each iteration of the calculation process. Validation of the capacity does not occur until successive iterations provide convergence to a single value. This value is compared to initial input data, and if percentages and volumes agree within program validation constraints, a final capacity is given.

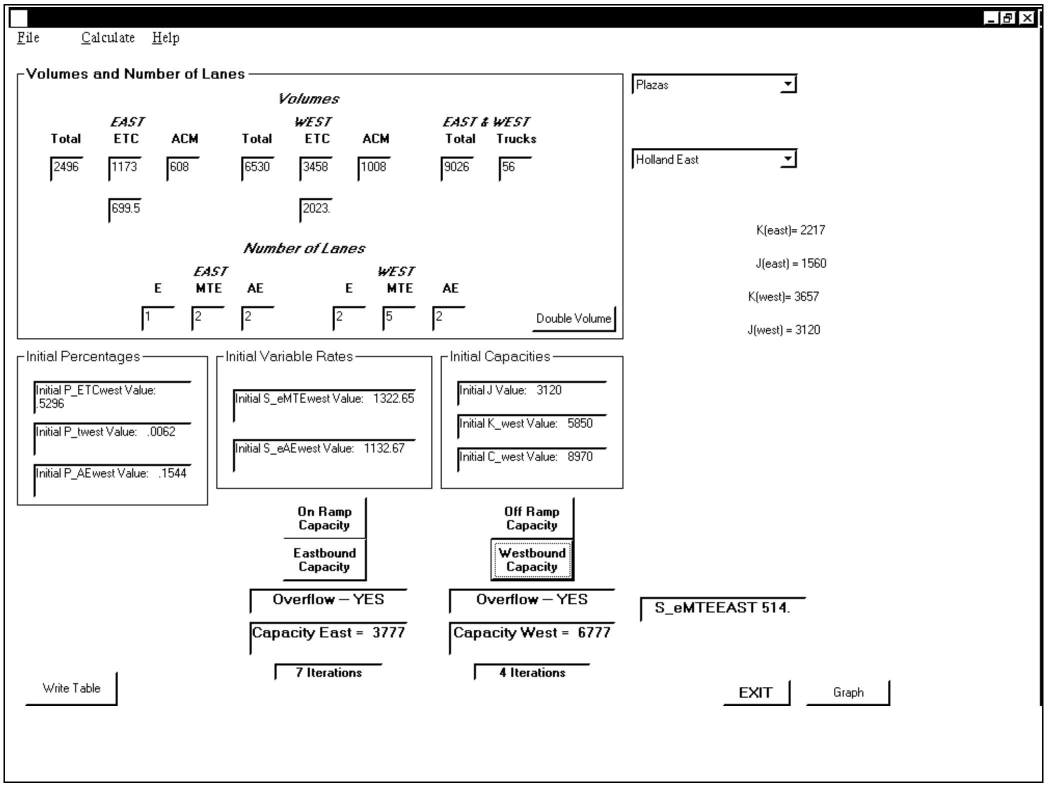

Figure 1. **Screenshot of TNCC Input and Calculation form**

A simplified flow chart of the TNCC decision process is given in Figure 2. It is important to note that a queue formed in any of the service lanes indicates an overflow from that lane. These points in the decision flow indicate a percentage shift throughout a plaza's lanes, altering the program path with each iteration. The percentages apply to incoming volume separated by customer-group.

Toll plaza characteristics required for capacity calculations include number of lanes, configuration by customer group and processing rates of each customer group. (Zarrillo 1999) For the initial version of TNCC, Four categories of customer-groups, manual (M), Automatic Coin Machine (A), manually processed trucks (T) and Electronic Toll Collection (E), were identified. Each group has its own specific processing rate whose value measures within a small definable range under queuing conditions. (Zarrillo, 2000)

Lane configuration is required for initial input. TNCC is currently capable of determining capacities for any of the single-service lanes from the four customer-groups, along with mixed lane configurations AE and MTE. (Zarrillo et al., 1998) The mixed lane MTE offers the traditional manual toll collection service in conjunction with ETC; thus MTE lanes provide service to three customer-groups, M, T and E, a common installation. The mixed lane AE offers toll collection service to ACM users and ETC users. Analytical queuing models that have addressed the issue of *mixed queues* have used similar definitions. (Al-Deek, et al., 1996)

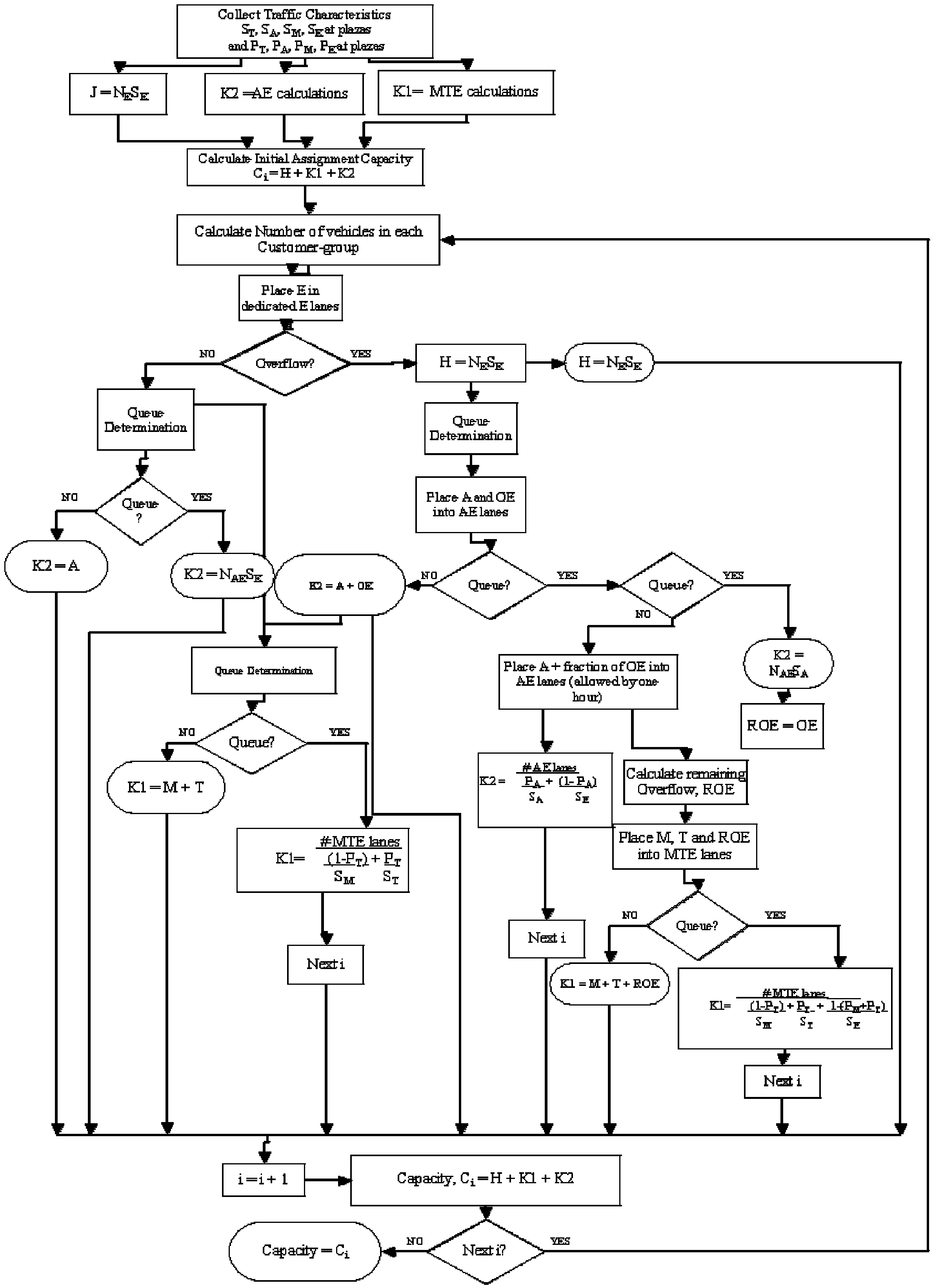

Figure 2. TNCC Logic Flow Diagram

Capacity Calculation Process

The mathematics of the capacity calculation is based on the distribution of customer-group percentages by incoming traffic volume. (Zarrillo, et al., 2001) Customer-group rates for mixed service lanes, MTE and AE, are determined by customer-group percent distribution ratios. When a queue is detected within the calculation process, percentages are shifted to available lanes according to plaza configuration. A queue in a single-service ETC lane indicates E vehicle overflow and remaining E vehicles are shifted first to available AE lanes, then to MTE lanes by convention. (Zarrillo, et al., 1997)

ETC vehicle overflow is critical in determining accurate capacity. At a flow rate of 1560 *vphpl*, the impact of a shift from a dedicated E lane to a mixed AE lane both alters traffic flow and works to reduce overall plaza capacity if a plaza does not have adequate mixed-lane available service. For mixed lanes under queuing conditions, the application of a variable processing rate is applied to ETC vehicles forced to utilize mixed service lanes.

The iterative nature of the calculation process allows for a validation of percent distribution with successive capacity determinations. By keeping with initial percent distributions provided at input, each iteration shifts overflow to appropriate lanes until output agrees with transaction data and rate constraints of customer-groups. (Zarrillo 2000) An absence of overflow simplifies the process and reduces iteration number. To arrive at a final capacity, the following requirements must be met: 1.) 100% of all vehicles should be accounted for in the initial calculation. 2.) No vehicle overflow from single to mixed lanes should remain. 3.) No indicated under-utilization occurring from division of customer-groups should be indicated.

Validation of these constraints is performed following each iterative calculation. Input traffic characteristics are checked for consistency with observations and vehicles are shifted to correct discrepancies. From the data used for the 58 toll facilities in the Orlando network, iteration number varied from one to 22.

Allowances and Assumptions

In capacity calculation for the toll facilities, allowances had to be given relative to the available data. Transaction data provided hourly volumes for all customer-groups and additional volumes for violators. As violators could not be identified per their respective customer group, the number was distributed throughout all groups. Within the toll network, violators generally accounted for less than 2% of the total volume and the allowance was nominal.

Also lacking from transaction data was ETC-enabled trucks separated by direction. That is, the ETC truck volume available was for the entire plaza with a total for both directions. The total ETC truck percentage was thus assigned by assuming a percentage-by-volume-by-direction ratio. For each direction, the percent derived from the entire plaza volume was applied to give a directional volume. The assumption of equal ETC truck percentages in each direction was reconciled by considering total percentages from data were generally less than 5%.

In capacity assessment for the entire toll network, volumes, percent trucks and capacities were given for toll plazas and ramps with toll facilities. Capacities for highway segments without toll facilities had to be calculated according to assumed defaults in the HCM 2000. Thus truck percentages were assigned values of 5% for urban segments and 10% for rural segments.

Generated Capacities Applied to Orlando-Orange County Toll Network

The ability to manipulate input data to simulate incidental occurrences at a toll complex provides means of software and iterative process validation. Through the changing of percentage distribution input values, while maintaining a constant volume, it was possible to predict a change in capacity. Integrating capacity changes to toll network capacities will allow for further analysis of traffic flow throughout the network.

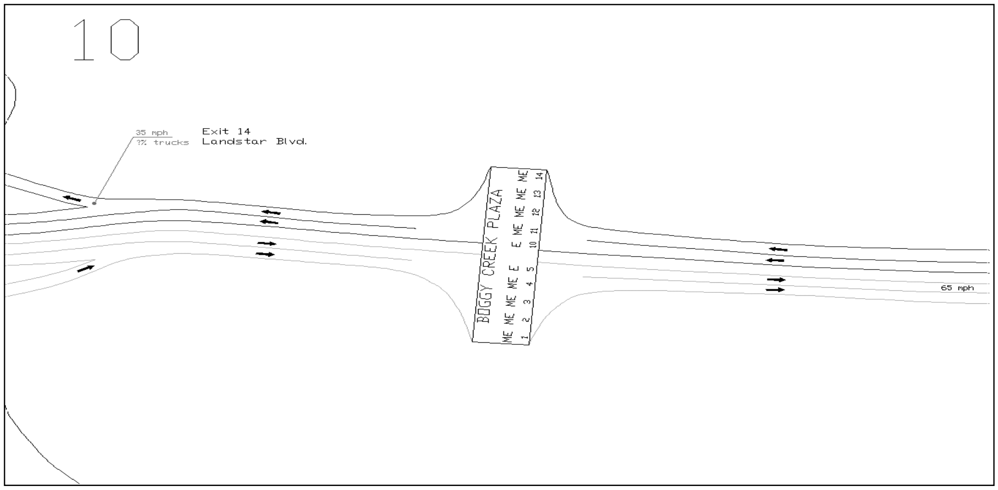

Figure 3. Sample Section of Orlando Toll Network Map with Boggy Creek Main Plaza

The Orlando toll network was mapped using AutoDesk® Mechanical Desktop and GIS ArcView® 8.0. Both software packages allow for multiple layering of data, enabling separation of information for analysis and allowing expansion of input. The highway network was mapped and divided in segments for capacity determination. Capacities were calculated for each segment according to the Highway Capacity Manual 2000. TNCC was then used to furnish capacity and vehicle percentage data for highway segments and ramps with toll facilities. A sample section of the map is given in Figure 3.

A naming convention was developed for highway segments and applied to reflect data **sequentially. The** naming format for highway segments takes the form: "Highway name-Segment number-Entrance or exit ramp and number-Number of lanes-Design speed-Toll facility (PP) or no toll facility (NP)." Capacity information could then be added to both the map and entered in tabular for on a spreadsheet to identify shifts and changes in capacities sequentially. A sample of the capacity tables is given in Table 1.

Shown in the sample table is a bottleneck from segment 528W-04.0-#NA#-2-70-NP to 528W-05.0-#NA#-2-70-PP. TNCC provided the capacity for the BeeLine Main Plaza, while the preceding segment was calculated according to HCM 2000. Though a doubling of lanes occurs prior to entering the plaza, both design speed and plaza configuration results in the lower capacity from segment to segment. Note without the existence of a ramp preceding the plaza, the truck percentage, available from transaction data for the toll facility could be applied to both segments.

Table 1. Sample Capacity Table for Highway 528 Westbound

Segment Type	Section Name	P_T	C (per lane)	Capacity	Toll Facility
E Ramp	528W-03.0-20#N-2-70-NP	0.0500	2300	4263	
Basic	528W-04.0-#NA#-2-70-NP	0.0619	2400	4423	
Plaza	528W-05.0-#NA#-4-30-PP	0.0619	PM	2689	Bee Line Main Plaza
X Ramp	528W-06.0-16#X-3-70-NP	0.0500	2200	6302	
X Ramp	528W-07.0-16SX-1-45-NP	0.0500	2080	1928	
X Ramp	528W-08.0-16NX-1-45-NP	0.0500	2080	1928	

The utility of TNCC for toll network analysis is evident from this simple example. Manipulating input variables, i.e. changing lane configuration or altering customer-group percent distribution, can point out scenarios for lessening a bottleneck or anticipating a change in traffic flow. For instance, the capacity of 2689 *vph* given by TNCC for the BeeLine Main Plaza reflects a configuration of three MTE lanes and one E lane. In altering the configuration to two MTE lanes and two E lanes, TNCC generates a capacity of 1793 *vph*. The lower capacity value is due to under-utilization of the MTE lanes. Thus, the original configuration actually represents the optimal division of E and MTE lanes for the customer-group percent distribution present for this study.

Conclusions

TNCC was applied to the 58 toll plazas in the Orange County, Florida toll network, generating capacities for each. As with the sample from Highway 528, most of the capacities indicated a bottleneck entering a main plaza. For Highways 408, 417 and 528, seventeen of twenty main plazas indicated bottlenecks. As with the sample BeeLine Main Plaza, TNCC could be applied to determine optimal lane configuration for possible alleviation of a bottleneck. The given sample is representative of one of the simpler configurations (four lanes and no preceding ramp segments) and demonstrates how TNCC's capacities are implemented within the broader scope of the entire toll network.

With TNCC, it is possible to determine an optimal lane configuration for an expected customer-group distribution, making the program a useful planning tool. As an analysis tool, TNCC provided information on lane under-utilization and overflow. With the results produced by the program, a dependence on customer-group percent distribution is evident and overall volume dependence is absent. Further comparative analysis is needed to determine a general form of customer-group percent distribution dependence.

TNCC integration with map data tables, along with the visual map allows for quick identification of bottlenecks within the toll network. In its current form, TNCC works well for traffic flow analysis. It is desirable to expand the program's capabilities by increasing the number of customer-groups and to generalize the form of the logic to allow application to toll networks outside the scope of this study. Expansion and modification to these ends is already in progress.

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Appendix I: paper #2 presentation at ASCE's AATT 2002 Conference

Identification of Bottlenecks on a Toll Network of Highways

Marguerite L. Zarrillo[9] A. Essam Radwan[10] Angus Mak[11] Joseph Dowd[12] William Cyr[13]

Abstract

This study demonstrates a strategy for identifying bottlenecks on a network of roadways containing toll facilities. The network is divided into 295 highway segments, 58 of which contain toll facilities. It successfully implements TNCC, the Toll Network Capacity Calculator methodology, to calculate capacities of the 58 highway segments containing toll facilities. The capacities of the remaining 237 highway segments were obtained by the use of traditional capacity calculation methods borrowed from the Highway Capacity Manual 2000. Observed volumes and comparison checks of the Plazas' capacities with the capacities of the highway segments prior to the toll facilities supports the identification of bottlenecks on the network.

Introduction

The Orlando Orange County Expressway Authority, OOCEA, maintains a toll network of roadways in Orange County, Florida. This study divides the toll network, as configured during a typical morning rush hour, that of August 16, 2000, into 295 segments and determines their capacities. Capacities of basic freeway segments, entrance ramp-freeway junction segments and exit ramp-freeway junction segments were computed. Capacities for weaving segments are left for future calculations and consist of two adjacent entrance/exit ramp junction freeway segments. The portion

[9] Ph.D., Assistant Professor, University of Massachusetts Dartmouth, Physics Department, N. Dartmouth, Massachusetts 02747; phone 508-999-9268; FAX 508-999-9115; MZarrillo@UMassD.edu

[10] Ph.D., P.E., Chair, Civil and Environmental Engineering Department, Director, Center for Advanced Transportation Systems Simulation, University of Central Florida, Orlando, Florida 32816-2450; phone 407-823-6340; FAX 407-823-3315; AERadwan@mail.UCF.edu

[11] Student, University of Massachusetts Dartmouth, N. Dartmouth, Massachusetts 02747; phone 508-910-6647; Mak2fl@gis.net

[12] Graduate Student, University of Massachusetts Dartmouth, N. Dartmouth, Massachusetts 02747; phone 508-999-6647; JHDowd@aol.com

[13] Student, University of Massachusetts Dartmouth, N. Dartmouth, Massachusetts 02747; phone 508-999-6647; U_WCyr@UMassD.edu

of the network under study consists of three highways: the 408 or East-West Expressway, the 528 or Bee Line Expressway, and the 417 or Central Florida Greenway, see Figure 1. The two major interchanges connecting these highways are the 408/417 interchange and the 528/417 interchange. Another heavily used interchange is the 408 connection with Interstate 4 in downtown Orlando.

A section of roadway to which more demand is delivered than can be processed is defined as a bottleneck. (Roess et al., 1998) Traffic flowing out of a highway segment with a large capacity into a segment with a smaller capacity may approach a bottleneck situation whenever volumes in the first segment exceed the capacity of the second. When this occurs, queues build up into the first segment, increasing densities, decreasing speeds and resulting in excessive delays.

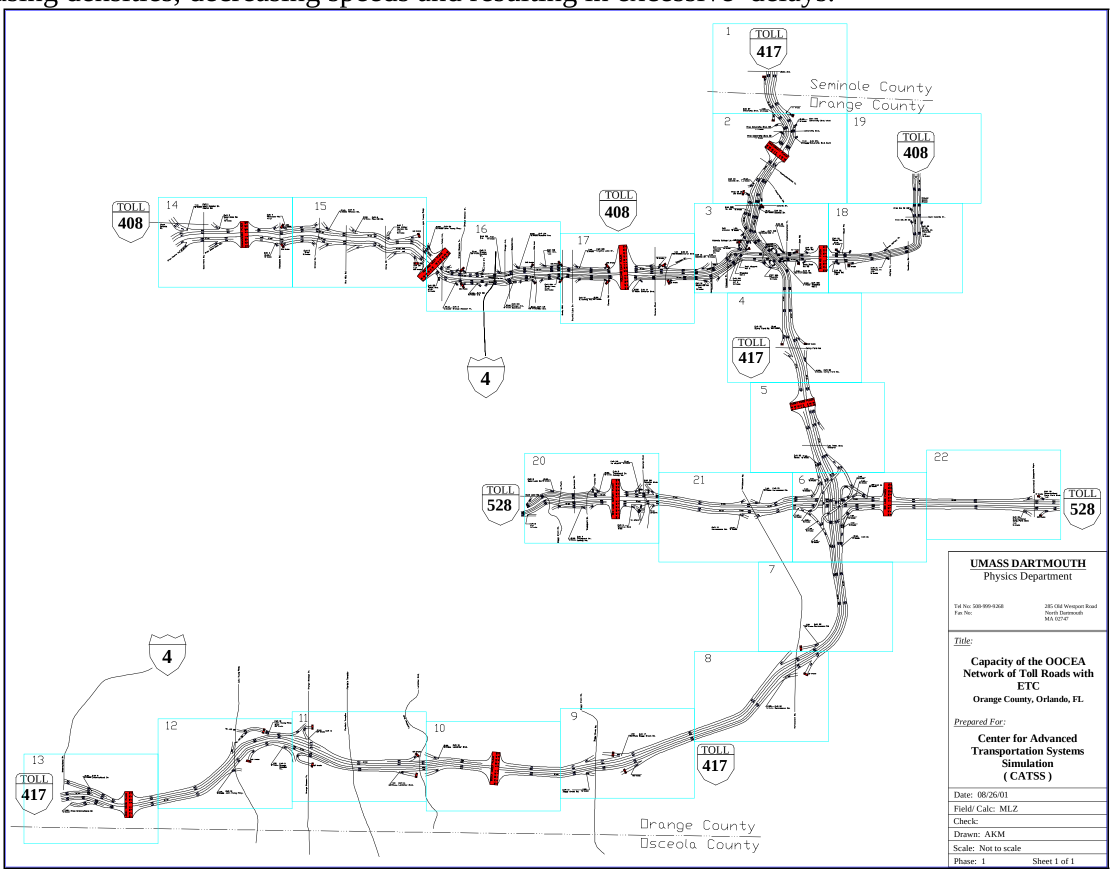

Figure 1. Toll Road network under study, not to scale.

In this study, comparisons of the capacities of adjacent segments on the network resulted in the identification of potential bottleneck situations. (Zarrillo et al., 2001) (Zarrillo et al., 2002) Toll transaction data of the morning rush hour on August 16, 2000, provided the volumes and the traffic characteristics such as percent trucks. Interpolation of percent trucks between toll facilities was used to determine percent trucks on segments between toll facilities. The original geometric plans and profile sheets provide roadway and plaza characteristics required in the capacity calculations. Videotapes taken of the toll network on August 16, 2000 captured the lane configurations of all 58 plazas. Videotapes of vehicles departing the toll facilities also provided the processing rates. (Zarrillo et al., 1999) (Zarrillo et al., 1999) (Zarrillo, 2000) Vehicles were categorized into customer-groups according to this rate. Both the type of toll collection service and the type of vehicle itself influenced the processing rate.

Segmenting the Network and Segment Identification

Freeway facilities are composed of connected segments consisting of basic freeway segments, ramp segments, and weaving segments. In addition, the network may contain toll facility segments. In this study, only a portion of the OOCEA's network was analyzed. Of the 295 segments, 58 were toll facility segments.

Every segment was assigned an identification number, ID#. The ID# consisted of six names/numbers connected by dashes: the Highway Number & Direction – Segment Number – Exit or Entrance Number linked to the Segment – Number of Lanes on the Segment – Design Speed of the Segment – whether a Plaza exists on the Link. For computer programming purposes, the pound sign fills in spaces so that there are always four spaces in the first three names. For example, segment 417S-01.0-37#X-2-65-PP is the first segment, 01.0, on the freeway traveling south on the 417. There are 2 lanes on this segment and the design speed is 65 miles per hour. The third name in the identification number, 37#X, indicates that Exit 37 is linked to this segment and leads drivers off of the 417. If there is an entrance ramp associated with Exit 37, then the X for exit ramp becomes an N for entrance ramp. In other words, the nomenclature becomes 37#N. If the exit or entrance number is 14B, then the nomenclature becomes either 14BX or 14BN. If there is no exit or entrance associated with a segment, then the nomenclature for the third name of that segment is #NA#. In this example, the exit ramp connected to this segment also contains a toll ramp plaza, indicated by the last name PP. If a plaza is situated on the segment, the identification will also carry PP in the last name. This becomes NP for all other cases. In order to facilitate bottleneck identification, these segments, their ID# and their capacities were placed on a large 42-inch by 66-inch map similar to Figure 1.

Capacity for Segments with Toll Facilities

The Toll Network Capacity Calculator, TNCC, methodology determines the optimum number of vehicles and/or passenger car equivalents that a toll collection facility can process in one hour. (Zarrillo et al., 2002) There were four customer-groups identified and their rates at which the toll was collected for each group was measured. (Zarrillo et al., 1997) (Zarrillo, 1998) (Zarrillo et al., 1998) Users of Electronic Toll Collection, ETC, were processed at a fast 1560 vehicles per hour, vph. Automatic Coin Machine users, A, were processed at 618 vph. There were two types of manual users: those in semi-trucks, T, were processed at a slow rate of 138 vph and those, not in semi-trucks, M, were processed at 498 vph. (Zarrillo et al., 2001). A combination of the toll facility's configuration, the percent distribution of customer-groups and the processing rates for each of the customer-groups provide the input required for the capacity calculation of the toll facility segments. The results of the calculations meet constraints set by the characteristics of the arriving traffic. For instance, variables such as the percentage of arrivals that were ETC patrons and the percentage of arrivals that were semi-trucks requiring non-ETC services influenced the plazas' capacities. Overflow of ETC users from the dedicated ETC lanes into the mixed lanes was also a factor. (Zarrillo, 2000) (Zarrillo et al., 2002) Capacity was independent of hourly arrival volumes. Videotapes and transaction data at the 58 plazas, on the morning rush hour of August 16, 2000, provided necessary input. The calculated capacity of a plaza becomes an optimum value when the chosen plaza lane-configuration best matches the distribution of arrivals among the customer-groups. Capacities of the toll facilities were also calculated in units of passenger car equivalents per hour, pcph. The heavy vehicle and the driver population adjustment factors are discussed in the next section.

Capacity for Segments without Toll Facilities

Traditional methods, taken from the Highway Capacity Manual 2000, HCM, were used to calculate capacities of the segments between the plazas. The number of lanes was constant along any one segment, as was the lane width and right lateral clearance. The heavy vehicle factor and driver population adjustment factor were also uniform within each segment. Freeway segments did not include more than one entrance or exit. Entrance ramp freeway segments included the region 1500 feet downstream of the on-ramp. Exit ramp freeway segments included the region 1500 feet upstream of the off-ramp. No regions were found in which further division would be necessary where there were speed limit changes or whenever grades were larger than 2% and prevailed a distance longer than a quarter of a mile.

Figure 2 is a sample view of the network that contains a basic freeway segment, identification name/number 417S-21.0-#NA#-2-65-NP. Equation (1) was used for the capacity calculation of the basic freeway segments in passenger cars per hour, pcph, for E Level of Service, LOS. It is the product of the number of lanes, N, and the Maximum Service Flow, MSF, for one lane under ideal conditions listed in the HCM 2000. Multiplying this by the heavy vehicle factor, f_{HV}, and the driver population factor, f_P, result in the Service Flow, SF, rate in vph, as illustrated by equation (2). SF is the Service Flow rate during the peak 15 minutes for LOS E.

Terrain is best described as somewhere between level and rolling. This is because some of the time, heavy vehicles on the basic freeway segments are able to maintain the same speed as passenger cars. In addition, the freeway segments consists mostly of terrain that includes short grades of no more than 2%. Thus, the passenger car equivalent for a heavy vehicle is taken to be a value of 2.0. Finally, most drivers are commuters and familiar with the facility so that a value of 1.0 is taken for the driver population factor, f_P.

The ideal freeway Free Flow Speeds, FFS, of 70 mph and 75 mph are used. After corrections are applied, appropriate Speed Flow Curves for basic freeway segments determine the Maximum Service Flow, MSF, rate, for LOS E. The lanes are 12 feet wide so there is no need for a lane width adjustment. In addition, no adjustments are made for right lateral clearance. There are few obstructions and those are continuous and drivers have become accustomed to them so that their influence on traffic flow is negligible. On some of the basic freeway segments, however, a correction was necessary due to the number of lanes. Two, three and four lanes on a basic freeway segment reduces the ideal FFS by 4.5, 3.0 and 1.5 mph respectively. In addition, a reduction in ideal FFS is necessary due to interchange density. These corrections are taken from the HCM 2000.

$$C = N^* MSF = N^*(10^*FFS+1700) \quad \text{(pcph)} \quad (1)$$

$$SF = C^*f_{HV}^*f_P = N^* MSF^*f_{HV}^*f_P = N^*(10^*FFS+1700)^*f_{HV}^*f_P \quad \text{(vph)} \quad (2)$$

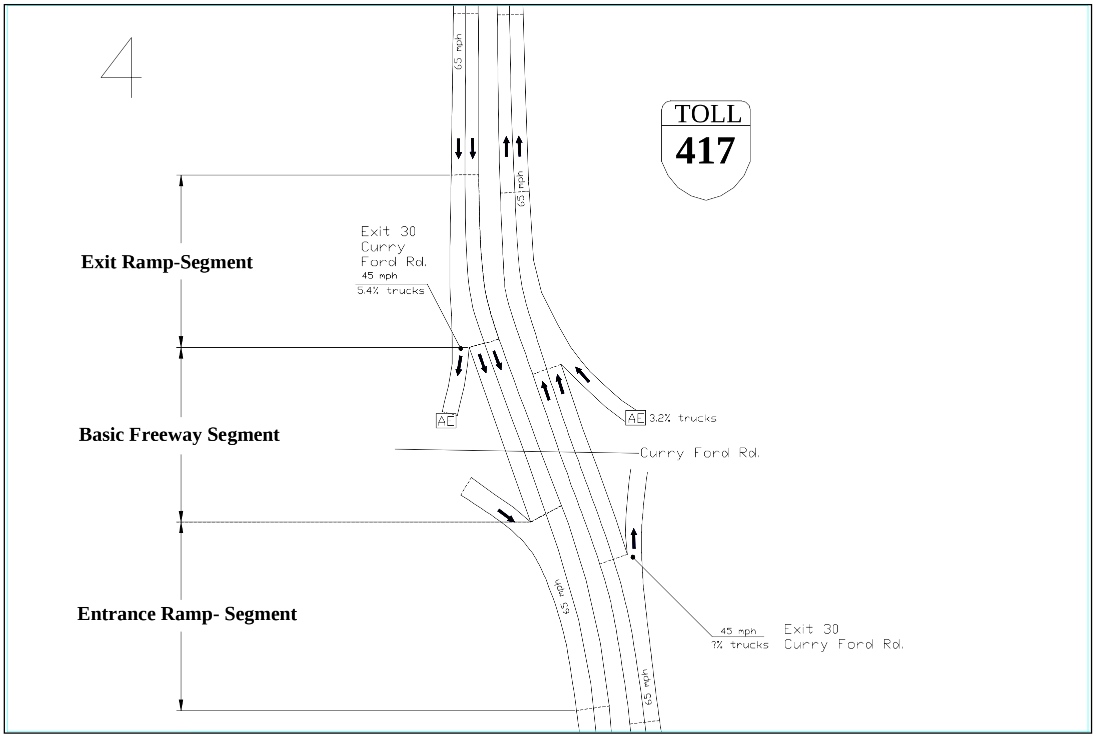

Figure 2. Sample view of the network containing typical freeway segments.

Possible Bottlenecks located on the East West Expressway, 408

The Holland West Main Plaza is located on the 408 west of Orlando. Table 1 lists results for the segments before and after the Plaza. Identification numbers distinguish the segments. Capacities of the Holland West Main Plaza are based on morning rush hour lane configurations and traffic characteristics. According to the calculations, there exists the possibility of a bottleneck before the Holland West Main Plaza in either direction in the morning rush hour. Eastbound volumes during the morning rush hour from 7 to 8 a.m. of August 16, 2000, were 3473 vph, slightly below the Plaza's capacity of 3882 vph. If, however, the volumes surpass the Service Flow rate of 3882 vph in the segment prior to the Plaza, then the Plaza will act as a bottleneck. This scenario is a real possibility because the capacity of the segment prior to the Plaza has a larger capacity of 4480 vph and because traffic consists of commuters on their way to work traveling east toward downtown Orlando. In addition, westbound volumes may reach the Service Flow rate of 4472 vph in the segment prior to the Plaza. Although this again exceeds the Plaza's capacity of 4353 vph, there is very little chance of volumes exceeding the Plaza's capacity. This is because the Plaza in the westerly direction is currently not functioning anywhere near capacity in the morning; volumes of 2289 vph were observed on the same morning from 7 to 8 a.m. and there was no observed congestion at the Plaza in the westerly direction.

Table 1. Bottlenecks before and after the Holland West Main Plaza

Segment-Type	Identification	SF (vph) at LOS E Capacity*f_{HV}*f_P
Segment prior to plaza	408E-16.0-08AN-2-45-NP	4480
Holland West Main Plaza	408E-17.0-#NA#-6-30-PP	3882
Segment following plaza	408E-18.0-08BX-2-55-NP	4482
Segment prior to plaza	408W-44.0-08BN-2-45-NP	4472
Holland West Main Plaza	408W-45.0-#NA#-6-30-PP	4353
Segment following plaza	408W-46.0-08AX-2-55-NP	4471

The Holland East Main Plaza is also situated on the 408, but on the east side of Orlando. Table 2 lists a portion of the capacity results for the segments before and after the Plaza. Bottlenecks are a real possibility in the traffic traveling west through the Plaza; morning volumes were 6530, quite near the Plaza's capacity of 6777 vph. In addition, the feeder segment prior to the Plaza has a larger capacity of 9114 vph.

The segments following the Plaza had increasing capacities of 6791 followed by 9110 vph. This was required due to the Conway Road entrance Plaza with capacity 1257 vph also feeding traffic into this later segment.

In the easterly direction, although the calculations indicate there is a possibility of a bottleneck, it is unlikely due to the low observed morning volume of 2496, far from the Plaza's capacity of 3777 vph. As previously noted, most traffic consists of morning commuters on their way to work traveling west toward downtown Orlando.

Table 2. Bottlenecks before and after the Holland East Main Plaza

Segment-Type	Identification	SF (vph) at LOS E Capacity*f_{HV}*f_P
Segment prior to plaza	408W-26.0-14SN-4-55-NP	9114
Holland East Main Plaza	408W-27.0-#NA#-9-30-PP	6777
Segments following plaza	408W-28.0-#NA#-3-55-NP	6791 + 1257
Segment following	408W-29.0-13#N-4-55-PP	9110
Segment prior to plaza	408E-35.0-#NA#-3-55-NP	6806
Holland East Main Plaza	408E-36.0-#NA#-5-30-PP	3777
Segment following plaza	408E-37.0-14#X-3-55-NP	6806

A Possible Bottleneck Situation on the Bee Line Expressway, 528

The Bee Line Main Plaza is located on the Bee Line Expressway, 528, just south of Orlando. Table 3 lists results for the segments before and after the Plaza, one side only. According to the calculations, there exists the possibility of bottleneck in the easterly direction at the Bee Line Main Plaza in the current configuration; the segment prior to the Plaza has a very large capacity of 6290 vph, larger than the Plaza's capacity of 2763 vph. However, there is currently no need for concern, two lanes at the Plaza are not in use due to low volumes. In fact observed volumes of 840 vph from 7 to 8 a.m. on August 16, 2000, are quite a bit lower than the Plaza's capacity. Also, if future volumes increase, opening up the two unused lanes would substantially increase the Plaza's capacity, thus alleviating a potential bottleneck.

Table 3. Bottleneck on the eastbound side of the Bee Line Main Plaza

Segment-Type	Identification	SF (vph) at LOS E Capacity*f_{HV}*f_P
Segment prior to plaza	528E-24.1-#NA#-3-70-NP	6290
Bee Line Main Plaza	528E –25.0-#NA#-4-30-PP	2763
Segment following plaza	528E -26.0-#NA#-2-70-NP	4151

A Possible Bottleneck Situation on the Central Florida Greenway, 417

The Curry Ford Main Plaza is located on the Central Florida Greenway, 417, circling around Orlando. Table 4 lists results for the segments before and after the Plaza, one side only. According to the calculations, there exists the possibility of a small bottleneck in the southerly direction at the Curry Ford Main Plaza in the current configuration. This is due to the Plaza's capacity of 4022 vph being slightly smaller than the capacity of the segment prior to the Plaza, 4356 vph. Observed volumes, however, from 7 to 8 a.m. on August 16, 2000, were quite a bit lower, 2929 vph. Thus, a bottleneck does not exist and there is little potential of developing one.

Table 4. Bottleneck on the southbound 417 due to Curry Ford Main Plaza

Segment-Type	Identification	SF (vph) at LOS E Capacity*f_{HV}*f_P
Segment prior to plaza	417S-23.0-#NA#-2-65-NP	4356
Curry Ford Main Plaza	417S-24.0-#NA#-5-30-PP	4022
Segment following plaza	417S-25.0-#NA#-2-65-NP	4356

Conclusions

This study has demonstrated a strategy for identifying bottlenecks on a network of roadways containing toll facilities. Six locations on the network were illustrated. In four locations there was very little potential of a bottleneck situation occurring due to low volumes. At the other two locations, easterly traffic flow through the Holland West Main Plaza and westerly flow through the Holland East Main Plaza, there was a greater chance of a bottleneck. Morning rush hour volumes approached the capacity limits of the Plazas. In addition, the capacity of the highway segment prior to the Plaza exceeded the Plaza's capacity, so there was a real possibility of a bottleneck occurring on other days.

This study has successfully implemented the TNCC methodology for calculating the capacities of highway segments containing toll facilities. The remaining capacities of highway segments on the network under study used traditional capacity calculation methods borrowed from the HCM 2000.

Future research may expand the network analysis to include portions of Interstate 4 through downtown Orlando. Future research may also look at alternate traffic scenarios to predict shifts in bottleneck locations on the network. Typical scenarios may simulate the occurrence of a planned regional special event, an unexpected incident or a traffic disruption due to planned roadway construction.

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