Facility Performance Model Enhancements for Multimodal Systems Planning: Part I

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16. Abstract

This report presents the results of Part I of a research project carried out by the University of Florida Transportation Research Center for the Florida Department of Transportation. The entire project includes four specific and somewhat independent research tasks determined by the Systems Planning Office to be critical to its future efforts to promote uniform and defensible procedures for the planning level assessment of performance on transportation facilities in Florida. Part I of this project includes Tasks 1, 2 and Phase I of Task 3. Phase II of Task 3 and Task 4 will be completed under a separate follow-on research contract.

Task 1 addresses the initial development of the new LOSPLAN suite of software programs for the 2002 FDOT Quality/Level of Service Handbook. Task 2 addresses the investigation, by microscopic simulation, of some alternative service measures for rural freeway LOS. Phase I of Task 3 addresses the conducting of a field survey on motorist opinions about the factors that affect traveler perceived quality of service on rural freeways.

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Facility Performance Model Enhancements for Multimodal Systems Planning (Part I)

This report presents the results of Part I of a research project carried out by the University of Florida Transportation Research Center for the Florida Department of Transportation. The entire project includes four specific and somewhat independent research tasks determined by the Systems Planning Office to be critical to its future efforts to promote uniform and defensible procedures for the planning level assessment of performance on transportation facilities in Florida. Part I of this project includes Tasks 1, 2 and Phase I of Task 3. Phase II of Task 3 and Task 4 will be completed under a separate follow-on research contract.

A brief overview of each task is given below. The remainder of this report contains the detailed outcomes of each task.

Task 1. Update Service Volume Table Models and Software for Two-Lane Uninterrupted Highways, Multi-Lane Uninterrupted Highways and Isolated Signalized Intersections

The 1998 LOS Handbook includes Lotus spreadsheets that generate service volume tables for:

- Rural and urban two-lane uninterrupted highways
- Rural and urban multi-lane highways
- Signalized arterials

These tools were developed several years ago and are in need of the following updates and enhancements for inclusion in the 2002 LOS Handbook edition.

- Update the computational models to implement the HCM 2000 procedures.
- Convert the model logic from Lotus spreadsheets to executable Windows™ programs.
- Expand the functionality to include direct LOS computations for specific inputs in addition to the present service volume table-generating features.
- Establish the credibility of the results by comparison with other programs/models.

The principal product of this task was the computational software, all of which has been delivered to the FDOT for distribution to state and local agencies. The design, development, and evaluation of this software are presented in the 'Task 1' section of this report.

Task 2. Development of Preliminary LOS Criteria and Thresholds for Rural Freeways.

The HCM applies the same criteria and thresholds for determining the LOS on both urban and rural freeways. The FDOT has found this condition difficult to apply in Florida because of the widely held belief that drivers on rural freeways view the quality of service from a different perspective than those on urban freeways. As a preliminary step towards changing the LOS criteria, detailed simulation studies were carried out to establish the feasibility of a field data collection project, and to provide guidelines for the conduct of such project.

The specific objectives of this task were to establish several simulation scenarios and process the second-by-second data for each scenario with traffic volumes varying from near zero to the full capacity of the facility. The properties of each scenario included such parameters as number of lanes, free-flow speed, traffic composition, driver characteristics, etc.

The results of this task are contained in the section of this report labeled 'Task 2'.

Task 3. Development and Validation of a Procedure for Estimating LOS on Rural Freeways

The purpose of this task is to build upon the efforts of Task 2, and eventually develop specific recommendations for rural freeway LOS criteria and thresholds, and the documentation of those criteria, supported by empirical data, in a form suitable for presentation to the Highway Capacity and Quality of Service Committee.

The first phase of this task was focused on performing a field survey on motorist opinions about the factors that affect traveler perceived quality of service on rural freeways. The results of this phase are to be used to guide the research for Phase II that will culminate in specific recommendations for rural freeway LOS criteria and thresholds. Phase II of this task will be conducted under a separate follow-on research contract.

The results of Phase I of this task are contained in the section of this report labeled 'Task 3, Phase I'.

Task 1

Updated Procedures for Florida Department of Transportation Planning Level Software Tools

January 2002

Introduction

The Florida Department of Transportation (FDOT) began using LOTUS 1-2-3 spreadsheet templates developed by Polytechnic University to implement the 1985 HCM at a planning level beginning in 1987. By 1989, FDOT was using a combination of spreadsheets and internally developed stand-alone programs for all types of roadway analyses throughout the state. In 1990, the predominant preference of users was to convert all of the programs to spreadsheets because that allowed users to see the deriving formulas and calculations. By 1992, Polytechnic and FDOT had developed eight spreadsheet programs.

The FDOT's statewide Level of Service (LOS) Task Team also felt the need to develop separate techniques for undeveloped and developed situations for uninterrupted flow two-lane and multilane facilities because of Florida's experiences in using the HCM techniques in the Florida Keys and elsewhere. These uninterrupted flow highway spreadsheet programs developed maximum service volume tables and were labeled R2LN_TAB, U2LN_TAB, RMUL_TAB and UMUL_TAB based on location and number of lanes. These four spreadsheet templates essentially remained the same in FDOT's 1995 and 1998 Level of Service Handbooks.

Throughout an approximately 10-year period, FDOT's spreadsheet programs were the mainstay of Florida's highway planning level of service efforts. Nevertheless, by 1998 the arterial spreadsheet began to push the limits of spreadsheet capabilities and LOTUS 1-2-3 had lost a significant amount of market share to other competing spreadsheet programs. In anticipation of the HCM2000 publication, FDOT decided to completely update and enhance the programs, reduce the eight programs to three, and make them stand-alone executable programs.

These three new programs were developed with an object-oriented programming language to run under the Windows™ operating system. The programs were named ARTPLAN, FREEPLAN, and HIGHPLAN. Collectively, the three FDOT planning level software programs are grouped under the name LOSPLAN. ARTPLAN performs arterial facility analysis, FREEPLAN performs freeway facility analysis, and HIGHPLAN performs two-lane and multilane highway facility analysis. Each program and its corresponding analysis methodologies have been incorporated into FDOT's 2002 Quality/Level of Service Handbook.

The three software programs have two major LOS calculating features. First, each calculates the LOS for the facility being analyzed and also shows the calculated performance and service measures. Second, each calculates three service volume tables: hourly volumes in the peak direction, hourly volumes in both directions, and annual daily traffic volumes. Thus, based on roadway and traffic characteristics (and in the case of arterials, control characteristics) each of the programs has the capability of calculating the LOS for a facility (and its segments) and generating service volume tables. They can be used at a generalized planning level with numerous defaults or at a conceptual planning level with specific roadway, traffic and control inputs.

The remainder of this task report describes of the three LOSPLAN component programs in more detail.

ARTPLAN

ARTPLAN is the LOSPLAN component program that performs analysis on signalized arterial streets. The computations are based on the concepts contained in HCM [1] Chapter 10 and on the procedures prescribed by HCM Chapter 15. ARTPLAN performs a separate analysis for four different modes of travel, including automobiles, pedestrians, bicycles and buses. A maximum of nine segments, usually terminated by a signalized intersection may be included in each analysis. The automobile mode properties associated with each segment include:

- Segment length,
- Cycle length for the terminating signal
- g/C ratio for the terminating signal
- AADT
- Hourly volume
- Percent turns from exclusive lanes
- Arrival type
- Number of through lanes and
- Free-flow speed, that defaults to a value 5 mph greater than the posted speed.

The directional hourly volumes are computed from the AADT volumes using globally specified values of the K factor, D factor and peak-hour factor. The selected arterial class and area type determine default values for these factors. Other arterial inputs such as median type, existence of left turn lanes and arterial class are applied globally to the whole facility.

The screen display organization for the ARTPLAN automobile mode is illustrated in Figure 1. Separate data input/edit screens are provided for the overall facility data and for the segment-specific data. The results are also presented in two screens. The first displays the segment and arterial performance measures reflecting the currently entered data. The second displays the service volume tables for arterials with 1-4 through lanes in each direction. Note that the graphics presented in Figure 1 are intended to show the schematic organization of the screens, and are not legible at the level of detail required for a complete understanding of the data. Full size screen reproductions may be found in Appendix A.

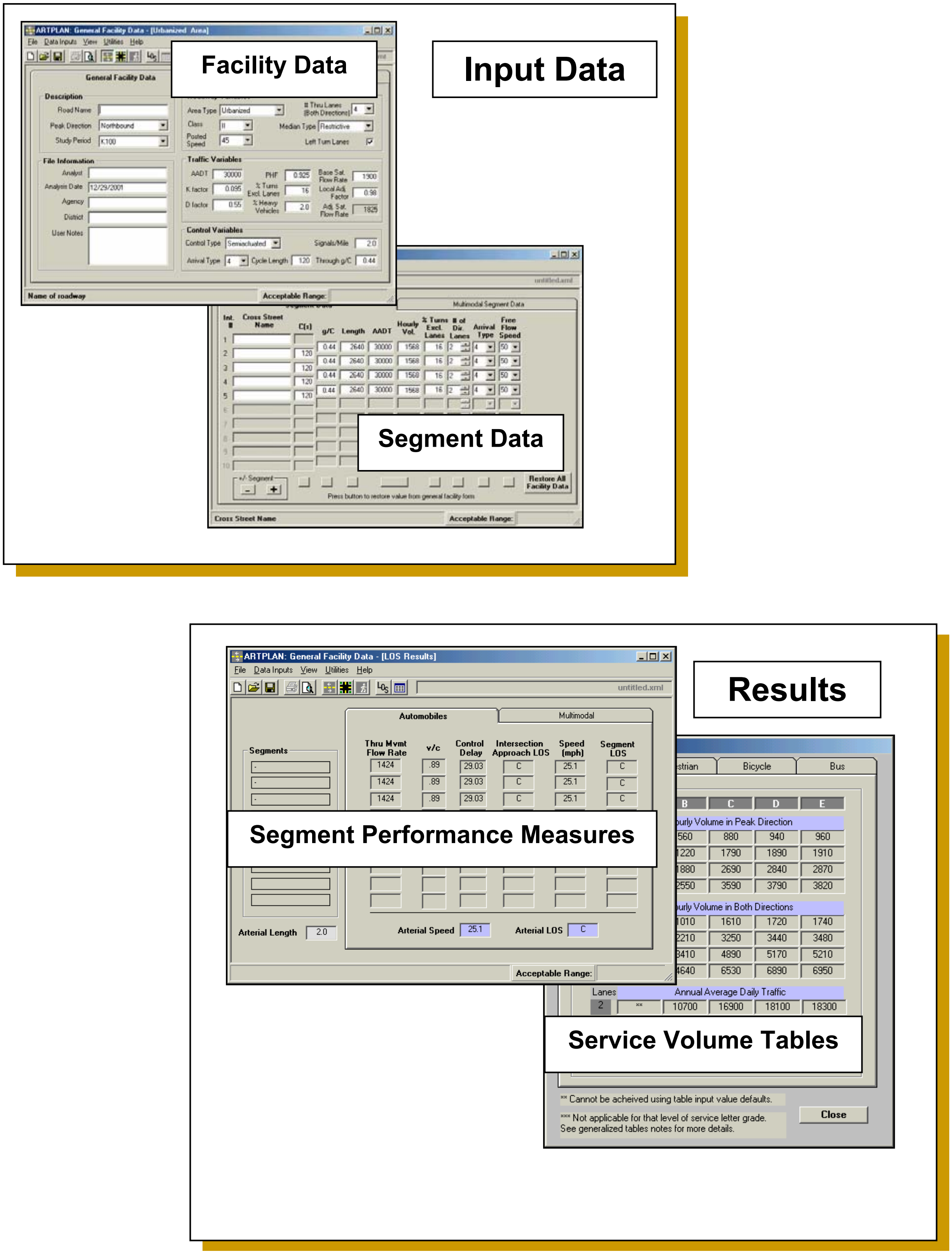


Figure 1. Screen Display Organization for ARTPLAN (Automobile Mode)

Supplemental screens are provided for the other modes of operation, as illustrated in Figure 2. The additional inputs required for pedestrians, bicycles and buses include:

- Existence of a paved shoulder or bicycle lane,
- Outside lane width,
- Pavement Condition,
- Type of sidewalk/roadway separation,
- Existence of sidewalk/roadway protective barrier,
- Existence of obstacles to bus stop,
- Bus service frequency and
- Bus span of service.

Global default values entered on the multimodal facility data screen are transferred to the segment-specific multimodal screen, where each value may be edited to reflect the conditions on a specific segment. Because segments are often long and their properties are not always homogeneous for pedestrians (e.g., a sidewalk covering a portion of a segment) each segment may be divided into a maximum of three sub segments for pedestrians. Each sub segment may have different properties assigned.

The presentation of results is similar to the automobile mode. The multimodal segment results are presented on one screen, and the service volume tables are presented on separate screens for each mode. Service volumes are computed for the bicycle and pedestrian modes as a function of the number of through lanes. The transit level of service is a function of the bus service frequency and is independent of the number of through lanes on the facility.

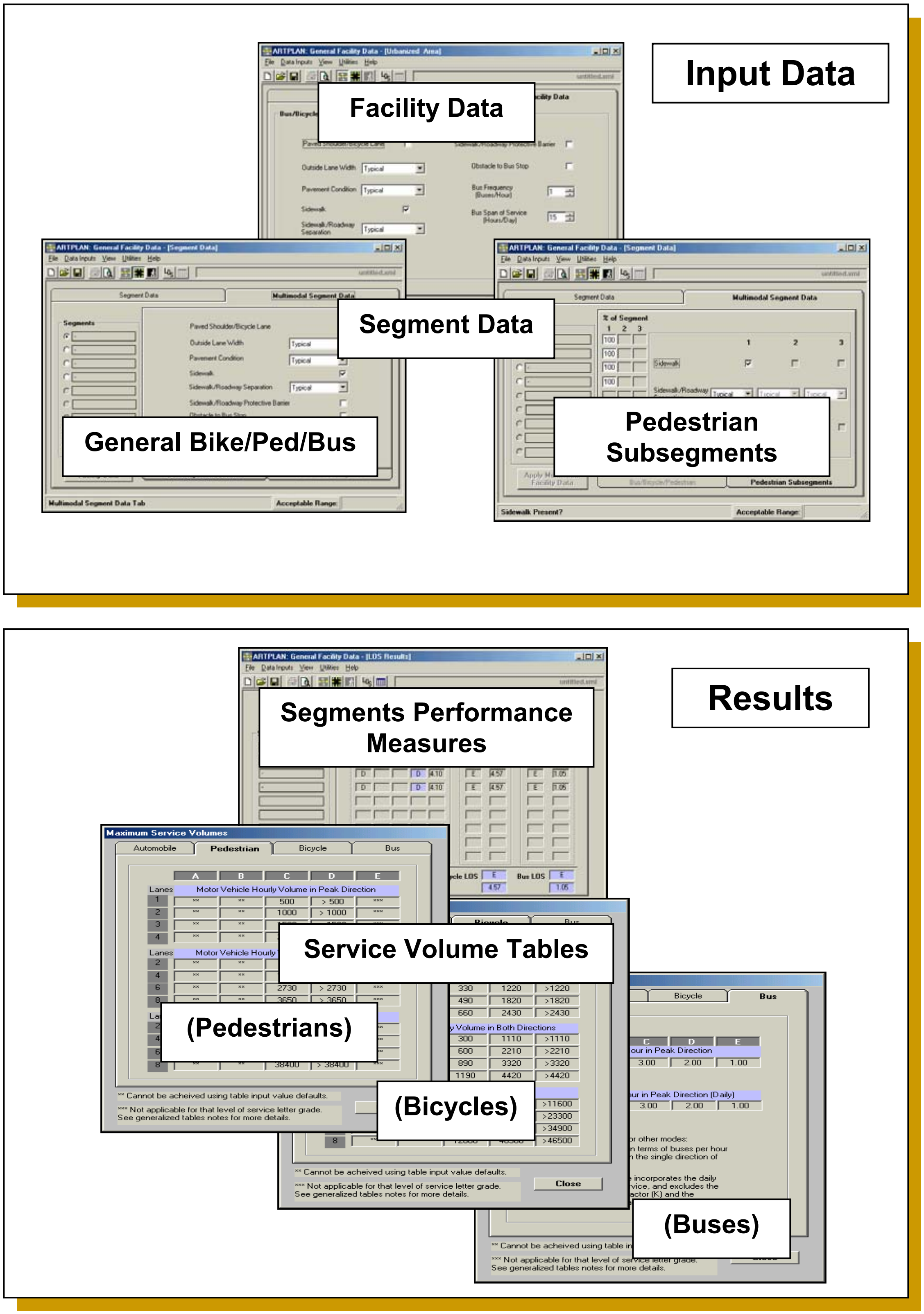


Figure 2. Screen Display Organization for ARTPLAN (Multimodal)

HIGHPLAN

HIGHPLAN is the LOSPLAN component program that performs analysis on two-lane and multilane highways. The computations are based on the concepts contained in HCM [1] Chapter 12 and on the procedures prescribed by HCM Chapter 20 for two-lane highways and 21 for multilane highways. HIGHPLAN is much simpler in concept than ARTPLAN because it deals only with the automobile mode and it does not break the facility into segments.

The simplicity of HIGHPLAN is evident in the screen display organization illustrated in Figure 3. HIGHPLAN has only two screens, one for facility data and LOS results, and another for the service volume tables. The input data include roadway and traffic variables, which are essentially the same as ARTPLAN to the extent that they apply (e.g., none of the signal operating parameters applies to open highways). The type of terrain (level or rolling) is required for both two-lane and multilane highways. Information on exclusive passing lanes and no passing zones is also required for two-lane highways:

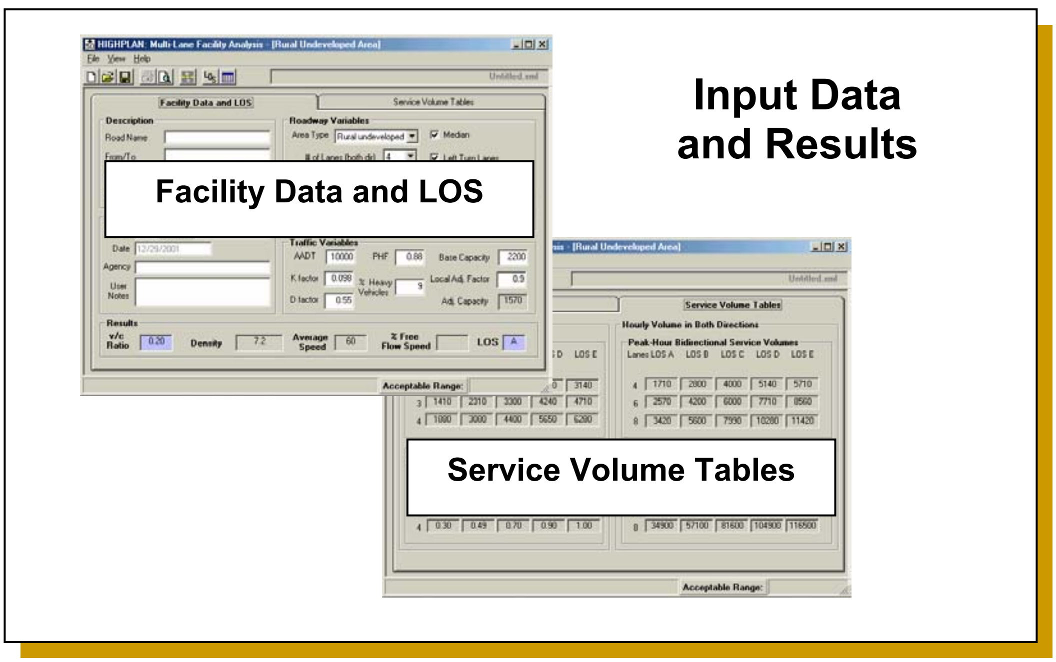


Figure 3. Screen Display Organization for HIGHPLAN

FREEPLAN

FREEPLAN is the LOSPLAN component program that performs analysis on freeway facilities. The computations are based on the concepts contained in HCM [1] Chapter 13 and on the procedures prescribed by HCM Chapter 23, 24 and 25 for basic freeway segments, freeway weaving and ramp operations, respectively. FREEPLAN deals only with the automobile mode, and is therefore able to avoid the complications of multimodal inputs, computations and results. It accommodates a maximum of 20 segments in each analysis.

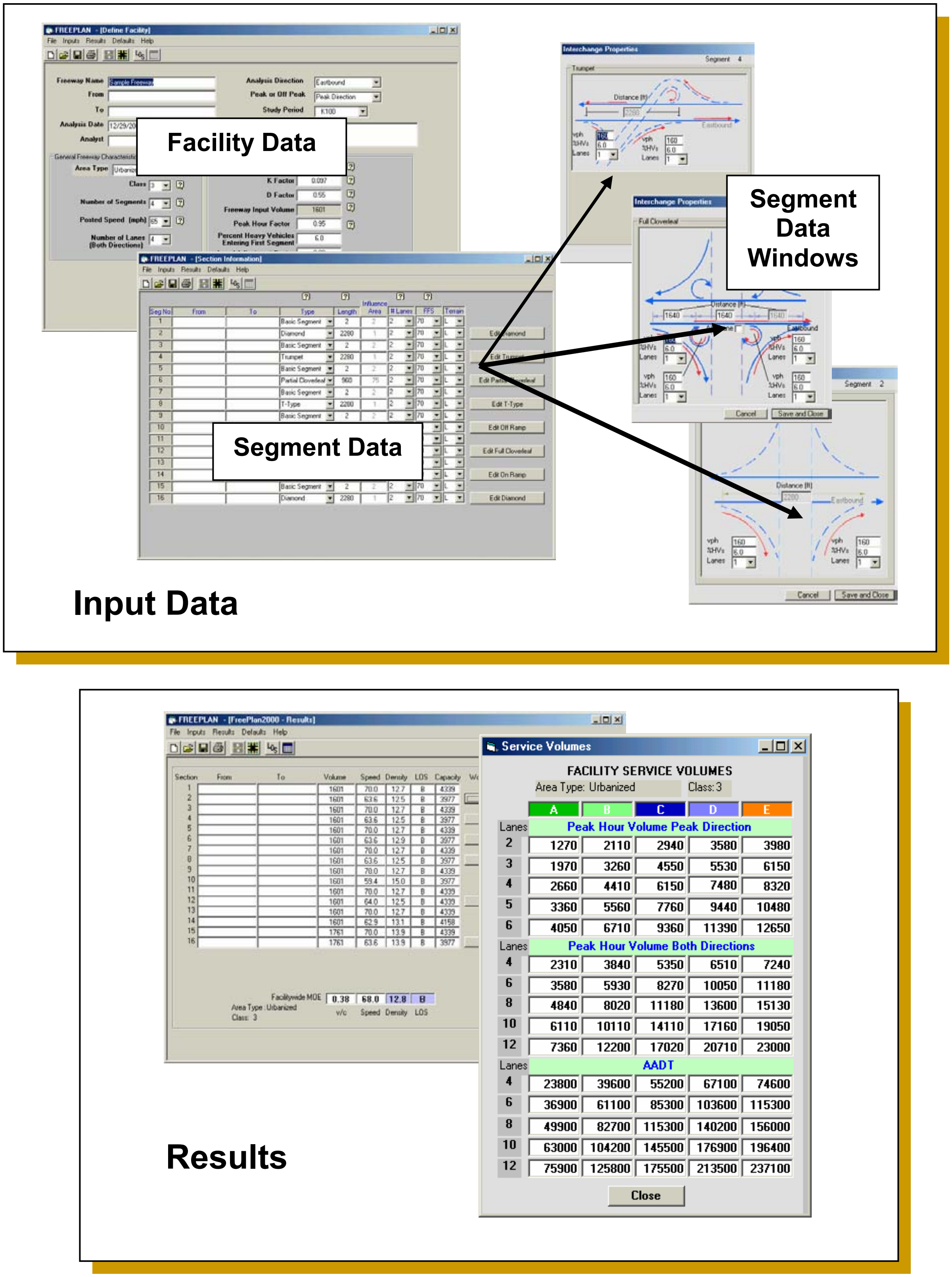
Like ARTPLAN, the FREEPLAN input data are organized into separate screens for facility data and segment-specific data. The facility data are essentially the same as ARTPLAN, but the segment specific data are substantially different. The screen display organization for FREEPLAN is illustrated in Figure 4. Each FREEPLAN segment may be assigned to one of the following types:

- Basic freeway segment
- Various types of interchange
- Partial or full cloverleaf
- On ramp
- Off ramp

Each of the segment types has its own special data entry window because different segment types have slightly different data requirements. The display of results follows the conventional LOSPLAN scheme involving one screen for the segment and overall LOS results and a separate screen for the service volume tables.

Additional Program Details

Additional details on all of the LOSPLAN component programs are provided in the following three appendices: Appendix A presents full views of all of the data entry and edit screens. Appendix B describes the data definitions for each program. Appendix C contains a paper presented to the Transportation Research Board (TRB) to describe the planning level adaptation of the HCM 2000 procedures for performance evaluation of two-lane highways.



Lanes	A	B	C	D	E
	Peak Hour Volume Peak Direction				
2	1270	2110	2940	3580	3980
3	1970	3260	4550	5530	6150
4	2660	4410	6150	7480	8320
5	3360	5560	7760	9440	10480
6	4050	6710	9360	11390	12650
Lanes	**Peak Hour Volume Both Directions**				
4	2310	3840	5350	6510	7240
6	3580	5930	8270	10050	11180
8	4840	8020	11180	13600	15130
10	6110	10110	14110	17160	19050
12	7360	12200	17020	20710	23000
Lanes	**AADT**				
4	23800	39600	55200	67100	74600
6	36900	61100	85300	103600	115300
8	49900	82700	115300	140200	156000
10	63000	104200	145500	176900	196400
12	75900	125800	175500	213500	237100

Figure 4. Screen Display Organization for FREEPLAN

APPENDIX A: LOSPLAN Screens

This appendix contains all of the LOSPLAN Data Entry and Display Screens for quick-reference purposes. Each screen is presented in a separate figure as follows:

Figure A-1. ARTPLAN: General Facility Data 1
Figure A-2. ARTPLAN: Multimodal Facility Data 2
Figure A-3. ARTPLAN: Segment Data 3
Figure A-4. ARTPLAN: Multimodal Segment Data 4
Figure A-5. ARTPLAN: Pedestrian Subsegment Data 5
Figure A-6. ARTPLAN: Automobile LOS Results 6
Figure A-7. ARTPLAN: Multimodal LOS Results 7
Figure A-8. ARTPLAN: Maximum Service Volume Tables for Automobiles and Pedestrians 8
Figure A-9. ARTPLAN: Maximum Service Volume Tables for Bicycles and Buses 9
Figure A-10. FREEPLAN: General Facility Data 10
Figure A-11. FREEPLAN: Segment Data 11
Figure A-12. FREEPLAN: Sample Data Screens for Specific Interchange Properties 12
Figure A-13. FREEPLAN: LOS Results 13
Figure A-14. FREEPLAN: Facility Service Volumes Tables 14
Figure A-15. HIGHPLAN: Facility Data and Performance Analysis 15
Figure A-16. HIGHPLAN: Service Volume Tables 16

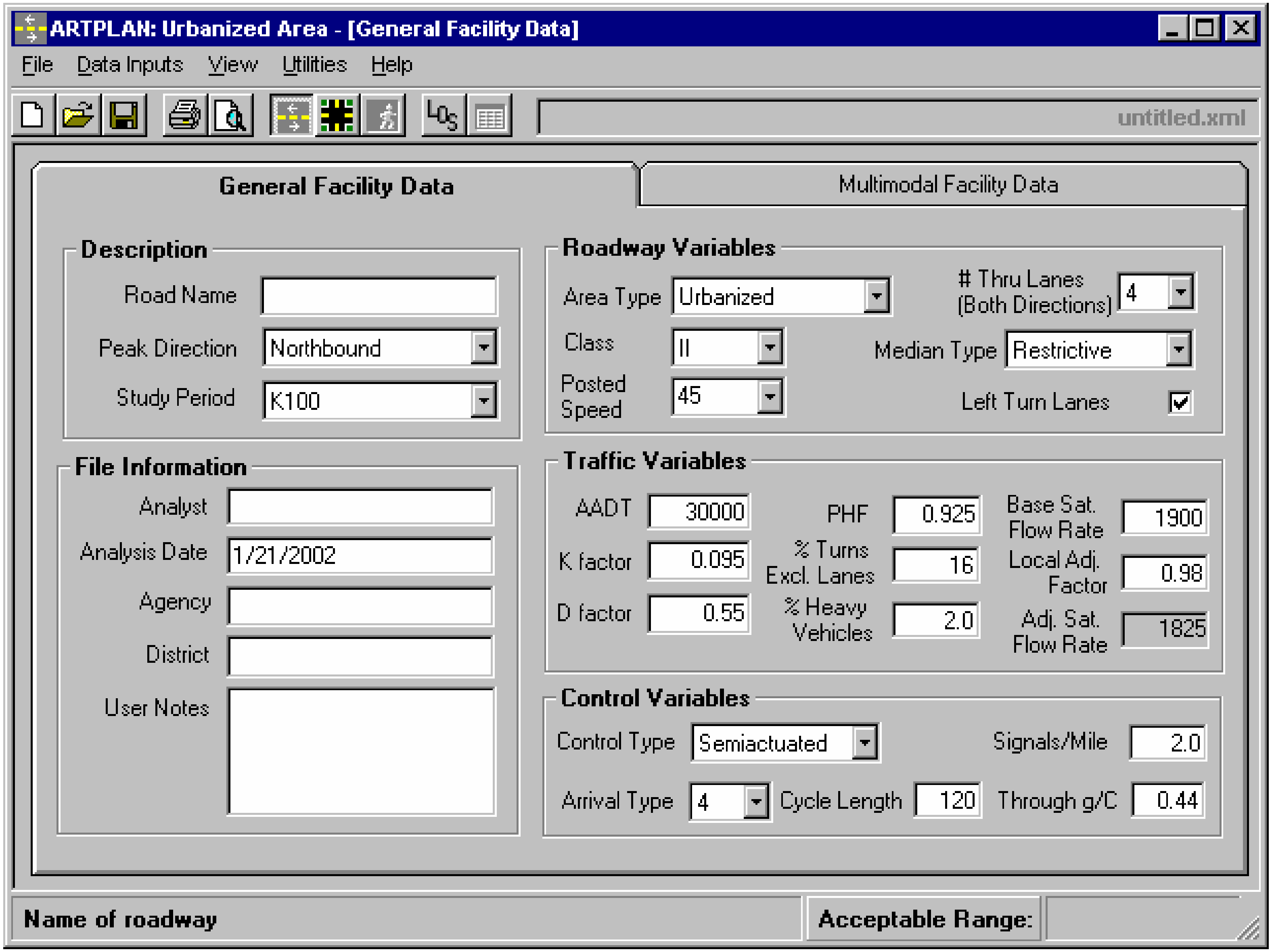


Figure A-1. ARTPLAN: General Facility Data

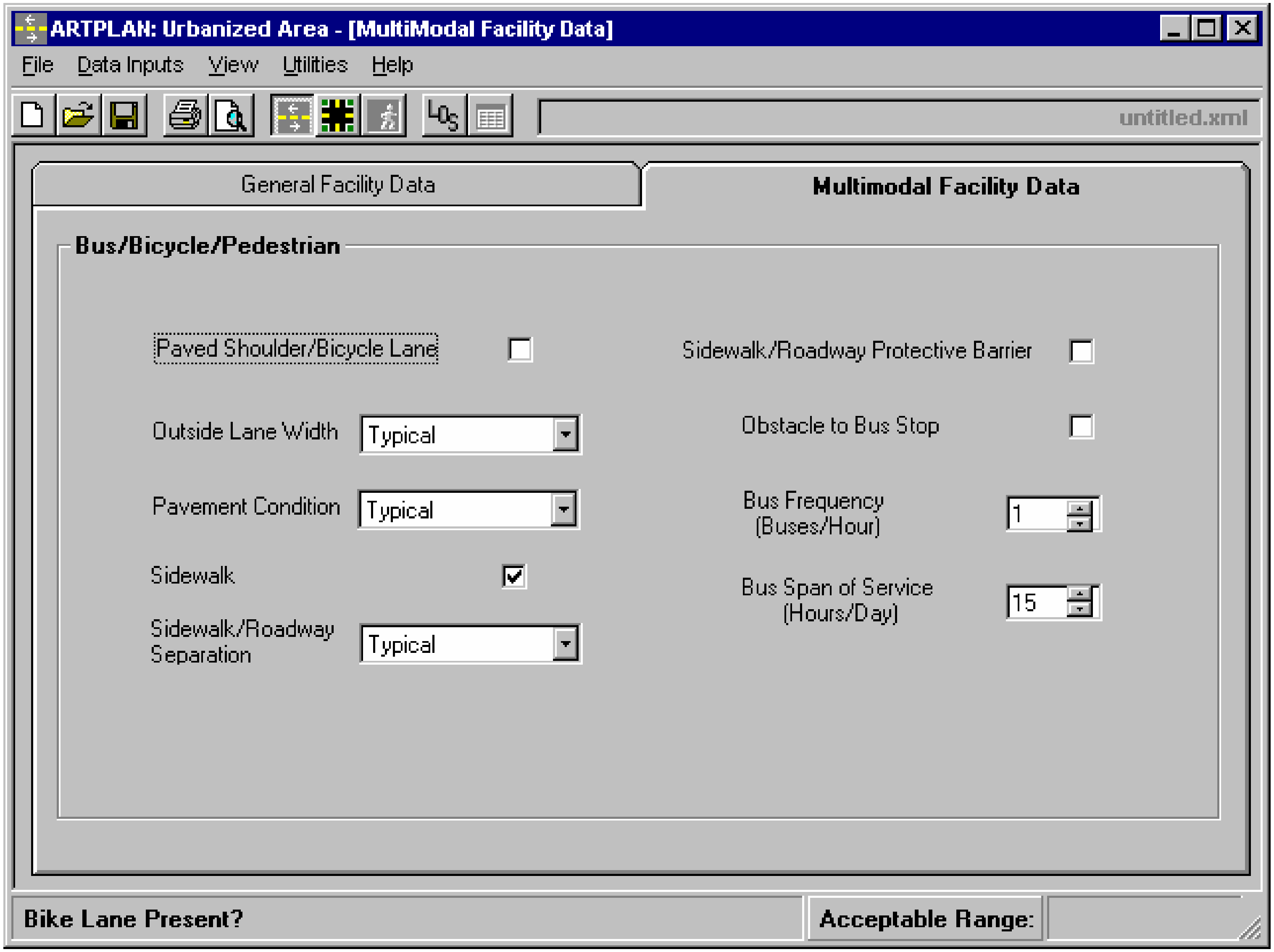


Figure A-2. ARTPLAN: Multimodal Facility Data

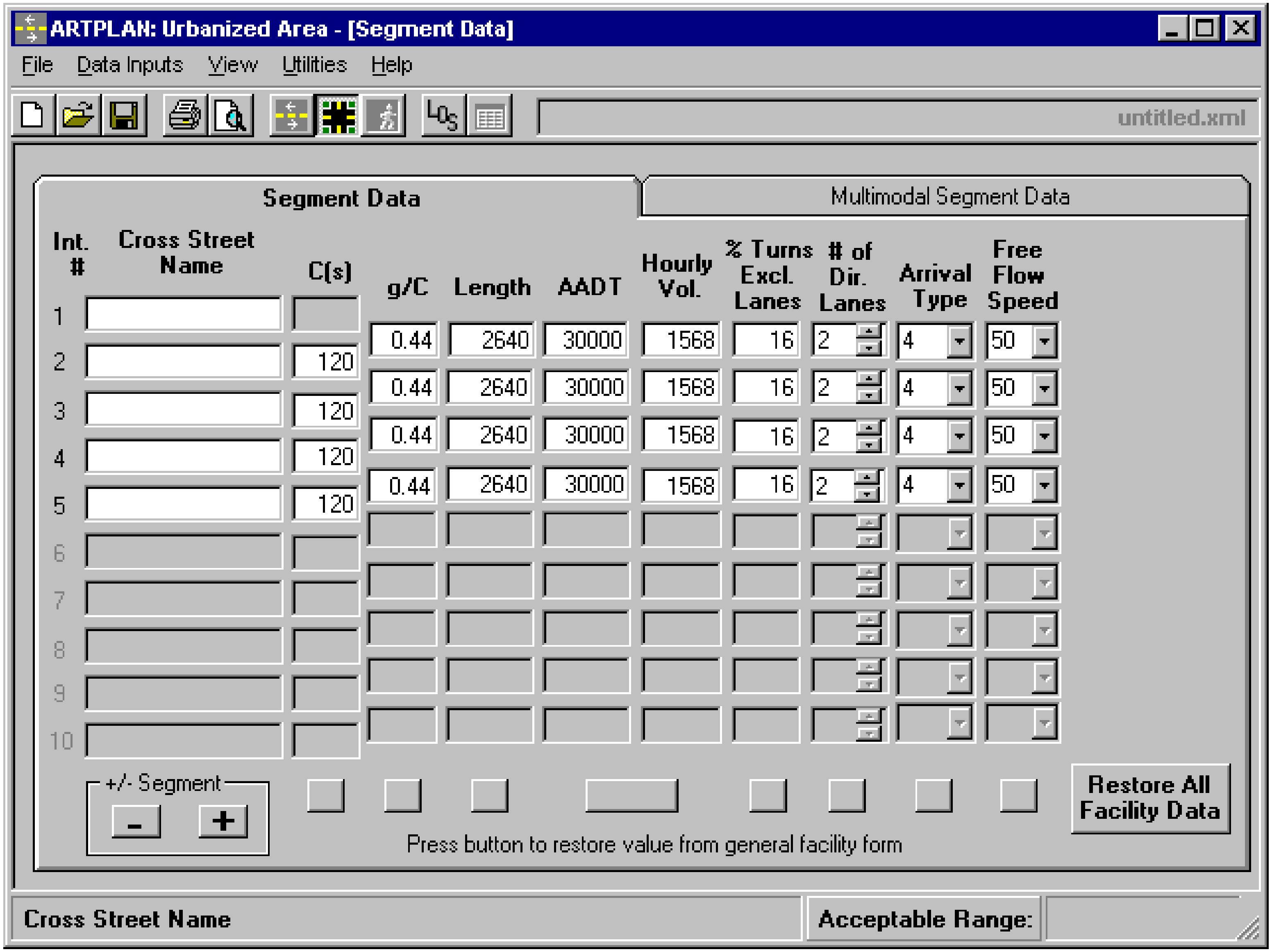


Figure A-3. ARTPLAN: Segment Data

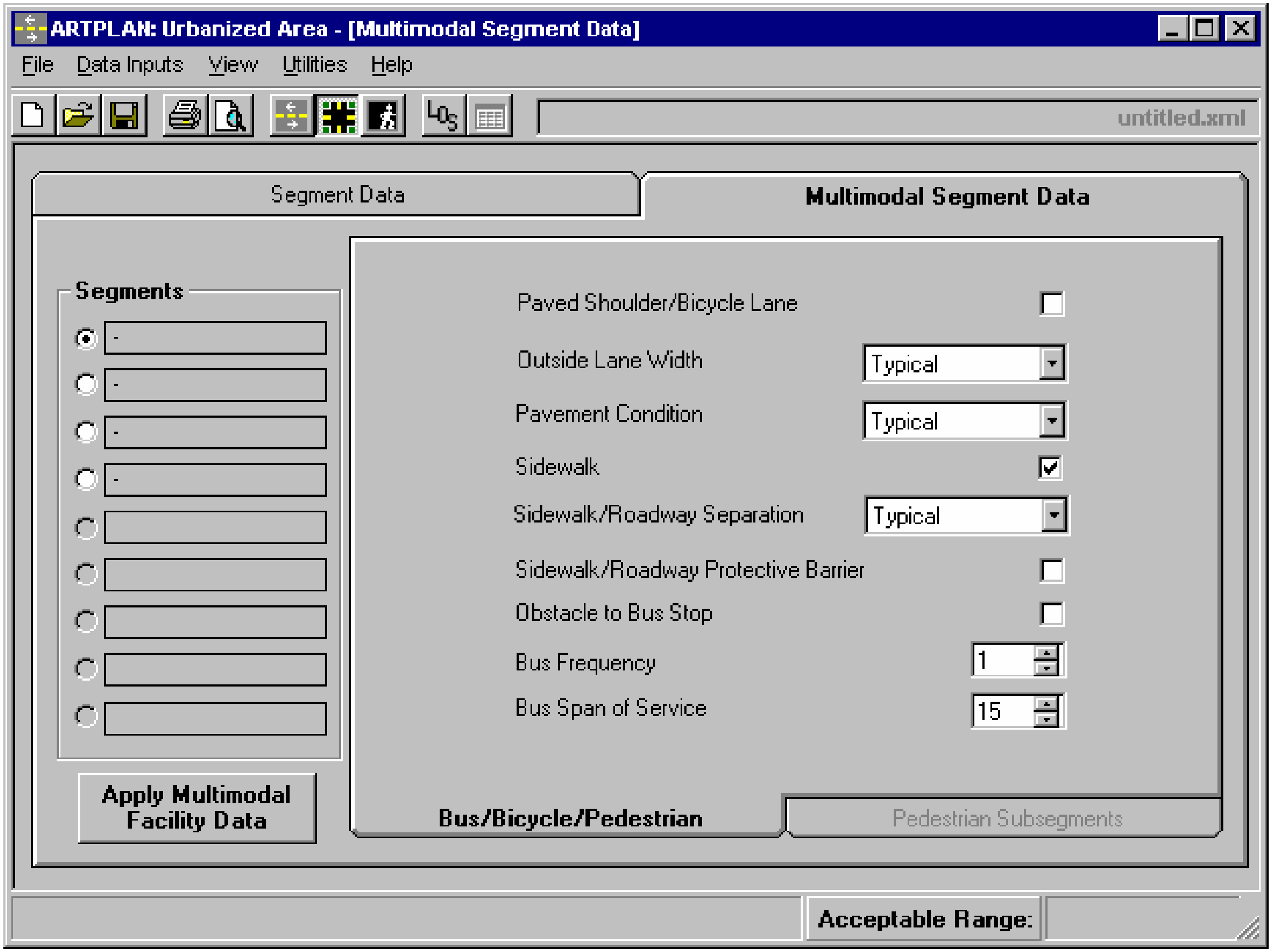


Figure A-4. ARTPLAN: Multimodal Segment Data

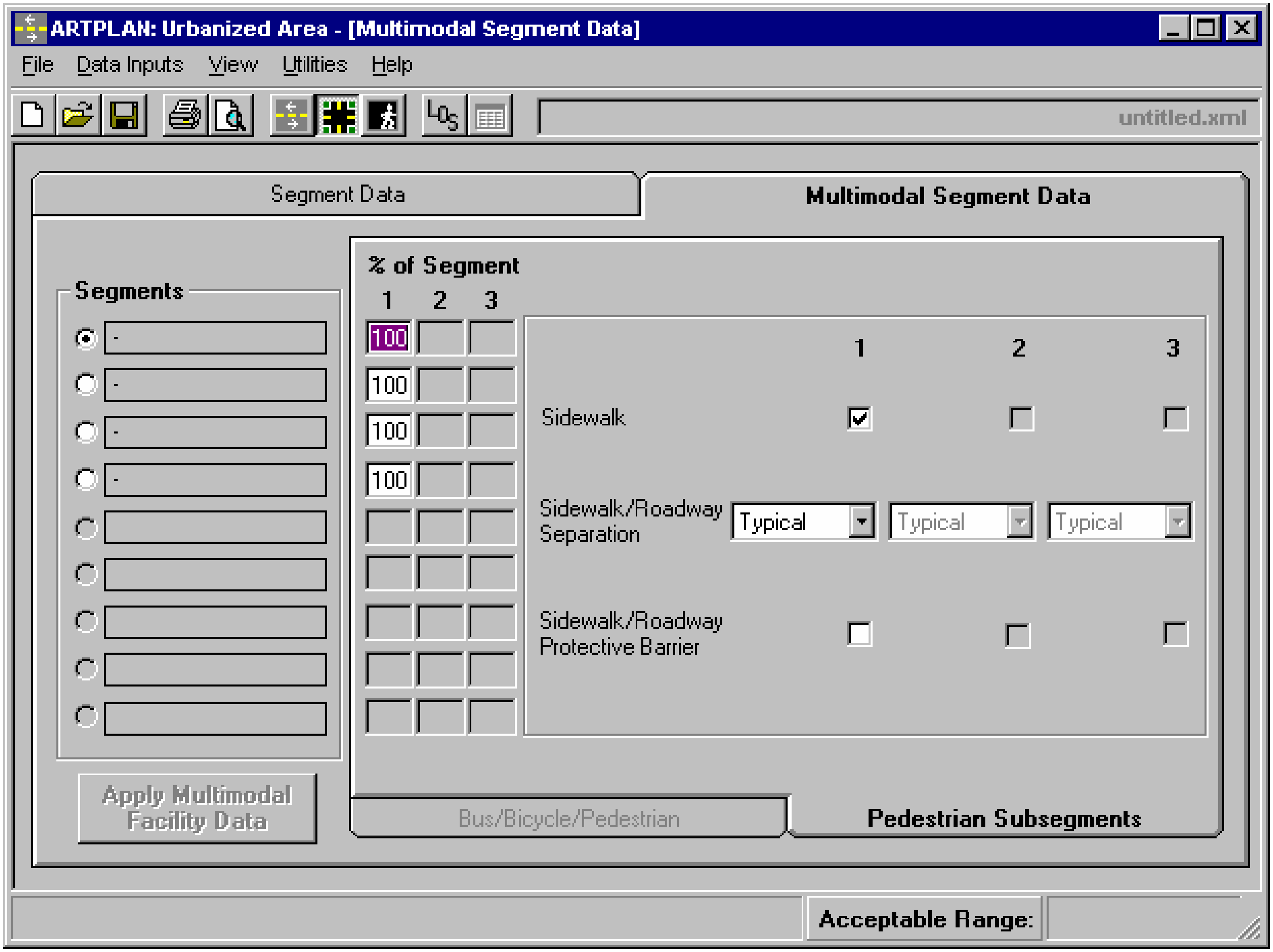


Figure A-5. ARTPLAN: Pedestrian Subsegment Data

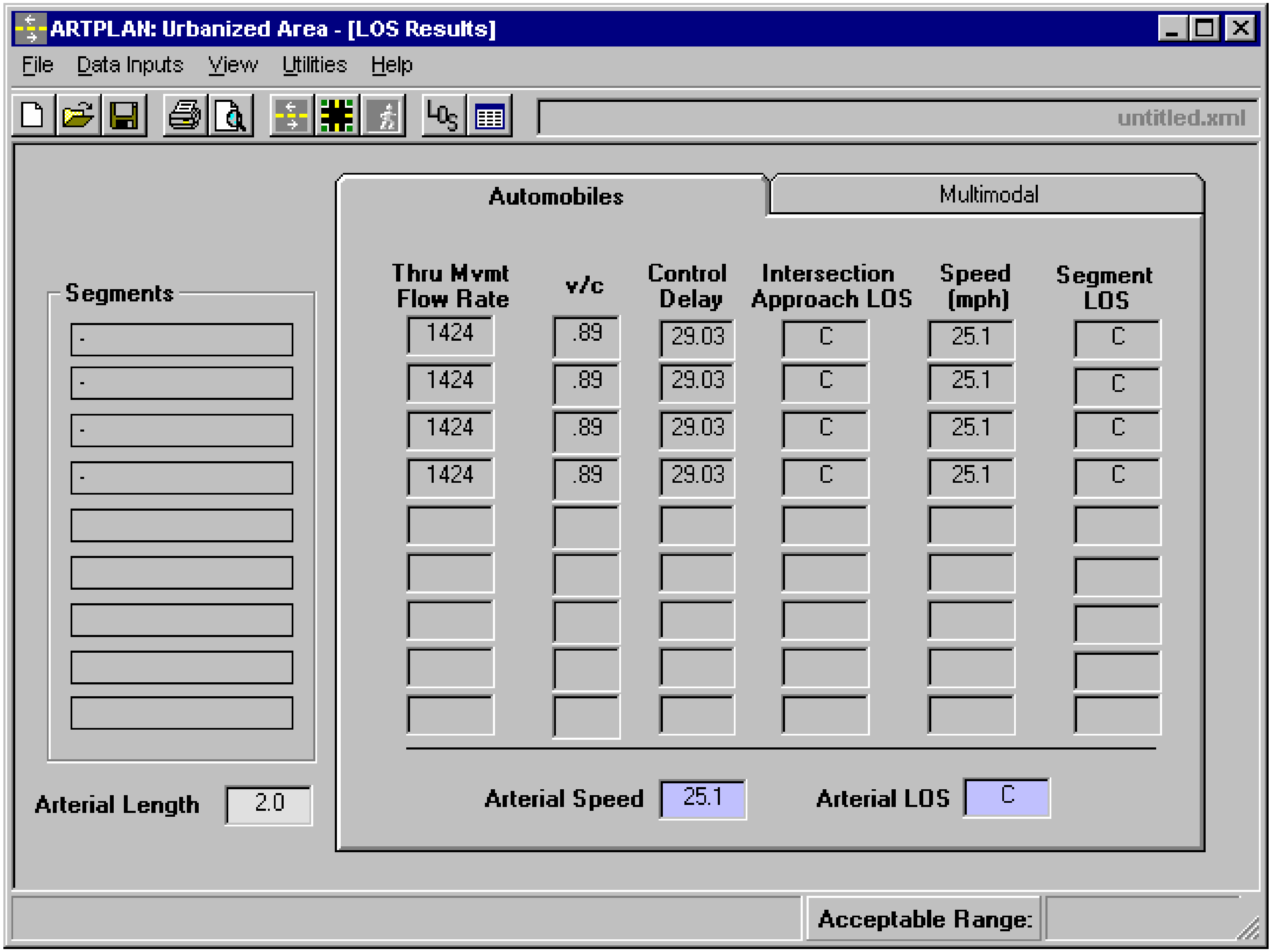


Figure A-6. ARTPLAN: Automobile LOS Results

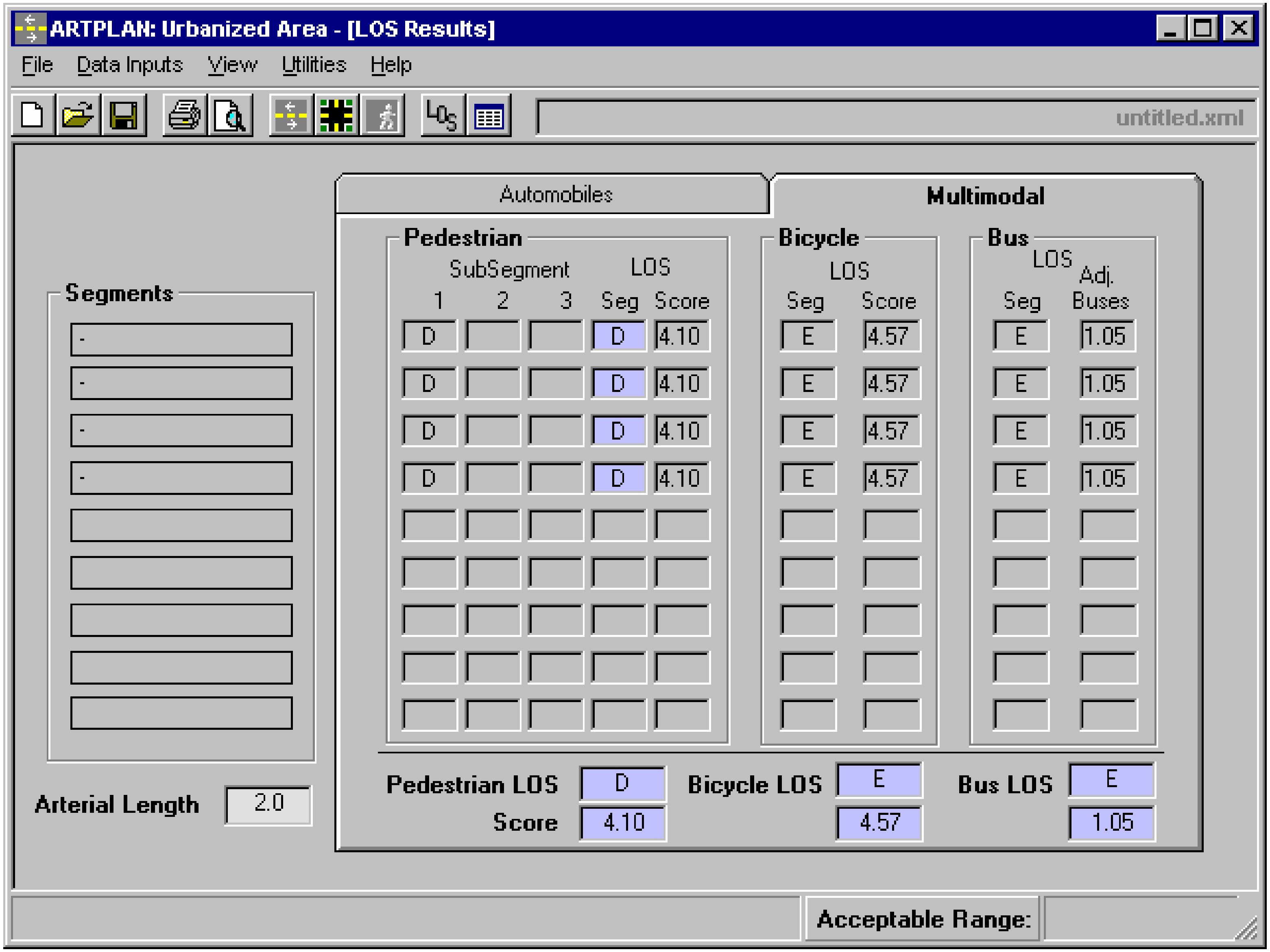


Figure A-7. ARTPLAN: Multimodal LOS Results

Maximum Service Volumes

Automobile | Pedestrian | Bicycle | Bus

Lanes	A	B	C	D	E
	Hourly Volume in Peak Direction				
1	**	560	880	940	960
2	**	1220	1790	1890	1910
3	**	1880	2690	2840	2870
4	**	2550	3590	3790	3820
Lanes	Hourly Volume in Both Directions				
2	**	1010	1610	1720	1740
4	**	2210	3250	3440	3480
6	**	3410	4890	5170	5210
8	**	4640	6530	6890	6950
Lanes	Annual Average Daily Traffic				
2	**	10700	16900	18100	18300
4	**	23300	34200	36200	36600
6	**	35900	51400	54400	54900
8	**	48800	68700	72500	73200

** Cannot be acheived using table input value defaults.

*** Not applicable for that level of service letter grade.
See generalized tables notes for more details.

Close

Maximum Service Volumes

Automobile | Pedestrian | Bicycle | Bus

Lanes	A	B	C	D	E
	Motor Vehicle Hourly Volume in Peak Direction				
1	**	**	500	> 500	***
2	**	**	1000	> 1000	***
3	**	**	1500	> 1500	***
4	**	**	2010	> 2010	***
Lanes	Motor Vehicle Hourly Volume in Both Directions				
2	**	**	920	> 920	***
4	**	**	1830	> 1830	***
6	**	**	2730	> 2730	***
8	**	**	3650	> 3650	***
Lanes	Annual Average Daily Traffic				
2	**	**	9600	> 9600	***
4	**	**	19200	> 19200	***
6	**	**	28800	> 28800	***
8	**	**	38400	> 38400	***

** Cannot be acheived using table input value defaults.

*** Not applicable for that level of service letter grade.
See generalized tables notes for more details.

Close

Figure A-8. ARTPLAN: Maximum Service Volume Tables for Automobiles and Pedestrians

Maximum Service Volumes

Automobile | Pedestrian | **Bicycle** | Bus

Lanes	A	B	C	D	E
	Motor Vehicle Hourly Volume in Peak Direction				
1	**	**	160	610	>610
2	**	**	330	1220	>1220
3	**	**	490	1820	>1820
4	**	**	660	2430	>2430
Lanes	Motor Vehicle Hourly Volume in Both Directions				
2	**	**	300	1110	>1110
4	**	**	600	2210	>2210
6	**	**	890	3320	>3320
8	**	**	1190	4420	>4420
Lanes	Annual Average Daily Traffic				
2	**	**	3100	11600	>11600
4	**	**	6300	23300	>23300
6	**	**	9400	34900	>34900
8	**	**	12600	46500	>46500

** Cannot be acheived using table input value defaults.

*** Not applicable for that level of service letter grade.
See generalized tables notes for more details.

Close

Maximum Service Volumes

Automobile | Pedestrian | Bicycle | **Bus**

A	B	C	D	E
Buses Per Hour in Peak Direction				
>6.00	>4.00	3.00	2.00	1.00
Buses in Study Hour in Peak Direction (Daily)				
>6.00	>4.00	3.00	2.00	1.00

Unlike service volume tables for other modes:

All numbers shown are in terms of buses per hour only for the study hour in the single direction of higher traffic flow; and

The daily reporting table incorporates the daily variable bus span of service, and excludes the planning analysis hour factor (K) and the directional distribution factor (D).

** Cannot be acheived using table input value defaults.

*** Not applicable for that level of service letter grade.
See generalized tables notes for more details.

Close

Figure A-9. ARTPLAN: Maximum Service Volume Tables for Bicycles and Buses

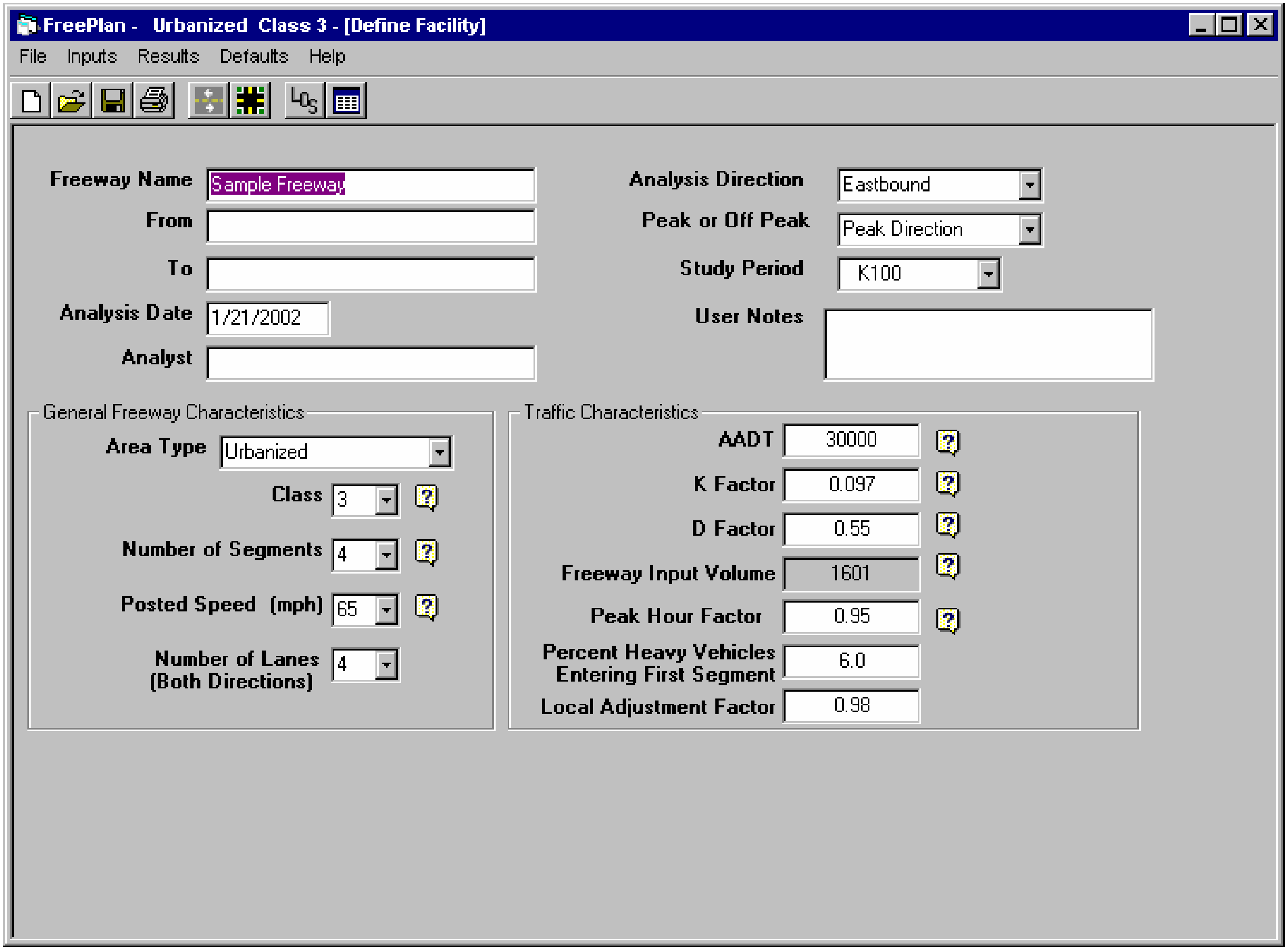


Figure A-10. FREEPLAN: General Facility Data

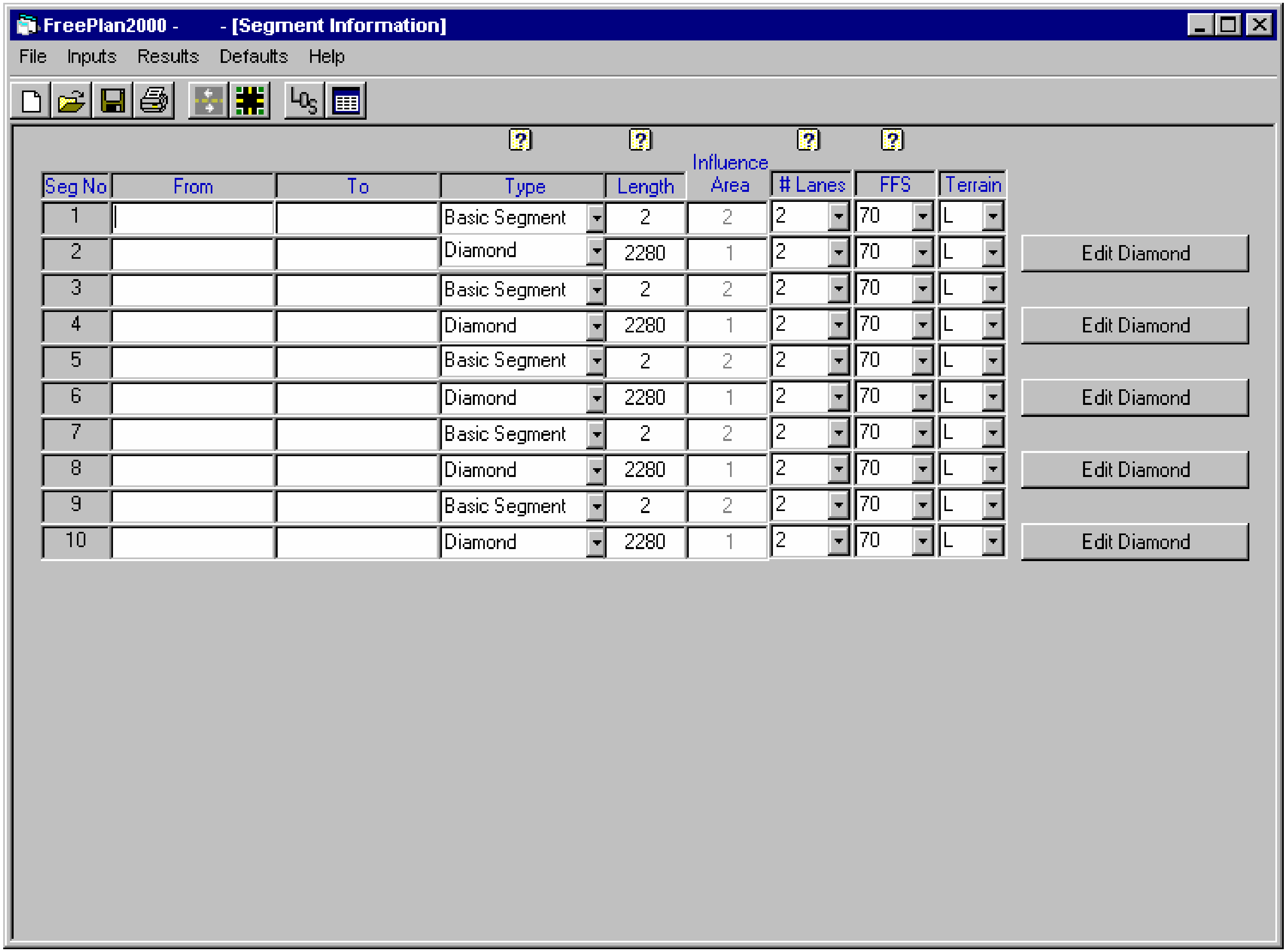


Figure A-11. FREEPLAN: Segment Data

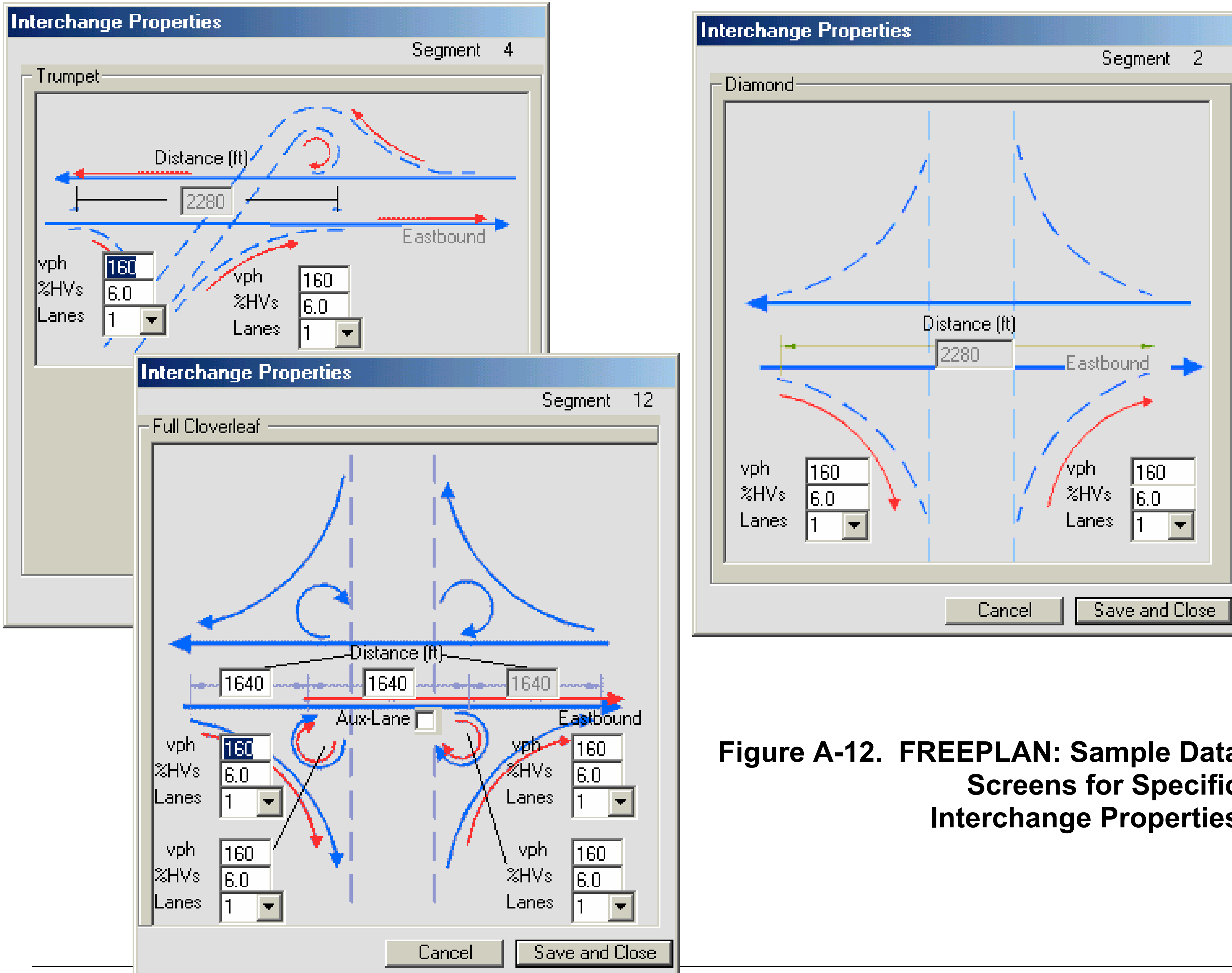


Figure A-12. FREEPLAN: Sample Data Screens for Specific Interchange Properties

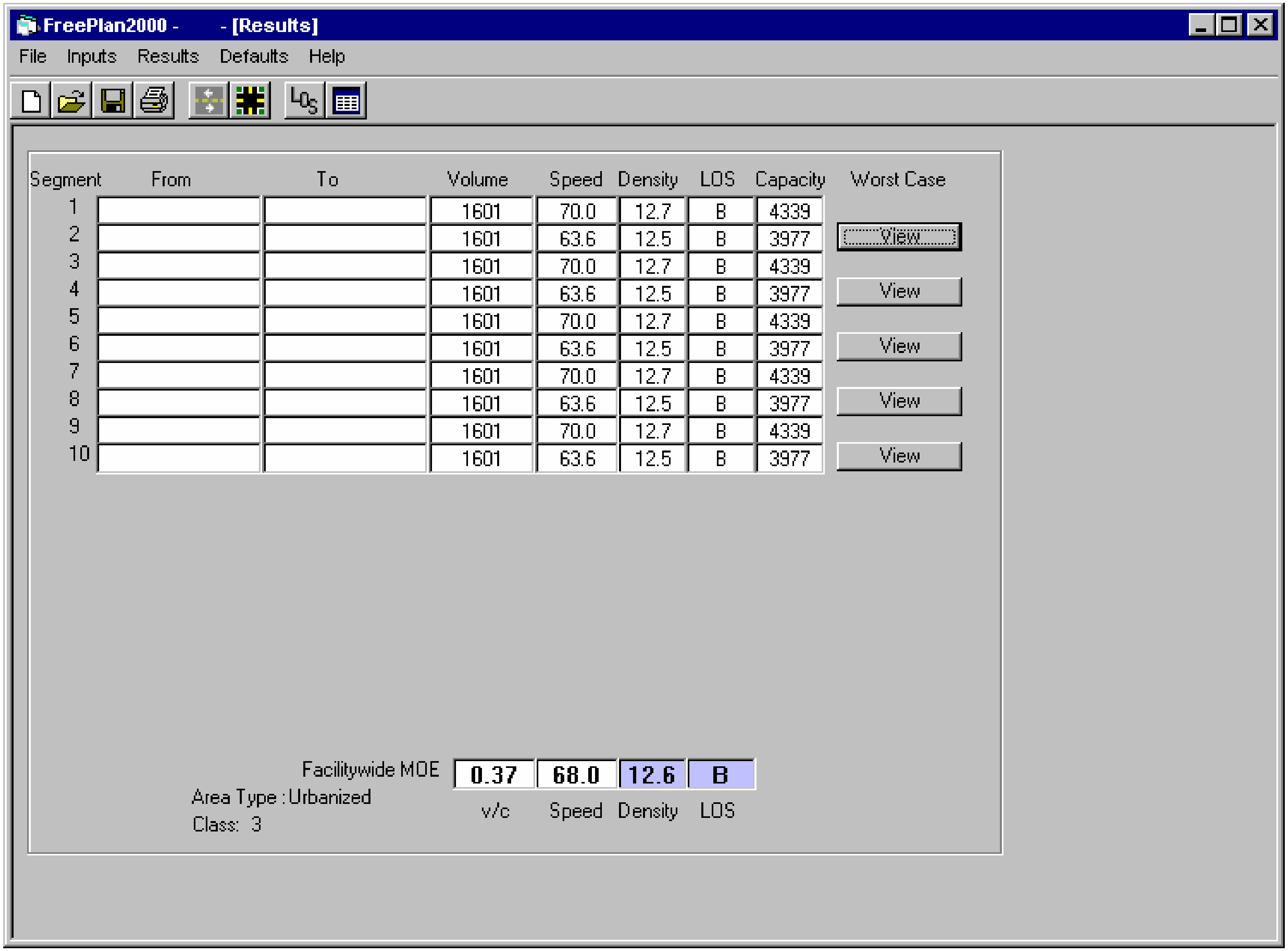


Figure A-13. FREEPLAN: LOS Results

Service Volumes

FACILITY SERVICE VOLUMES

Area Type: Urbanized | Class: 3

Lanes	A	B	C	D	E
	Peak Hour Volume Peak Direction				
2	1270	2110	2940	3580	3980
3	1970	3260	4550	5530	6150
4	2660	4410	6150	7480	8320
5	3360	5560	7760	9440	10480
6	4050	6710	9360	11390	12650
Lanes	**Peak Hour Volume Both Directions**				
4	2310	3840	5350	6510	7240
6	3580	5930	8270	10050	11180
8	4840	8020	11180	13600	15130
10	6110	10110	14110	17160	19050
12	7360	12200	17020	20710	23000
Lanes	**AADT**				
4	23800	39600	55200	67100	74600
6	36900	61100	85300	103600	115300
8	49900	82700	115300	140200	156000
10	63000	104200	145500	176900	196400
12	75900	125800	175500	213500	237100

Close

Figure A-14. FREEPLAN: Facility Service Volumes Tables

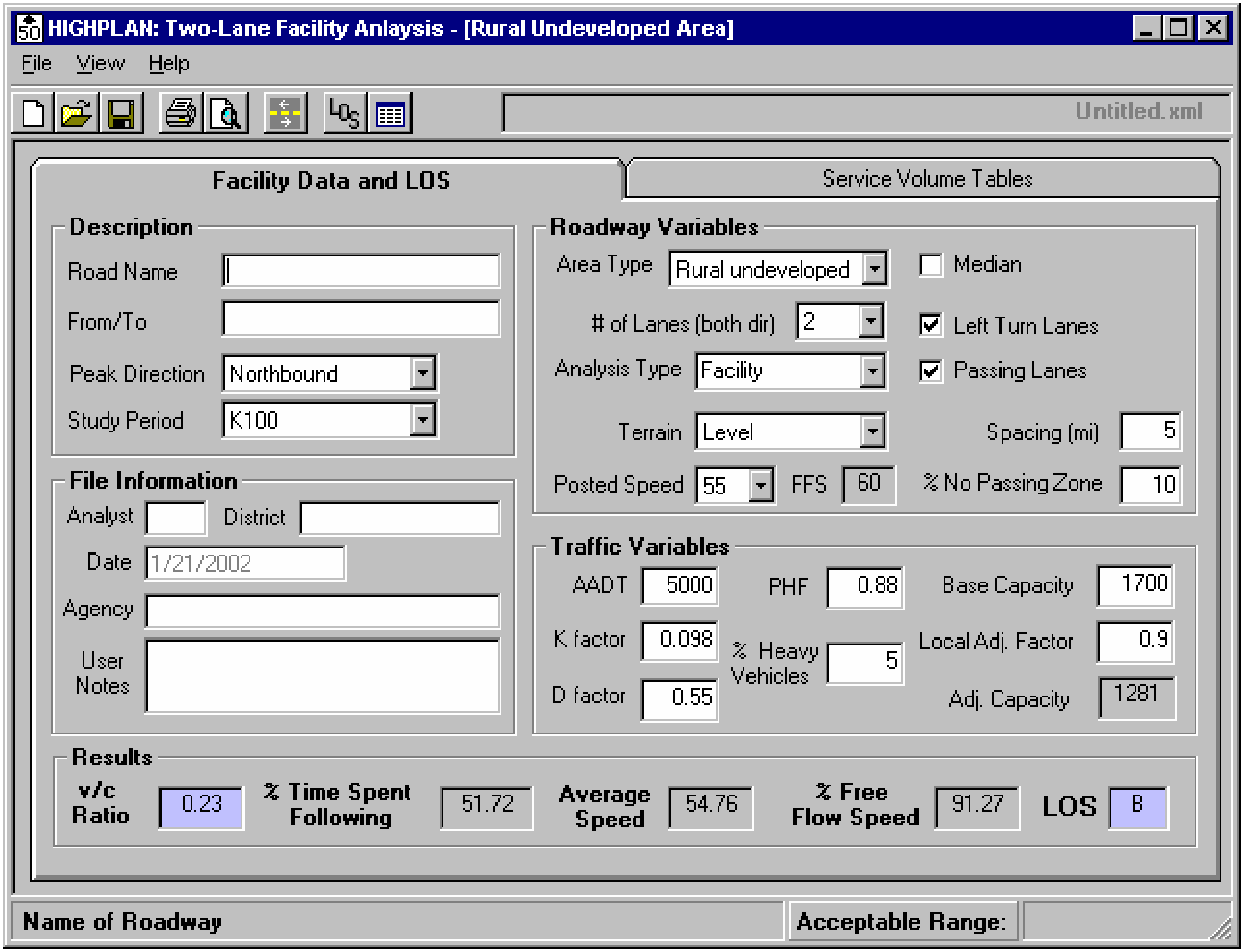
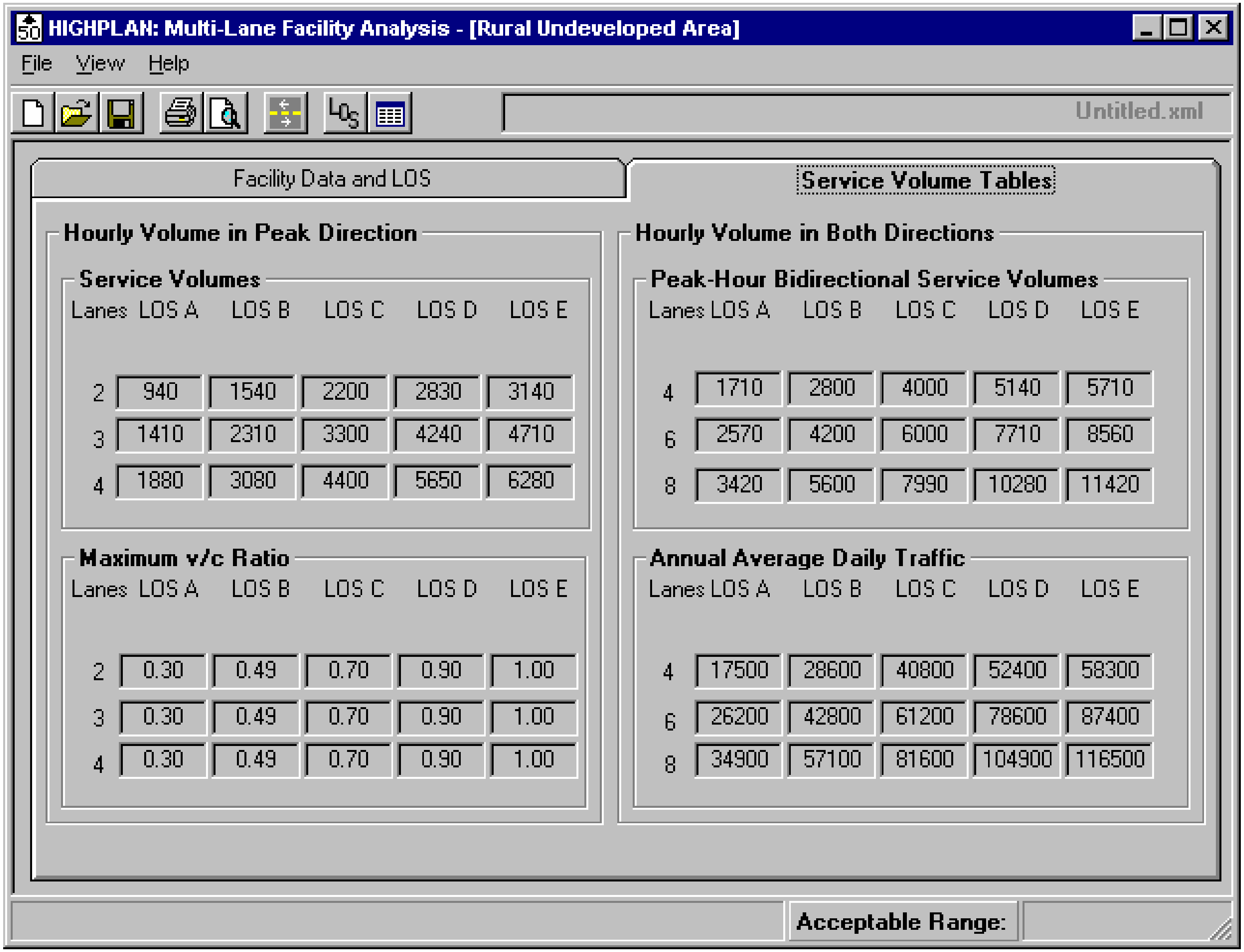


Figure A-15. HIGHPLAN: Facility Data and Performance Analysis



Service Volumes

Lanes	LOS A	LOS B	LOS C	LOS D	LOS E
2	940	1540	2200	2830	3140
3	1410	2310	3300	4240	4710
4	1880	3080	4400	5650	6280

Maximum v/c Ratio

Lanes	LOS A	LOS B	LOS C	LOS D	LOS E
2	0.30	0.49	0.70	0.90	1.00
3	0.30	0.49	0.70	0.90	1.00
4	0.30	0.49	0.70	0.90	1.00

Peak-Hour Bidirectional Service Volumes

Lanes	LOS A	LOS B	LOS C	LOS D	LOS E
4	1710	2800	4000	5140	5710
6	2570	4200	6000	7710	8560
8	3420	5600	7990	10280	11420

Annual Average Daily Traffic

Lanes	LOS A	LOS B	LOS C	LOS D	LOS E
4	17500	28600	40800	52400	58300
6	26200	42800	61200	78600	87400
8	34900	57100	81600	104900	116500

Figure A-16. HIGHPLAN: Service Volume Tables

Appendix B

LOSPLAN
Data Structure and
Interface Requirements

The LOSPLAN package is a set of software tools developed and used by the Florida Department of Transportation to conduct planning level analyses to assess the performance of signalized intersections, arterial routes, highways and freeways throughout Florida. A new version of LOSPLAN has been developed to add multimodal functionality and to enhance the user interface. The total package contains analysis procedures for:

- Signalized arterials
- Signalized intersections
- Freeways
- Two-lane and multi-lane roadways

Previous versions of FDOT's planning level software offered two categories of programs named according to their function. The "PLAN" programs (e.g, ARTPLAN) produced an estimate of the level of service based on specific inputs. The "TAB" programs (e.g., ARTTAB) produced tables of service volumes for a variety of conditions. The purpose of the LOSPLAN software is to combine the PLAN and TAB functions into a single product.

This document describes the general requirements for the user interface and proposes a detailed structure for loading, saving and exchanging the required input and output data.

Guidelines for User Interface Design

To facilitate training and use of the LOSPLAN programs it is desirable that all programs within this suite present the user with essentially the same "look and feel," and that the user interfaces conform to accepted software industry practices. The following guidelines are proposed to achieve this objective:

1. All screen displays shall use the "SVGA" standard resolution of 800 x 600 pixels, and the display screens shall fit within these limits to avoid the need for scrolling through partial screen displays.

2. The common Microsoft conventions for menus and dialog boxes should be followed.

3. The global data for each analysis type should fit on a single screen display and all data should be visible without the need for scrolling or tab controls.

4. A Multiple Document Interface (MDI) container should be used to manage the display of, and navigation through, the required data entry forms.

5. A pull-down menu and tool bar should be implemented on the MDI form. Standard icons should be placed on the tool bar for common tasks such as loading, saving and printing data. Unique icons may be required for program-specific tasks. An effort should be made to coordinate the program-specific icons among the different programs.

6. The standard font for all text and labels should be MS Sans Serif, 8 points.

7. A status bar should be used to provide common information such as the name of the current file, etc. It is not necessary or desirable to promote strict conformance of the status bar to any specific requirements.

8. On-line help should be provided in the form of tool tip text boxes as a minimum.

9. The allowable ranges for all data should be made clear to the user, and range checks should be implemented for all data fields. The “validate” event should be used to establish conformity to the data ranges. A two-level diagnostic scheme should be employed to invoke both “warning” and “error” level diagnostics. The warning level should flag the associated data field with an asterisk. The error level should require the used to reenter the data.

10. Color may be used to enhance the appearance of a screen or output, but color should not convey essential meaning, especially on printouts.

11. All programs should be capable of operation within the security environment of Windows 2000 or Windows NT.

12. The Windows registry should be used where appropriate to identify system-specific features, but the contents of the registry should not be modified except when the program is installed.

13. All files written to the windows temporary directory during the course of program execution should be removed when the execution terminates.

14. A unique “splash screen” should be displayed when the program is loaded. The Florida Department of Transportation should be identified on the splash screen.

15. Appropriate controls should be used for all data entry and editing. Text boxes should be used for free-form text entry. Multiple choice text-based alternatives should employ combo boxes. Simple “yes/no” choices should be implemented with check boxes. Text boxes should be supplemented with spinners when a limited range of numerical data is to be entered. While combo boxes are generally preferable for multiple choice data, option buttons may be used as long as space is available and the number of choices is limited to four or fewer.

16. Computations should be invoked where feasible without the need for a dedicated command button.

Proposed Data Structure

To facilitate loading and saving of data, as well as data exchange between programs, a common data storage scheme should be employed. The mechanism proposed in this document is based on the Traffic Model Markup Language (TMML), a fully XML-compliant method consisting of a structure and vocabulary designed specifically for traffic data. A complete specification for

TMML has been developed to encompass several of the most commonly used traffic analysis models.

A specific data structure based on TMML is proposed for each facility type. The structure and vocabulary of the existing TMML specification has been extended to accommodate the new LOSPLAN functionality with minimal modifications. The following discussion assumes at least a rudimentary knowledge of XML, plus a general familiarity with the current TMML specification.

The LOSTABLES Class

A new data class must be added to accommodate the LOS tables that were previously produced by the TAB programs. The LOS Tables are facility specific and present the following information for LOS A through E

- Peak-hour service volumes for the peak direction
- Peak-hour service volumes for both directions
- Maximum AADT for both directions
- Maximum peak-hour v/c ratios for the peak direction

The LOSTABLES class serves as a container for this information. There are no data elements at the class level. Instead, two sub classes (child classes) have been created to contain the information for the peak direction and both directions, respectively. The information for the four data items identified above is presented within those two sub classes.

The ARTERIAL Facility Structure

It was necessary to add one new XML class for arterials to deal with the division of arterial segments into subsegments for bicycle, pedestrian and transit purposes. Another class was added to represent all of the information that appears in the LOS tables previously generated by the "Tab" programs. About a dozen new data element tags were also created to accommodate the additional input and output requirements for these three modes of travel.

The data class structure, which includes the new "SUBSEGMENT" class is presented as follows:

```
<TMML Facility = "Arterial">
<GENERAL>
</GENERAL>
<AGENCY>
</AGENCY>
<ARTERIAL ID=#>
        <INTERSECTION ID=# >
                <CONTROLLER>
                </CONTROLLER>
                <APPROACH ID= (Code)>
                        <LANEGROUP ID="T")>
                        </LANEGROUP>
                        <SUBSEGMENT ID=# >                    (New data Class)
                        </SUBSEGMENT>
                </APPROACH>
        </INTERSECTION>
        <MOEGROUP ID=(Code)>
        </MOEGROUP>                                           (New definition)
        <MODELPARAMETERS>
        </MODELPARAMETERS>
        <LOSTABLES Lanes =#>                                  (New data class)
                <PEAKDIRECTION LOS=(A-E)>
                </PEAKDIRECTION>
                <BOTHDIRECTIONS LOS=(A-E)>
                </BOTHDIRECTIONS>
        </LOSTABLES>
</ARTERIAL>
</TMML>
```

The TMML specification provides for the MOEGROUP class, which is intended for grouping measures of effectiveness (MOEs) according to program-specific rules. This class will be used in ARTPLAN to aggregate the bicycle, pedestrian and transit MOEs over multiple contiguous segments. This capability is important for bicycle and pedestrians because their trips often do not cover the entire arterial route. It is important to transit because the character of transit operations may change within the arterial route.

The HIGHWAY Facility Structure

The highway facility encompasses both two lane and multilane highways. The structure is much simpler than the arterial facility because there are no segments, signal control parameters or multimodal features to accommodate. The LOSTABLES class was added to all facilities to represent of the information that appears in the LOS tables previously generated by the "Tab" programs. A few new data element tags were also created to accommodate the additional input and output requirements for this facility type.

The proposed HIGHWAY facility structure is presented as follows:

```
<TMML Facility = attribute>, where attribute = “TwoLane” or “MultiLane”
<GENERAL>
</GENERAL>
<AGENCY>
</AGENCY>
<HIGHWAY ID=”1”>
        (Input data elements)
</HIGHWAY>
<LOSTABLES Lanes =#>
        <PEAKDIRECTION LOS=(A-E)>
        </PEAKDIRECTION>
        <BOTHDIRECTIONS LOS=(A-E)>
        </BOTHDIRECTIONS>
</LOSTABLES>
</TMML>
```

Since there are no links to be grouped for analysis purposes, the MOEGROUP class is not used in representing the roadway facility.

The FREEWAY Facility Structure

The freeway facility structure is more complicated than the highway structure because it must accommodate segments. But it is still simpler than the arterial structure because of the lack of signal control and multimodal features. The LOSTABLES class was also added to this facility to represent all of the information that appears in the LOS tables previously generated by the “Tab” programs. A few new data element tags were also created to accommodate the additional input and output requirements for this facility type.

The proposed FREEWAY facility structure is presented as follows:

```
<TMML Facility = “Freeway”>
<GENERAL>
</GENERAL>
<AGENCY>
</AGENCY>
<FREEWAY ID=”1”>
        (Input data elements)
        &lt;SEGMENT ID = “#”>  (20 segments max. Segment 0 applies to the whole facility)
                <ONRAMP ID=”#”>  (Max 2 on-ramps per segment)
                </ONRAMP>
                <OFFRAMP ID=”#”>  (Max 2 off-ramps per segment)
                </OFFRAMP>
        &lt;/SEGMENT&gt;
</FREEWAY>
<LOSTABLES Lanes =#>
        <PEAKDIRECTION LOS=(A-E)>
        </PEAKDIRECTION>
        <BOTHDIRECTIONS LOS=(A-E)>
        </BOTHDIRECTIONS>
</LOSTABLES>
</TMML>
```

DATA ITEM	USE	FORMAT	VB CONTROL	CLASS	TAG *** Indicates a new tag**
PHF	ABP	Single	Text spinner: increment = .005	ARTERIAL	PHF
Adjusted Sat Flow Rate	A	Integer	Text box	ARTERIAL	SatFlowPerLn
Pct Turns from Exclusive lanes	A	Integer	Text box	APPROACH	PctTurnExclLn
Pct Trucks		Integer	Text box	ARTERIAL LANEGROUP	HVPct
AADT		Long	Text box	ARTERIAL APPROACH	AADT
DDHV	ABP	Integer	Text box	APPROACH	Vol
K Factor		Single	Text spinner: increment = .001	ARTERIAL	KFactor
D Factor		Single	Text spinner: increment = .001	ARTERIAL	DFactor
Initial Queue		Integer	Always zero	LANEGROUP	InitialQueue
Other Delay		Single	Always zero	LANEGROUP	OtherDelay
Bus Frequency	T	Integer	Text spinner: increment = 1	ARTERIAL SUBSEGMENT	NumberOfBuses
Bus Span of Service	T		{??}		
Area Type	A	String	Combo box 1. Urbanized 2. Transititioning/Urban 3. Rural	ARTERIAL	AreaType (U+, T+, R+)
# Thru Lanes	ABPT	Integer	Text spinner: increment = 1	ARTERIAL LANEGROUP	NumberOfLns
Arterial Class	AT	Integer	Text spinner: Increment = 1	ARTERIAL	ArterialClass_HCM
Bus route segment number				APPROACH	*BusRouteSegment
Pedestrian section number				APPROACH	*PedSection
Bike section number				APPROACH	*BikeSection
Percent of segment in subsegment	BP	Integer	Text box	SUBSEGMENT	*PctOf Segment
Segment Length		Integer	Text box	LANEGROUP	LinkLength
FF Speed	ABP	Integer	{Need decision}	APPROACH	FreeFlowSpeed
Arterial Length	A	Integer		ARTERIAL	TotalLength
Shared LT Lanes	A	Boolean	{??}		
LT Bays	A	Boolean	{??}		
Median Type	AT		Combo box 1. Raised 2. Painted 3. None	ARTERIAL SUBSEGMENT	*MedianType

Bike Lane?	B	Boolean	Check box	ARTERIAL SUBSEGMENT	*BikeLnYN
Outside Lane Width	B	String	Combo box 1. Substandard 2. Standard 3. Wide	ARTERIAL SUBSEGMENT	*OutsideLnWidth
Pavement Condition	B	String	1. New 2. Typical 3. Terrible	SUBSEGMENT	*PavementCondition
Sidewalk?	PB	Boolean	Check box	SUBSEGMENT	*SidewalkYN
Sidewalk Separation	B	String	Combo Box 1. Substandard 2. Standard 3. Wide		*SidewalkSeparation
Sidewalk to Transit?	T	Boolean	Check box	SUBSEGMENT	*SidewalkToBusYN
Sidewalk Barrier	P		{??}		
On Street Parking	P	Boolean	Check box	SUBSEGMENT	ParkingRight
# Signals	A	Integer	Text spinner: increment = 1	ARTERIAL	NumberOfIntersections
Arrival Type	A	Integer	Text spinner: increment = 1	LANEGROUP	ArrivalType
Signal Type	A	String	Combo box 1. Pretimed 2. Semi actuated 3. Actuated	INTERSECTION	ControlMode
G/C Ratio	A	Single	Text spinner: increment = .05	LANEGROUP	GCRatio
Cycle Length	A	Integer	Text Box	ARTERIAL CONTROLLER	CycleLength
Unit Extension		Single	Always 3 if actuated	LANEGROUP	UnitExtension

DESCRIPTIVE INFORMATION						
Period Identification		String	{Combo box} 1. K30 2. K100 3. K5-6 4. AM Peak 5. PM Peak 6. Other	GENERAL	PeriodID	
Agency Name		String	Text box	AGENCY	AgencyName	
District			{??}	GENERAL	District	
File Name		String	Text box	GENERAL	FileName	
Program Name		String	Always "ARTPLAN"	GENERAL	Program	
Program Version		String	{We need a version}	GENERAL	Version	
Preparation Date		String	From system date	GENERAL	Date	
Analyst		String	Text box	GENERAL	Analyst	
Comment		String	Text box	GENERAL	Comment	
Peak Direction		String	Combo Box 1. Northbound 2. Southbound 3. Eastbound 4. Westbound	ARTERIAL	FwdDirection	
Off Peak Direction		String	Computed from peak direction	ARTERIAL	RevDirection	
Arterial Name		String	Text box	ARTERIAL	ArterialName	
Cross Street Name		String	Text box	INTERSECTION	CrossStreetName	
Period Length		Single	{Always 15 min?}	MODELPARAMETERS	PeriodHR, or PeriodMinutes	
Units		String	Always US	GENERAL	Units	

CALCULATIONS						
Arterial Length				ARTERIAL	TotalLength	
Auto/Truck Measures						
Through traffic volume				LANEGROUP	Vol	
Running Time				LANEGROUP	RunningTime	
Segment capacity				LANEGROUP	Cap	
Segment v/c ratio				LANEGROUP	VCRatio	
Control Delay				LANEGROUP	ControlDelay	
LOS based on control delay				LANEGROUP	LOS	
Total Delay				ARTERIAL LANEGROUP	TotalDelay	
Travel Time				ARTERIAL LANEGROUP	UnitTT	
Average speed				ARTERIAL LANEGROUP	AvgTravelSpeed	
LOS based on speed				ARTERIAL LANEGROUP	SegmentLOS	
Bicycle Measures						
Bike LOS				APPROACH MOEGROUP	*BikeLOS	
Pedestrian Measures						
Ped LOS				APPROACH MOEGROUP	*PedLOS	
Transit Measures						
Bus LOS				APPROACH MOEGROUP	*BusLOS	

Appendix C

Paper on HIGHPLAN Submitted to Transportation Research Board

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ADAPTATION OF THE HCM2000 FOR PLANNING LEVEL ANALYSIS OF TWO-LANE AND MULTILANE HIGHWAYS IN FLORIDA

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ABSTRACT

This paper describes a planning level adaptation of the Highway Capacity Manual 2000 (HCM2000) procedure for estimating the level of service (LOS) on two-lane and multilane highways in Florida. The paper identifies the problems associated with planning level adaptations in general and with uninterrupted-flow highways in particular. While much of the adaptation was achieved through the use of default values for data items, some departures from the HCM procedures were required, which are explained in detail in this paper. The most significant deviation was the creation of a third class of two-lane highway to supplement the two classes currently defined by the HCM. The paper makes a case for the existence of this class and argues that it should be included in a future edition of the HCM. FDOT's planning level methodology, termed HIGHPLAN, is well suited to its intended application, which is planning level analysis of two-lane and multilane highways in Florida. It maintains fidelity to the HCM procedures to the extent that Florida conditions will allow, and that Florida users will accept. As long as they are understood, the departures from the HCM should not pose significant problems for users outside of Florida. The planning level methodology has also been implemented in a software program that produces LOS estimates and service volume tables covering site-specific conditions.

INTRODUCTION

Florida has been a leader in the adoption and implementation of the Highway Capacity Manual (HCM) [1], especially at the planning level. The Florida Department of Transportation's (FDOT) commitment to the HCM has been further advanced by the development of software tools that implement various planning level procedures from the HCM2000.

Planning level analysis is characterized by the use of assumptions, approximations and default values to reduce the need for the detailed field data upon which operational level analyses are based. Procedures have been developed based on the HCM2000 for application at two levels:

- Generalized planning, which typically makes use of statewide service volume tables, and
- Conceptual planning, which applies user-specified parameter values. The conceptual planning level procedure includes features that estimate the level of service (LOS) for site-specific conditions and features that generate service-volume tables.

The focus of this paper is on HIGHPLAN, the FDOT's implementation of the HCM2000 multilane and two-lane highway methodologies (chapters 20 and 21) at a planning level. Due to some unique characteristics in the State of Florida, and some philosophical differences of opinion by the FDOT, HIGHPLAN incorporates a number of concepts and calculations that differ significantly from the basic procedures in chapter 20 and 21, particularly the two-lane methodology (chapter 20). The topics covered in this paper include an overview of FDOT concerns with the HCM2000 highway analysis methodologies, a detailed discussion on HIGHPLAN's methodological and computational deviations from the HCM2000, and a brief overview of the software implementation of the HIGHPLAN procedures.

PROBLEM STATEMENT

The basic problem is how to maintain fidelity with the HCM and create a methodology that will be accepted by a broad constituency of users, some of which have no particular allegiance to the HCM. The product must be able to stand the scrutiny of state-level administrators, quasi-judicial proceedings, developers, etc. Specific problems encountered in the development of planning applications of the HCM2000 two-lane and multilane methodologies include:

- Reconciling abrupt changes in performance measures brought about by the transition to the HCM2000.
  - There has been an approximately one level of service letter grade shift for LOS A-D between the two-lane methodologies of the HCM1997 and HCM2000.
  - A large proportion of the state highway system that was previously considered adequate cannot suddenly be declared deficient because of the appearance of a new manual; using a LOS C criterion, the amount of two-lane highway deficiencies would change from about 25% to 60%, without any change in the actual operating conditions.
- Reconciling LOS assessments with established minimum LOS standards, and with the administrator-perceived meaning of the various levels of service.

  - Agencies can change LOS standard letter grades, but there is at least some common understanding of the meaning of LOS across facility types and by transportation professionals.
- Applying the two-lane and multilane chapter methodologies to a broad range of applications, especially in meeting the analysis expectations of "rural interests".
  - There is wide concern in Florida and apparently elsewhere in the U.S. that the new two-lane chapter methodology does not adequately address quality of service in small communities.
  - The chapters essentially remain "segment" chapters instead of "facility" chapters by not addressing how to treat isolated intersections on roadways that generally feature uninterrupted flow.
- Balancing the need for site-specific data with planning level interests and resources.
  - Planning applications feature greater use of default values and there is a need to determine which are the most important input values.
- Maintaining parity with other facility analyses in the estimation of capacity, other performance measures, and inputs.
  - Multilane capacity values must be lower than freeway values, yet straight application of multilane inputs would yield higher values than Florida is experiencing on its freeways; this occurs because Florida is experiencing capacity reductions in freeway interchange areas, but no particular treatment is available in the multilane methodology.
  - If a driver population factor is applicable to freeway commuters, than a driver population factor less than 1.0 should probably routinely be applied to drivers on two-lane and multilane highways outside urbanized areas.
  - If signalized arterials experience reductions in capacity or service volumes because of the lack of medians and left turn lanes at major intersections, similar results should also be anticipated on two-lane and multilane highways.

FDOT's problems with the planning level implementation of the two-lane highway procedure date back to the 1985 HCM. The main difficulty in implementing the 1985 HCM two-lane chapter was its perceived inaccurate level of service results in developed areas. Florida has many two-lane uninterrupted flow roads that are in developed areas, such as roads passing through communities, along beaches or rivers, and on causeways.

The problem came to the forefront with the analysis of US-1 (the Overseas Highway), a predominantly two-lane highway serving well over 100,000 people in the Florida Keys [2]. To Florida's Level of Service Task Team[1], the primary objective of travelers on these facilities was to travel at a reasonable speed, and percent time delayed (i.e., percent time spent following) was of secondary concern. Furthermore, capacities were higher in more urban situations. Thus, FDOT adopted a hybrid of the 1985 HCM two-lane (based on percent time delayed) and arterial (based on average travel speed) methodologies for applications on two-lane uninterrupted flow highways in developed areas.

In developing HIGHPLAN, the intent was to incorporate the new HCM2000 two-lane and multilane procedures, yet also tailor the procedures to meet the special needs of the FDOT

[1] FDOT has coordinated a statewide Level of Service (LOS) Task Team composed of approximately 20 representatives since 1988, and it has addressed many highway capacity issues that have arisen in the state since that time.

and address common roadway environments encountered in the state that do not fit well with current HCM classifications.

HIGHPLAN METHODOLOGICAL DESCRIPTION

This section will describe the inputs, assumptions, approximations and deviations from the HCM2000 that went into the methodology development of HIGHPLAN.

Summary of Data Requirements

A summary of the input data items required for the HIGHPLAN computations, along with their choices, ranges and initial default values, is presented in Table 1. The initial defaults reflect the most common conditions and facilities that are encountered in the State of Florida. User–specified values may be substituted for all of the defaulted items.

Methodological and Computational Deviations from the HCM2000

From the inception of FDOT's level of service planning program, FDOT has committed to the maximum feasible extent to rely on the HCM methodologies to address the automobile mode. Because HIGHPLAN is a planning level methodology, some simplifying assumptions and/or extensions have been made and documented in FDOT's Quality/Level of Service Handbook [3]. The deviations in the HIGHPLAN methodology from the HCM methodology are summarized below.

Facility and Segment Level Analysis

HIGHPLAN includes an adjustment to account for whether the analysis is at the segment level or the facility level. If a segment level analysis is performed, it is assumed that the highway section under consideration is short enough that it does not include any capacity reducing effects due to the presence of intersecting driveways or cross streets. If a facility level analysis is chosen, a 10% reduction is applied to the base capacity to account for driveway and cross street friction. This value is consistent with the capacity reducing effects of interchanges experienced on Florida freeways.

Free-Flow Speed

Since HIGHPLAN is used for conceptual planning purposes, the determination of free-flow speed (FFS) by direct measurement is generally not an option. The HCM offers a method for estimating FFS when a direct measurement is not available. This method is based on applying reductions to the ideal FFS (i.e., FFS under ideal geometric conditions) for fixed site conditions that are less than ideal (e.g., narrow lanes, reduced lateral clearances, etc.). The FDOT has found that the posted speed for a highway serves as a reasonable surrogate for FFS, and therefore sets FFS equal to the posted speed plus 8 km/h (5 mph).

Furthermore, for the multilane procedure, the HCM's default upper limit of free flow speeds has been extended from 97 km/h (60 mph) to 113 km/h (70 mph). This allows the full range of multilane highways present in the State of Florida to be covered by the analysis procedure.

Medians and Left Turn Lanes

A primary simplifying analytical technique used by FDOT was the concentration on the through movement—side road and left turning movements are accommodated with their impacts handled generically. One of the earliest issues addressed was how to treat left turn lanes at intersections and mid-block medians at a planning level. In 1991, FDOT's Level of Service Task Team adopted a 5 percent reduction in service volumes if a roadway was undivided and a further 20 percent reduction if the roadway did not have left turn lanes at major intersections. Although most applicable to arterials, those adjustments have also been applied to two-lane and multilane highways. Essentially, the concept is to get left turning vehicles out of the through traffic stream and reflect some level of detriment if they cannot readily do so. In Florida, most multilane roadways are divided and have left turn lanes at major intersections. Two-lane highways are usually undivided (e.g., do not contain a two-way left turn lane) and have left turn lanes at major intersections, so the statewide default is somewhat different between two-lane and multilane highways. In the case of two-lane divided highways, which may occur in developed situations, service volumes are increased 5 percent; however, consideration would also be given to the effect of having 100 percent no passing. The LOS Task Team also adopted some passing lane adjustments, but these are now superseded by the values in HCM2000.

Local Adjustment Factor

Whereas historically the HCM only included a driver population factor, f_p, to account for potential capacity reducing effects on freeways due to a traffic stream not composed primarily of commuters, and the recommended default value continues to be 1.0, FDOT has for the last 10 years made extensive use of gradations of the driver population concept for all facility types. Research conducted by the University of South Florida [4, 5] indicated that base saturation flow rates are reduced up to 15% on freeways and 19% on arterials because of non-local drivers. Furthermore, limited research [6] in south Florida indicated higher base saturation flow rates occur in larger urbanized areas than in smaller urbanized areas.

Rather than using the HCM's CBD factor (but no recognition of non-CBD driver population factors) for signalized intersections and arterials, a driver population factor for freeways and multilane highways, and no adjustment factor for two-lane highways, FDOT uses the term "local adjustment factor" (LAF) to help obtain adjusted saturation flow rates for all facility types in all area types. The LAF is intended to primarily capture the effects of driver population, but allows the analyst to also capture capacity reducing effects that are not explicitly addressed at the planning level, but that the analyst may still consider important.

The LAF values primarily reflect the location of facilities, whether they are in rural undeveloped areas, small communities, small cities, metropolitan areas, large metropolitan areas or central business districts. Using gradations of the LAF has resulted in favorable matches with actual capacities on freeways throughout the state and on arterials in urbanized areas. Furthermore, FDOT believes that if a LAF is applicable to those facilities they should also be applicable to two-lane and multilane highways in similar areas.

Base Capacity and Adjusted Capacity Terms

The HIGHPLAN methodology incorporates a base capacity term and an adjusted capacity term, while the HCM uses just a single capacity term. These terms were introduced for consistency with FDOT's other facility planning methodologies.

In the HCM procedure, fixed site effects, such as geometry and access frequency are applied to the free-flow speed estimate (in lieu of a direct measurement), which in turn determines the capacity value. Temporal site conditions, such as percentage of heavy vehicles and the peak hour factor, are applied to the analysis flow rate. However, in HIGHPLAN, the FFS is based on the posted speed, as previously discussed, and the base capacity is based on FDOT recommended values[2], but can also be directly specified by the user. The fixed and temporal effects (e.g., median presence, percent heavy vehicles) get applied to the base capacity, which then results in an adjusted capacity. This adjusted capacity value is used in the calculations for the maximum service volume tables. However, for consistency with HCM level of service calculations, the adjustments (e.g., LAF) get applied to the analysis flow rate, and the base capacity value is used.

Passing Lane Implementation (Two-Lane Only)

The HCM procedure deals with a specific passing lane segment with three user-specified length parameters:

1. Length upstream of the passing lane,
2. Length of the passing lane itself, including taper, and
3. Length downstream of the passing lane.

The procedure divides the downstream segment computationally into two subsegments. The first segment is considered to be within the effective length of the passing lane. The second segment is beyond the influence of the passing lane.

For planning level analyses, the roadway is treated as a series of segments, each of which has its own passing lane. Using this approach, the only user-specified variable is the passing lane spacing in miles. The roadway is then modeled as a series of segments, each of which begins with a passing lane exactly one mile long. The HCM computations are then performed to determine what proportion of the downstream segment is within the influence of the passing lane. An example of the results of the HIGHPLAN passing lane computation is illustrated in Figure 1. This figure shows the effect of the passing lane spacing (8 km (5 mi) to 48 km (30 mi)) on the 'percent time spent following' (PTSF) for annual average daily traffic (AADT) values of 5000, 15000, and 25000. All other input data were kept at the HIGHPLAN defaults for two-lane roadways.

Class III Roadways (Two-Lane Only)

In 1990 a major issue arose over the adequacy of the HCM in addressing level of service on two-lane roads over a broad range of conditions and area types. A LOS Task Team subcommittee was formed to directly address those concerns that primarily centered on the analysis of such facilities in developed areas (e.g., small towns) and along coastal roads. In addition to FDOT members, the subcommittee included a transportation representative of the state's most rural regional planning council, and a representative of the state's land planning agency.

[2] For the two-lane analysis, the default base capacity values are the HCM values of 1700 pc/hr (one-way) and 3200 pc/hr (two-way). For multilane analysis, the values also correspond with HCM values, with additional values of 2250 and 2300 for free-flow speeds of 105 km/h (65 mph) and 113 km/h (70 mph), respectively.

As a result of this subcommittee's efforts, FDOT implemented a hybrid approach for two-lane uninterrupted flow facilities in developed areas in its 1991 LOS Handbook. Since that time, no serious questioning of the results has occurred from local governments, developers, preservationists, or others. It was anticipated that the HCM2000 would better address the aforementioned concerns, but the feeling in Florida is that it has not succeeded. The following discussion describes the rationale of the LOS Task Team in arriving at the recommendation to implement a third class for two-lane highways and the use of 'percent of free flow speed' as its primary performance measure.

Chapter 12 of the HCM2000 offers the following definitions for Class I and Class II highways:

- Class I—These are two-lane highways on which motorists expect to travel at relatively high speeds. Two-lane highways that are major intercity routes, primary arterials connecting major traffic generators, daily commuter routes, or primary links in state or national highway networks generally are assigned to Class I. Class I facilities most often serve long-distance trips or provide connecting links between facilities that serve long-distance trips.
- Class II—These are two-lane highways on which motorists do not necessarily expect to travel at high speeds. Two-lane highways that function as access routes to Class I facilities, serve as scenic or recreational routes that are not primary arterials, or pass through rugged terrain generally are assigned to Class II. Class II facilities most often serve relatively short trips, the beginning and ending portions of longer trips, or trips for which sightseeing plays a significant role.

Based on these definitions, the HCM uses two measures of effectiveness (MOE) for Class I LOS—percent time spent following (PTSF), and average travel speed (ATS), and just one measure for Class II—percent time spent following.

Many of the state's two-lane highways are in areas that would be considered scenic in nature (e.g., along the coasts, the Florida Keys route), implying a Class II classification, yet many of these highways also serve well-developed areas, which would imply a Class I classification. Quoting from Chapter 12 of the HCM, it is stated, "*…the primary determinant of a facility's classification in an operational analysis is the motorist's expectations, which might not agree with the functional classification*." This statement sums up very well the crux of the issue for the FDOT. Thus, the LOS Task Team had to decide if either one of these classifications would be appropriate for these types of highways, or if a new classification needed to be developed. From the US-1 (Florida Keys) analysis experience, the LOS Task Team concluded that the most important LOS measure for motorists on these types of highways was the ability to maintain a "reasonable" speed. Drivers in a small, developed, area which is posted for 89 km/h (55 mph) would primarily like to travel near that speed. Similarly, along a beach road posted at 72 km/h (45 mph) or in a community posted at 64 km/h (40 mph), drivers probably accept that they need to slow down and are quite satisfied to proceed through these areas close to those speeds. From this conclusion, PTSF was removed from consideration as an MOE applicable for these types of roadways. Consequently, the Class II definition was then removed from consideration, as PTSF is the only MOE for this Class. That left Class I for consideration, which included a speed-based MOE, as well as PTSF.

On Class I highways, the LOS is determined by the most critical of the two performance measures (ATS or PTSF). This raises the question of which measure dominates and under what conditions. The ATS is heavily influenced by the free flow speed and the PTSF is not. On the other hand, PTSF is much more sensitive to the traffic volume than ATS, whose relationship to the demand volume is fairly flat. So, it should be expected that the PTSF will govern at high speed and high volume while the ATS will govern at low speed and low volume. An experiment was conducted to test this premise. Keeping all parameters except free flow speed and AADT at their default values for two lane highways, a “crossover volume” was determined for each free flow speed. The crossover volume represents the point at which PTSF becomes the critical determinant of the LOS. The results of this experiment are presented in Figure 2. The volume is represented by the v/c ratio to give a normalized perspective on the numbers. It can be seen that ATS never governs at v/c ratios above 0.3, or at free flow speeds above 89 km/h (55 mph).

While free-flow speeds at or below 89 km/h (55 mph) are the condition on a very large percentage of these two-lane highways, the volumes can encompass a large range, with v/c ratios frequently exceeding 0.3. However, even for facilities in which the ATS would govern, the LOS Task Team had difficulty with the concept that a facility that had an average travel speed the same as a posted speed of 80 km/h (50 mph), for example, would only have a level of service of C (see Table 2). They felt these ATS LOS thresholds were unreasonably pessimistic for these types of roadways in developed areas.

In light of these results, and the DOT’s philosophy about ATS LOS thresholds, it was decided that for two-lane highways in developed areas there should also be a Class III classification, with percent of free flow speed being the primary performance measure. Working with average speed criteria in Exhibit 20-2 (also shown in Table 2) of the HCM2000, a percent of free flow speed criteria based on 97 km/h (60 mph) was easily derived.

Under this scheme, the resulting service volumes appear much more in line with previous FDOT findings. For example, based on statewide default roadway and traffic data, a two-lane uninterrupted flow roadway posted at 72 km/h (45 mph) with a 10,000 AADT would be LOS E using the HCM2000 criteria and LOS C using the proposed criteria (compare results shown in Figure 3a with the LOS criteria shown in Table 2). Given that vehicles are still averaging about 64 km/h (40 mph) in an urban situation, do not need to come to a stop, and are not trying to pass, the LOS C result appears more reasonable. FDOT’s position since the early 1990’s is that drivers primarily want to go at a reasonable speed on two-lane uninterrupted flow facilities in developed areas. Although originally presented as ‘average travel speed’ in the Florida Keys study, ‘percent of free flow speed’ best represents that concept of “reasonable” speed. Furthermore, the use of a Class III uninterrupted flow two-lane facility classification based on ‘percent of free flow speed’ is appropriate and needed.

SOFTWARE IMPLEMENTATION

This section discusses the software implementation of the HIGHPLAN two-lane and multilane level of service planning methodologies. HIGHPLAN is a stand-alone Windows™ application. For reference, the user interface is shown in Figure 3, where it can be seen that the inputs correlate with those shown in Table 1. At this point, HIGHPLAN deals only in US customary units, and a metric version does not exist.

Features

HIGHPLAN has two major level of service calculating features. First, it calculates the level of service for the facility being analyzed and also shows the calculated performance and service measures. Second, it calculates three service volume tables: hourly volumes in the peak direction, hourly volumes in both directions, and annual average daily traffic volumes. The program can be used at a generalized planning level with numerous defaults or at a conceptual planning level with specific roadway and traffic variable inputs.

HIGHPLAN uses the Traffic Model Markup Language (TMML) format (based on XML) for data interchange [7]. This facilitates direct results comparison to other TMML compliant programs that deal with highway analysis, such as the HCS. A companion utility program, TMRC (for Traffic Model Results Comparison), has been developed to compare the output of two TMML files generated by different programs for the same facility type. Furthermore, consultants that prefer to develop their own user interface for the input data can interface directly with the computational engine of HIGHPLAN by using TMML formatted data. This will ensure that third party developed programs maintain fidelity with FDOT's analysis procedures by utilizing the data validation capabilities and computational engine of HIGHPLAN.

CONCLUSIONS AND RECOMMENDATIONS

HIGHPLAN is well suited to its intended application, which is planning level analysis of two-lane and multilane highways. It maintains fidelity to the HCM procedures to the extent that Florida conditions will allow, and that Florida users will accept.

It is also important to recognize the limitations of a planning application, in which the input data requirements have been simplified to facilitate productive application. For example, the HCM provides a procedure for computing free-flow speed as a function of site-specific factors. HIGHPLAN assumes the free-flow speed to be 8 km/h (5 mph) above the posted speed. If more accurate estimates of free flow speed are required, then software that implements the full procedure may be a better choice than HIGHPLAN. This would also be the case if strict adherence to the HCM procedure were required.

The most significant deviation from the HCM is the introduction of a third highway class for analysis of two lane roadways in developed areas. The HCM now recognizes two classes of highways and prescribes two performance measures (PTSF and ATS) that could determine the level of service on a given highway. For Class I highways, the most critical of PTSF or ATS determines the LOS. For Class II highways, PTSF is the sole determinant, and the ATS is ignored. This paper argues that there exists, especially in developed areas, a third highway class in which the average travel speed, in relation to the free-flow speed is the sole determinant of LOS. The HCM2000 two-lane highway analysis methodology would be more useful and relevant if it recognized such a class.

Historically, Florida has been in the lead in applying HCM concepts at a planning level and developing corresponding guidance and software. Applying the HCM procedures in the second largest state in the eastern U.S. with major population centers and totally rural areas provides an excellent test case not only of the two-lane and multilane chapter methodologies, but the entire HCM. Perhaps naturally, when implementing the new HCM2000 procedures for two-lane and multilane facilities and applying them to roadways in urbanized areas (e.g., five-mile long causeways), in numerous small towns, and in totally undeveloped areas and in conjunction with freeway and arterial analyses, anomalies arise. The findings and recommendations in this paper should be applicable throughout the U.S. at the local, regional, state and national levels, whether applying the techniques to analyze a specific roadway or to conduct system-wide analyses.

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Table 1. Data Input Variable Summary

Data Item	Choice or Range	Initial Default
Roadway Variables		
Area Type	Rural undeveloped Rural developed Transitioning urban Urbanized	Rural undeveloped
Number of Thru Lanes	2,4, or 6	2
Posted Speed	35-65 mph	Depends on area and highway type
Median Presence	Yes or No	Depends on area and highway type
Left Turn Lane Presence	Yes or No	Depends on area and highway type
Terrain	Level or Rolling	Level
No Passing Zone %	0 - 100	20 (Two-lane only)
Passing Lane Spacing	0 - 30	None (Two-lane only)
Highway Class	I, II or III	I (Two-lane only)
Analysis Type	Segment or Facility	Segment
Traffic Variables		
AADT	1,000 - 100,000	10,000
K Factor	0.06 - 0.20	0.095
D Factor	0.5 - 1.0	0.55
PHF	0.75 - 1.0	0.925
% Heavy Vehicles	0 - 25	Depends on area and highway type
Local Adjustment Factor	0.8 - 1.0	1.0
Base Capacity	1700 (2-lane)	1700
	1900 – 2300 (multilane)	Depends on Free Flow Speed
Adjusted Capacity	Calculated Only	

Table 2. LOS Criteria for the Three Classes of Two-Lane Highways

	Class I[1]		Class II[1]	Class III
LOS	**PTSF[2]**	**ATS[3]**	**PTSF**	**% of FFS[4]**
A	≤ 35	> 55	≤ 40	> 0.917
B	> 35-50	> 50-55	> 40-55	> 0.833
C	> 50-65	> 45-50	> 55-70	> 0.750
D	> 65-80	> 40-45	> 70-85	> 0.667
E	> 80	≤ 40	> 85	> 0.583

[1] Values are directly from the HCM
[2] PTS – Percent Time Spent Following
[3] ATS – Average Travel Speed
[4] FFS – Free Flow Speed

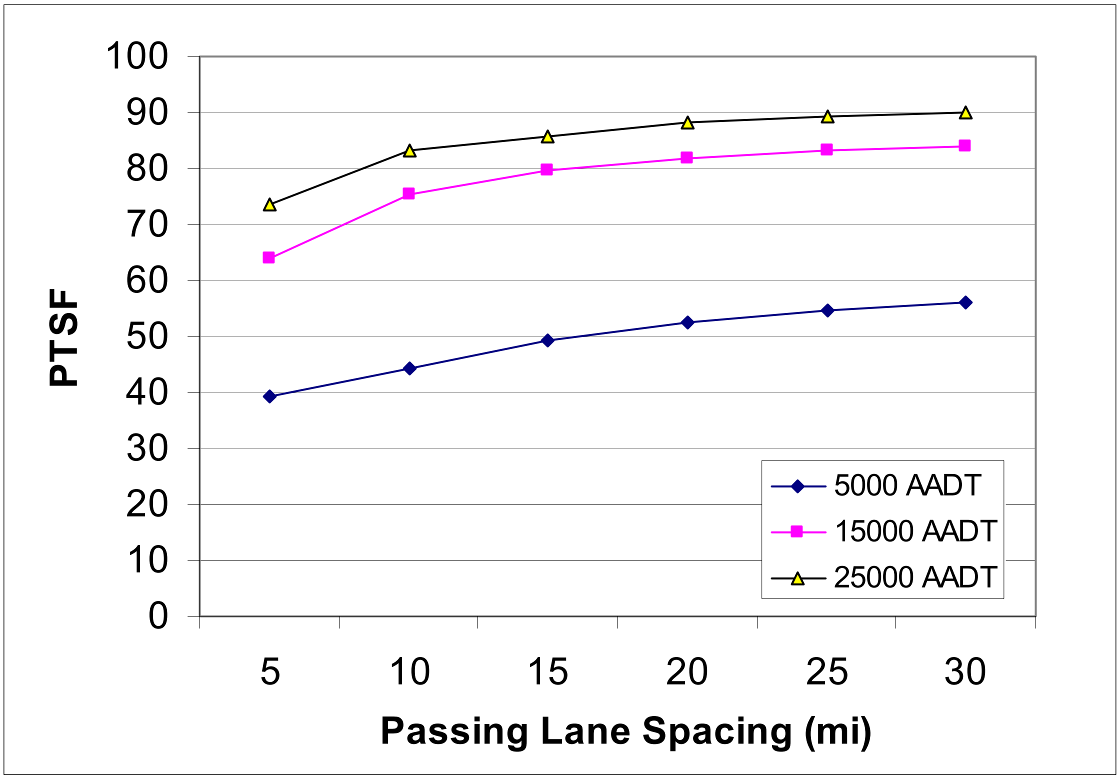


Figure 1. Effect of Passing Lane Spacing on PTSF in HIGHPLAN

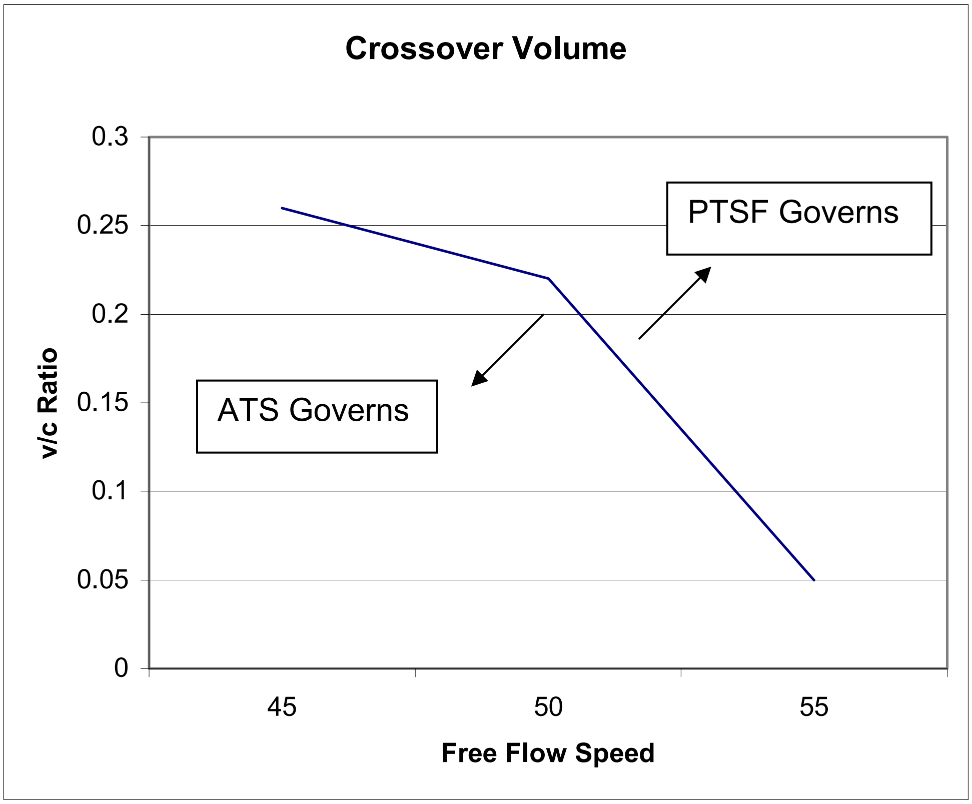
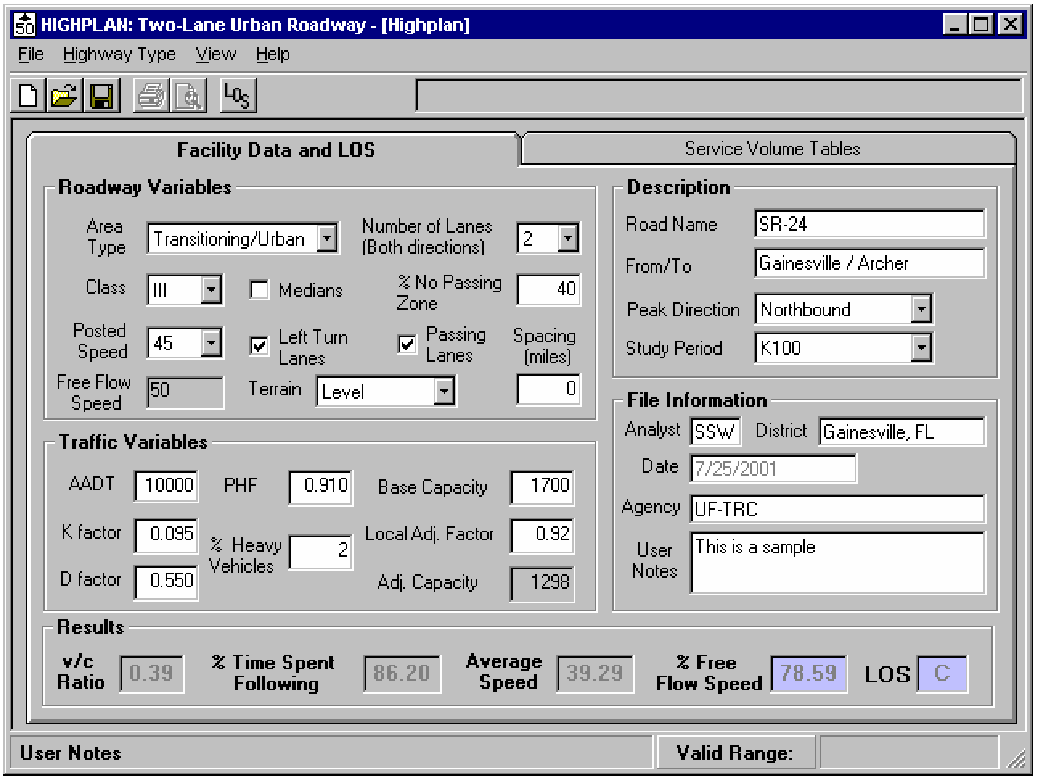
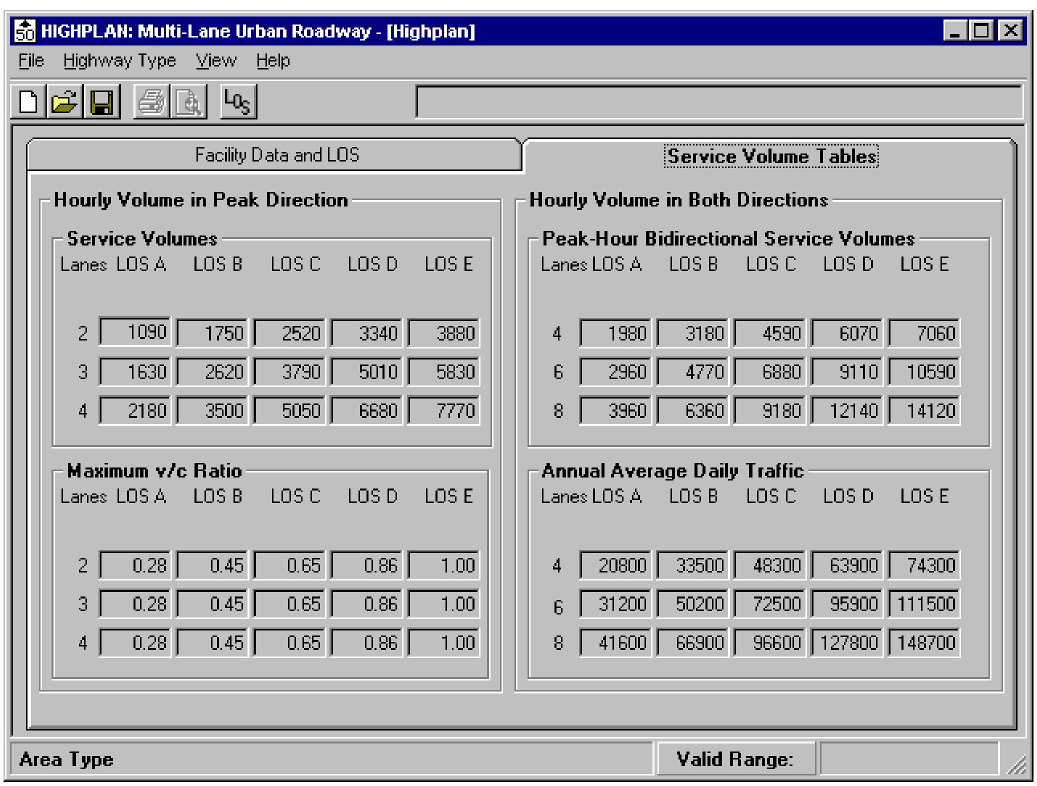


Figure 2. Effect of Free-Flow Speed on Crossover Volume



(a) Facility input data and site-specific results



(b) Service volume tables

Figure 3. HIGHPLAN user interface showing input data and results

Task 2

Development of Preliminary LOS Criteria and Thresholds for Rural Freeways

January 2002

Background

Capacity analysis is an important part of freeway traffic management. A set of methods from the Highway Capacity Manual (HCM) is widely used for this purpose. The HCM prescribes Level of Service (LOS) criteria as a function of traffic density to categorize the operational conditions of both rural and urban freeway sections. This density-based LOS is ideally suited to the assessment of urban freeways when the performance must be optimized to meet high traffic demand. There is, however some question as to whether density is the appropriate indicator of the quality of service on rural freeways. In particular, the Florida Department of Transportation (FDOT) has found this concept difficult to apply in Florida because of the widely held belief that drivers on rural freeways view the quality of service from a different perspective than those on urban freeways.

Previous research by Kim, Courage and McLeod on this subject identified a promising concept for assessing rural freeway LOS [1]. The researchers investigated the use of acceleration noise, measure of speed fluctuations as a criterion for assessing the LOS of a rural freeway section based on driver comfort. A set of LOS thresholds based on the acceleration noise level for rural freeways was developed using linear and nonlinear car-following models.

Acceleration noise is a measure of traffic turbulence, defined as the root mean square deviation of the acceleration of a vehicle in the traffic stream. Acceleration noise was first described by Hermann in 1959 [2]. A few years later, the concept was presented in a Highway Research Board (now TRB) Special Report [3]. It was first suggested as a level of service (LOS) measure by Drew in 1967 [4]. Drew's discussion was later incorporated into a textbook on traffic flow theory and control, which he authored in 1968 [5]. A more detailed discussion of this topic is presented in Appendix A.

The models were implemented in a simulation program developed by the researchers. To provide a basis for comparing density and acceleration noise with respect to driver perception, it was assumed that the driver perception of both performance measures would be the same as volume approached zero (i.e., the lower end of LOS A), and would again converge to the same value as volume approached the upper limit of LOS D. In other words, when the density is high enough to cause the operation to drop to LOS E, there is no longer a distinction between driver perception on an urban freeway and a rural freeway.

The results, as illustrated in Figure 1, show that, at low volumes, driver discomfort increases more rapidly than density as volume increases, and the rate of increase diminishes when the volume becomes higher. If acceleration noise could be accepted as a measure of driver perceived quality of service on rural freeways and if the simulation model developed by the researchers could be accepted as a reliable estimator of acceleration noise, then this research would indeed provide the basis for an argument for a separate set of criteria for assessing the level of service on rural freeways.

The paper described in Reference 1 was submitted to the Transportation Research Board (TRB) with the intent of exposing the Highway Capacity and Quality of Service (HCQS) Committee to the view that the level of service on rural freeways should be determined based on a different set of criteria than the corresponding measure for urban freeways. The paper was not accepted because reviewers indicated that, while the concepts were interesting, there was insufficient data to support the conclusions. Concerns were also expressed over the validity of the "home grown" simulation model.

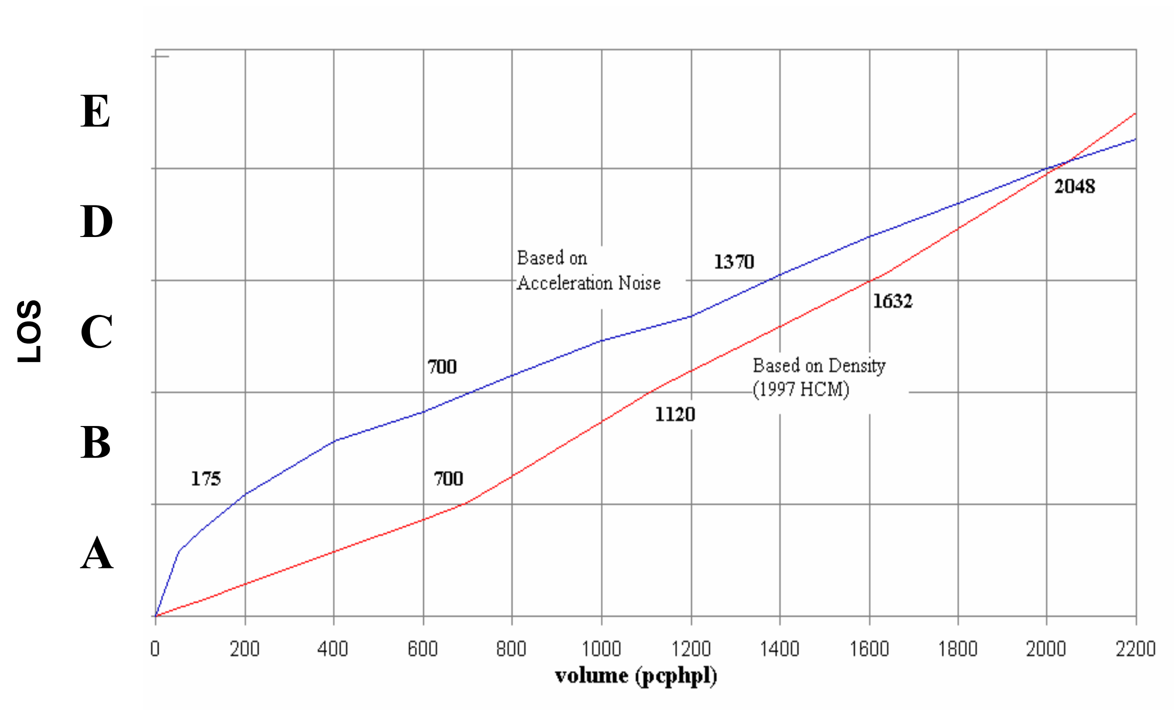


Figure 1. Effect of freeway volume on density and acceleration noise on a freeway (from Reference 1)

Research Approach

The Florida Department of Transportation considers rural freeway LOS to be an important issue that should be resolved in a future edition of the LOS Handbook. Field data will eventually be required to support any proposed changes in criteria and thresholds. As a preliminary step, it was decided that more detailed simulation studies be carried out to confirm the results obtained in the initial study, to establish the feasibility of a field data collection project, and to provide guidelines for the conduct of such a project.

For this purpose, the CORridor SIMulation (CORSIM) model, which was developed by the Federal Highway Administration (FHWA) was used as a surrogate for field data collection. CORSIM is a microscopic model that propagates individual vehicles through a facility. The logic is based on a realistic traffic flow model that considers the mutual influence of vehicles on each other (car following, lane changing, etc.) in addition to the influence of the roadway and traffic control system on each vehicle. The simulation process is updated each second and the attributes of each vehicle are stored for future analysis.

An example of a single second of simulation applied to a specific vehicle is illustrated in Figure 2. The full list of attributes stored for the flagged vehicle is seen to include variables such as acceleration, following distance, lane changing parameters, etc. that are related to driver perception of the quality of service. The parameters of each vehicle (type, length, driver type (aggressiveness), etc. are randomly assigned by CORSIM from a user-specified distribution.

The objectives of this task were to establish several simulation scenarios and process the second-by-second data for each scenario with traffic volumes varying from near zero to the full capacity of the facility. The properties of each scenario will include such parameters as number of lanes, free-flow speed, traffic composition, driver characteristics, etc.

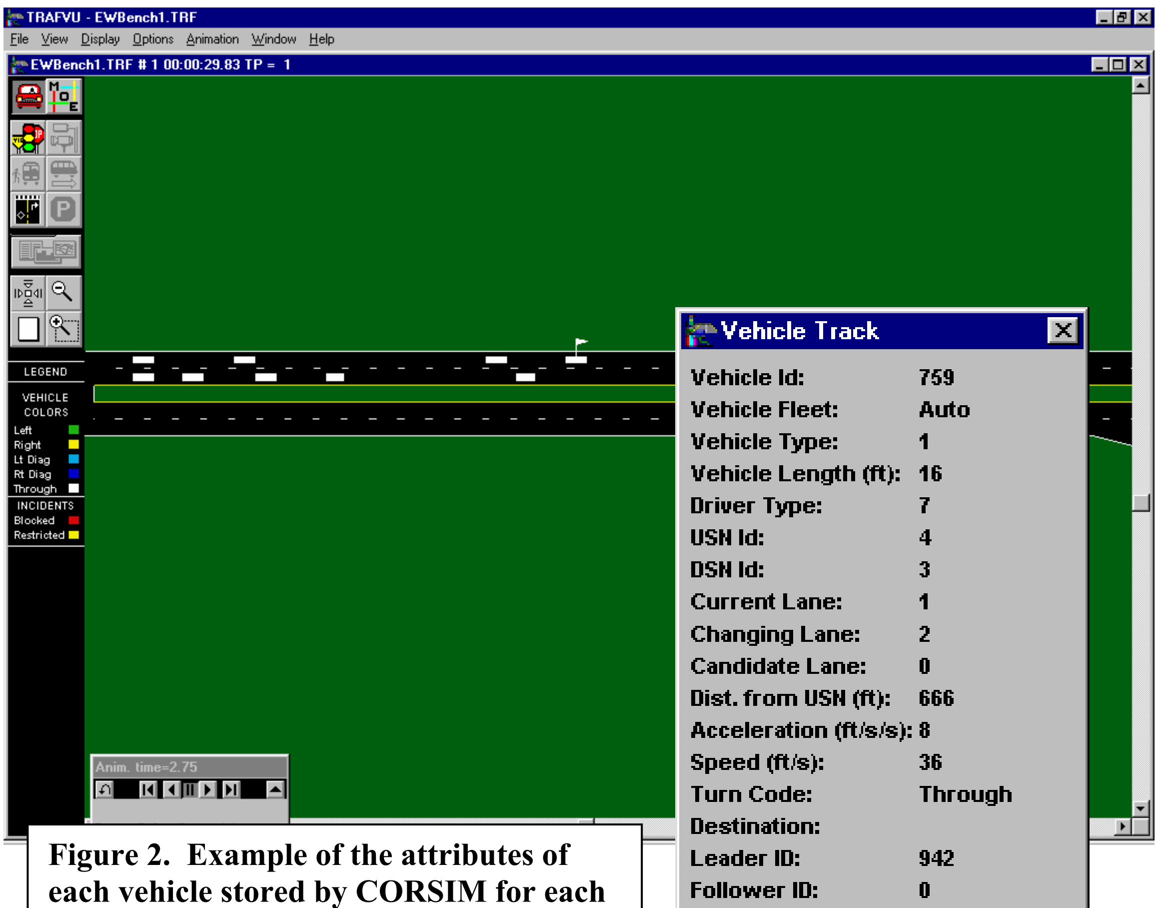


Figure 2. Example of the attributes of each vehicle stored by CORSIM for each second of operation.

This process was used to establish, confirm and refine the relationships between traffic volume and the various measures, or combination of measures that could reasonably be expected to influence driver perception of the quality of service.

The initial study on this topic, as described in Reference 1, was limited to acceleration noise as a surrogate for driver comfort. This measure certainly has conceptual merit, as it is reasonable to assume that a driver will attempt to maintain a uniform velocity when he/she is traveling along a freeway. Thus, under situations in which a driver's velocity and acceleration become subject to car-following laws, the acceleration noise will increase, and the driver's perception of level of service will deteriorate.

Two additional candidate measures were studied with CORSIM:

- *Cruise Control Emulation*: Since cruise control is an amenity that is associated with rural driving, it is logical to associate the driver's ability to use cruise control with the perception of quality of service.

- *Percent Time Spent Following:* This concept was originally suggested by the HCM as a service measure for two lane roadways. There is at least a partial analogy with rural freeway driving. Freeway drivers whose motion is dictated by the lead vehicle are not quite as constrained as two-lane rural roadway drivers because they are able to pass the lead vehicle without the problem of oncoming traffic. Nevertheless, it could be argued that driver comfort on a freeway is directly influenced by lead-vehicle constraints.

Simulation Study Description

The freeway sections that were modeled were all basic freeway segments with a length of 6000 ft. The free-flow speed in each case was 65 mph. Separate studies were performed on freeways with one, two and three lanes in each direction. The case of the single lane freeway was largely of theoretical interest. This case was included primarily as a check on the reasonableness of the overall study methodology.

CORSIM runs were performed for each scenario for a study period of 15 minutes (900 seconds). Vehicle generation was governed by the negative exponential distribution function. Ten different CORSIM runs were performed with different random seeds for each case. CORSIM only reports aggregate measures of performance and also does not directly generate the measures of interest for this study. Therefore, it was necessary to process the second-by-second simulation data of the TSD file to derive the measures of interest in this study. This file, however, is in a binary format that requires custom file reading routines to access. A TSD file reading tool developed by Leonard [6] was used for this purpose. This software tool is in the form of a dynamic-link library (DLL). Additionally, a custom program (developed in Visual Basic) was written to perform the following functions: 1) interface with the DLL and provide TSD file access instructions to extract the vehicle attributes of interest; 2) process the retrieved TSD file data in a manner consistent with one of the three measures of interest in this study; and 3) reduce and save the final data to a comma-delimited text file format. This text file was then imported into a Microsoft Excel spreadsheet, from which the results were plotted.

Simulation Results

The simulation data generation, reduction and analysis process described above was applied to determine the relationship between traffic volume on the freeway and each of the candidate performance measures. The results for each measure will be presented and discussed separately.

Acceleration noise

The instantaneous acceleration of each vehicle at each second is computed from the speed differential with respect to the previous second, and the standard deviation of acceleration foe each vehicle is computed over the 6000 ft segment. The results are plotted in Figure 3a, b and c for freeways with 1, 2 and 3 lanes respectively. Note that the acceleration noise displays the same non-linear characteristics as were first observed in Figure 1, by increasing more rapidly in the lower volume range and leveling off as volume increases. It is also observed that the non-linear effect is most pronounced on single lane freeways and diminishes as the number of lanes is increased.

These results confirm and expand the findings of the original studies presented in Figure 1. The additional investigation has added more credibility to the notion that acceleration noise is a good candidate as a performance measure for rural freeways:

1. The original simplistic model developed by the researchers has been replaced by CORSIM, which offers the most widely used freeway model in the USA.
2. The single-point analysis in the original work was expanded to cover a section more than a mile long.
3. The single lane analysis was expanded to cover two and three lane freeways.

A brief review of the literature pertaining to acceleration noise as a traffic performance measure and possible measurement techniques is presented in Appendix A.

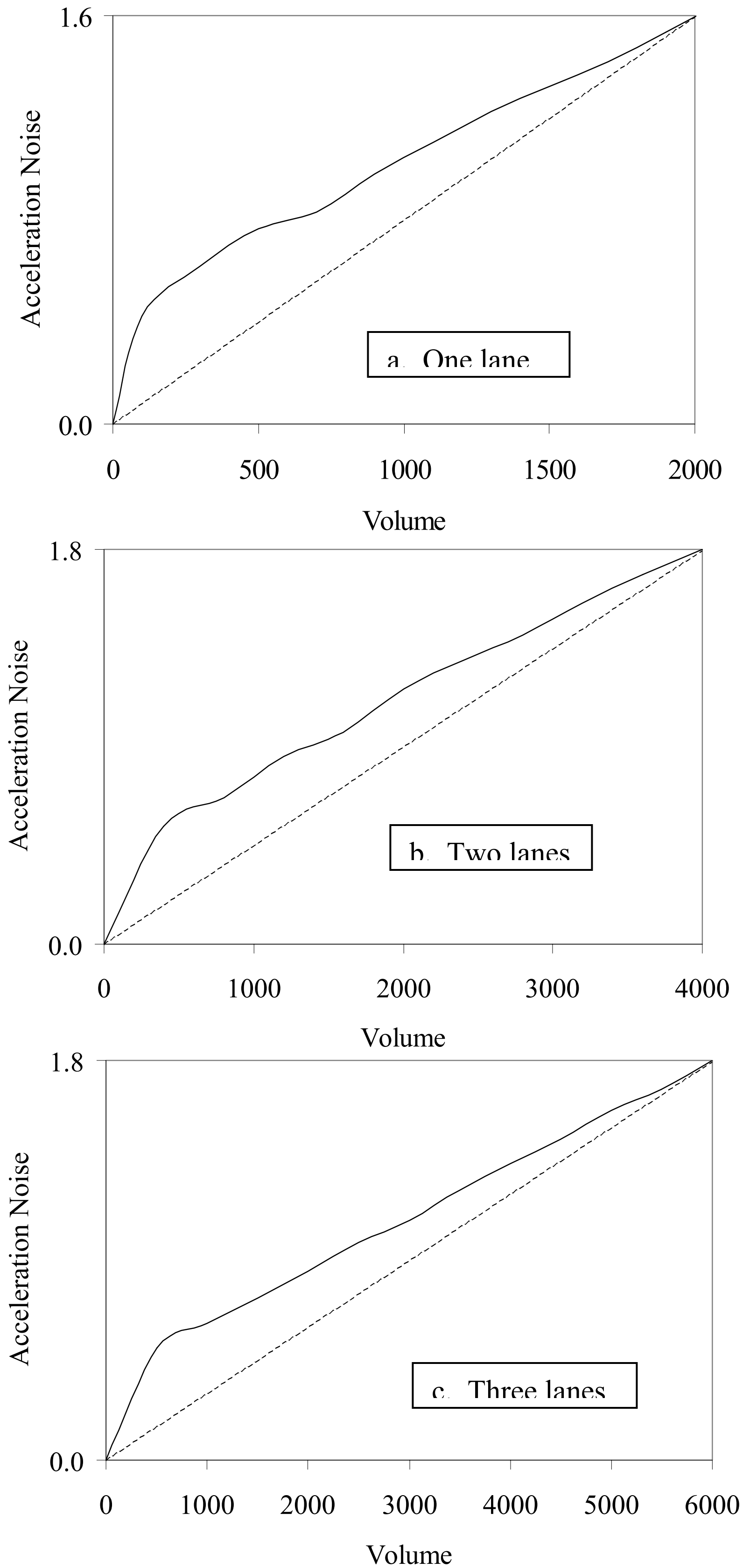


Figure 3. Acceleration noise vs. volume for 1, 2 and 3 lane freeways

Cruise Control Emulation

Since CORSIM does not provide explicit cruise control emulation, it was necessary to build a cruise control emulator into the post processor logic. The emulator applies the cruise control to a vehicle when the vehicle has been traveling at its desired speed for a specified number of seconds. A value of three seconds was chosen in the absence of any supporting information. The cruise control is released when the vehicle begins to decelerate for any reason. It is suggested that these rules should provide a reasonable emulation of a practical cruise control operation.

Two measures were reported by the cruise control emulator:

1. The proportion of time in which the cruise control was applied, and
2. The number of times that the cruise control was applied and released.

Each of these measures will be discussed separately.

Proportion of Time with Cruise Control Applied

This measure comes directly from the cruise control emulator. The results are presented in Figure 4a, b and c for freeways with 1, 2 and 3 lanes respectively. For compatibility with the other candidate measures, the value that is plotted is actually the proportion of time without cruise control because this value increases with volume. Note that the nonlinear characteristic evident in the acceleration noise (Figure 3) is much less pronounced for the cruise control measure. In fact, nonlinearity is only discernable to any degree in the case of the single-lane freeway, which is essentially a hypothetical situation. The conclusion here would have to be that the proportion of time without cruise control varies directly with traffic density on the freeway.

Number of Cruise Control Applications

This measure comes directly from the cruise control emulator. The results are presented in Figure 5a, b and c for freeways with 1, 2 and 3 lanes respectively. The nonlinearity in this case is much more pronounced; in fact probably too pronounced to be useful, because the number of cruise control applications reaches its maximum value at a v/c ratio in the range of 10 percent. There was very little difference between the two and three lane freeways with respect to this measure.

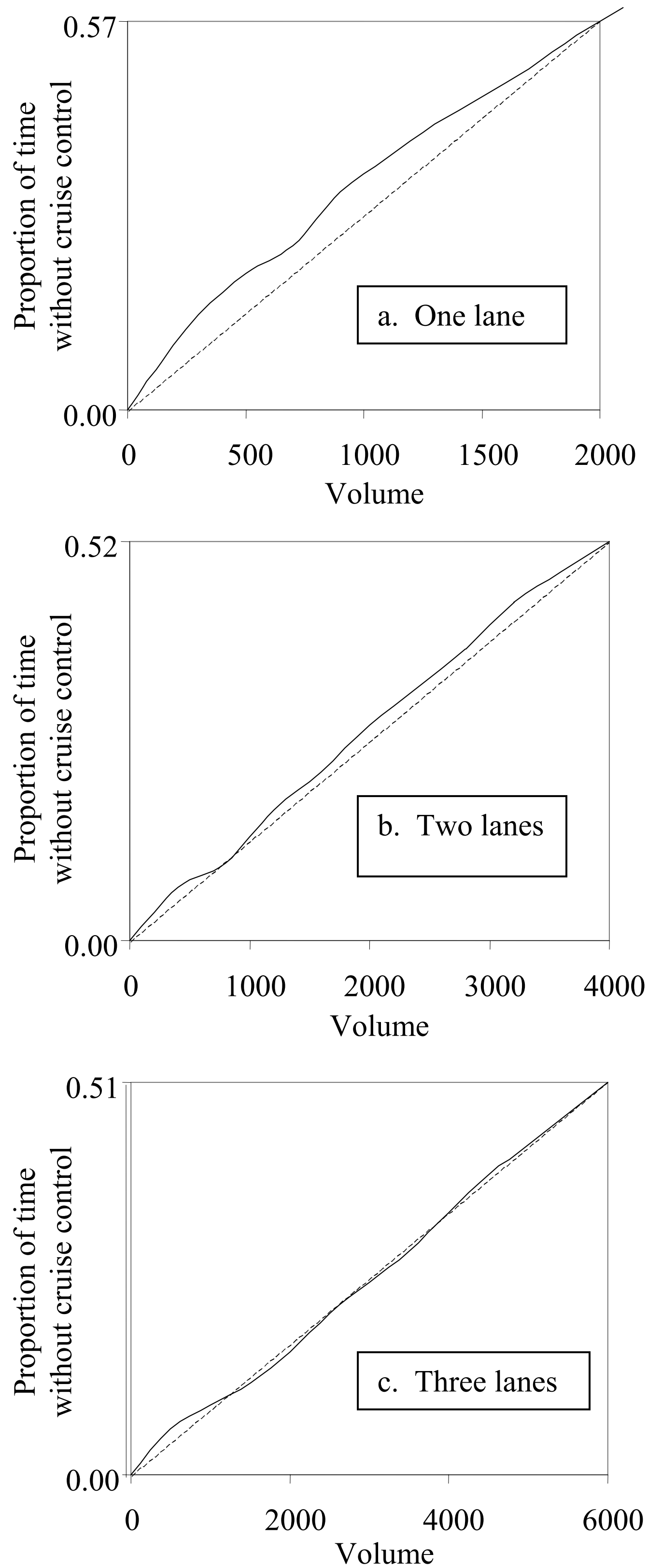


Figure 4. Proportion of time without cruise control for 1, 2 and 3 lane freeways

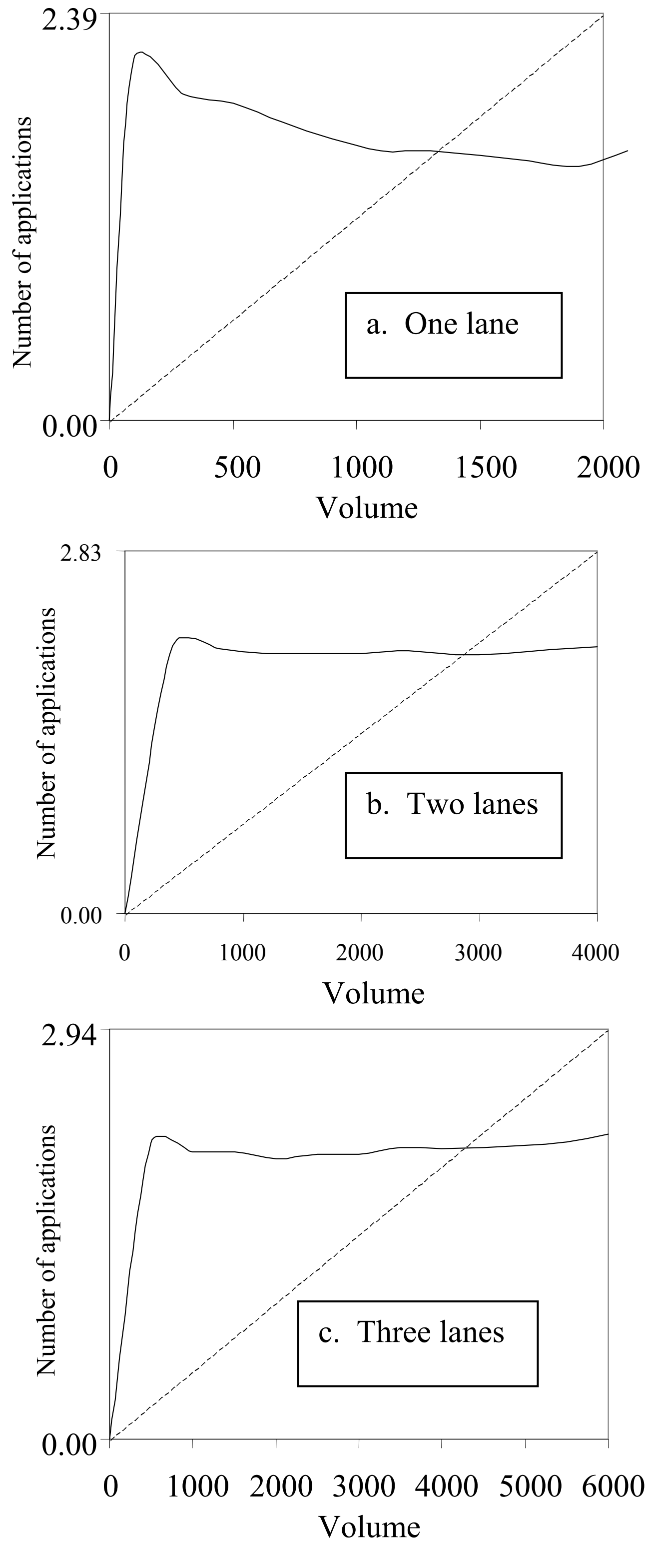
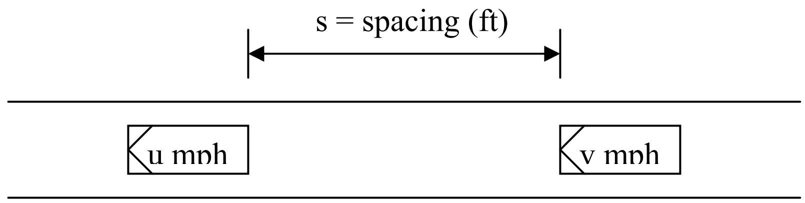


Figure 5. Number of cruise control applications for 1, 2 and 3 lane freeways

Percent Time Spent Following

This measure is also not produced explicitly by CORSIM, and therefore must be determined by the postprocessor logic. For this purpose, a vehicle is considered to be following its leader if the relationship between the position and speed with respect to the leader places it within the car following influence zone. The following scheme is used in CORSIM was employed to define the independency of following vehicle [7].



The vehicle is identified as independent when it is outside the car-following influence zone as determined by:

$$s \geq \frac{v^2}{8} + v + 4 \qquad \text{or} \qquad s > 2u + v + 4 \text{ and } v > u$$

The results are presented in Figure 6a, b and c for freeways with 1, 2 and 3 lanes respectively. The nonlinear characteristics are certainly evident in these graphs. They are more pronounced that the corresponding results for acceleration noise (Figure 3), but less pronounced than those associated with the number of cruise control applications (Figure 5). Note that, by visual inspection, there is no discernable difference between two- and three-lane freeways.

These results are certainly interesting, but may be largely of theoretical value. It is especially interesting to draw a parallel with two-lane rural roads. The value of the PTSF measure rises too rapidly to be of use as a direct determinant of LOS on rural freeways. On the other hand, preliminary experience with the application of the PTSF concept in the HCM 2000 has suggested that the same might be true for two lane roads. The HCQS Committee has already been asked by the Florida DOT to reexamine the PTSF concept.

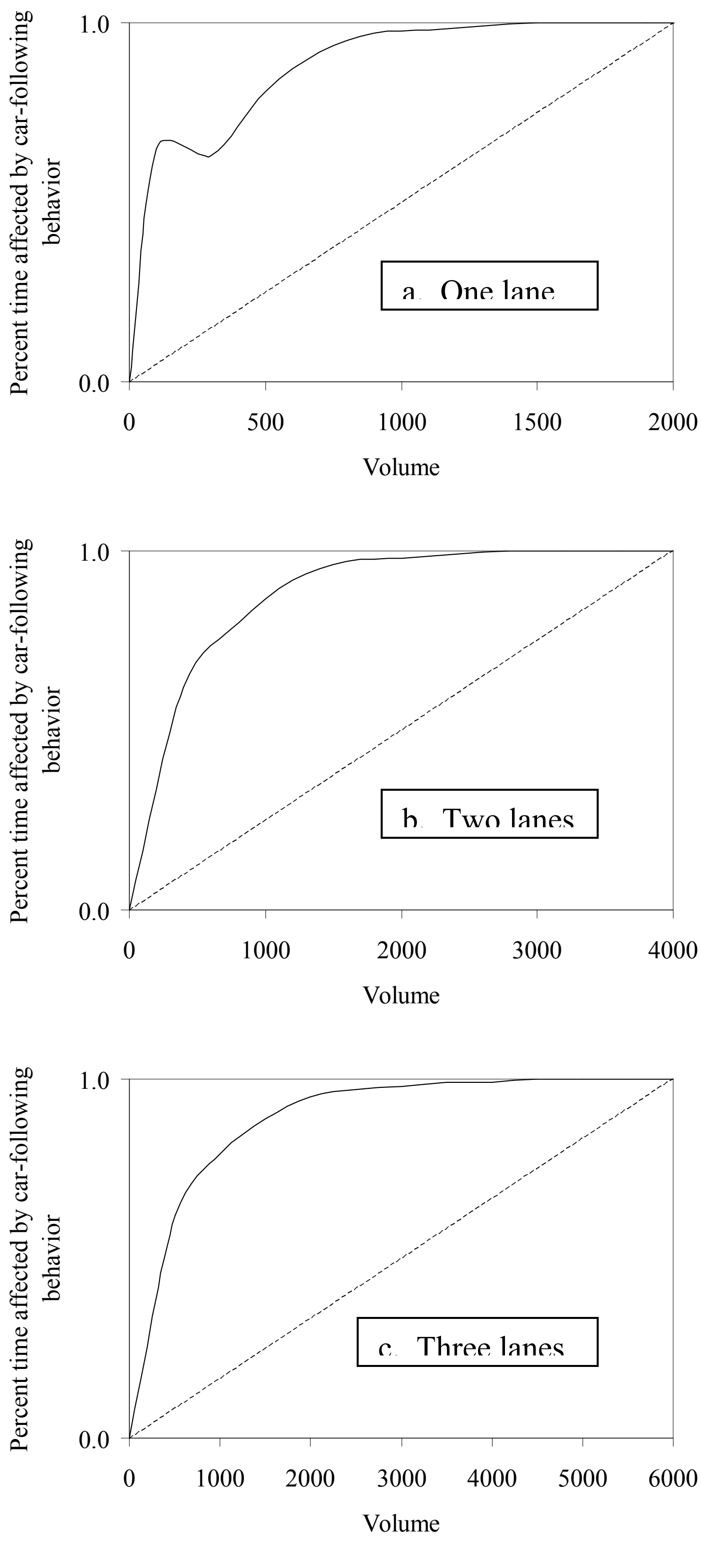


Figure 6. Proportion of time spent following for 1, 2 and 3 lane freeways

Conclusions

Within the limits of the study that was conducted, the following conclusions are offered:

1. The CORSIM studies confirm that there is a nonlinear relationship between acceleration noise and traffic volume on rural freeways. This relationship could be used directly as the basis of a new set of LOS criteria for rural freeways.

2. The other measures considered in this study all have conceptual appeal. All have produced very interesting results with respect to their relationships to traffic volume. No single measure, except for acceleration noise, could be proposed as the basis for determining LOS on a rural freeway.

3. The PTSF measure deserves further consideration. Some redefinition would be required, but there are several parameters in the car following model that could be adjusted. The HSQS committee should be asked to consider both rural freeways and two-lane rural roads in the same context with a view to establishing a parallel measure for both facilities.

At this point, it is difficult to recommend specific field studies to verify the value of acceleration noise as a determinant of LOS. The HCQS committee should be presented with the results of the studies described in this report, along with a set of recommendations to be formulated by FDOT, considering the results of this study, as well as information from other sources.

Closure

The FDOT Technical Coordinator for the study described in this document organized a teleconference involving the Florida-based members of the TRB Committee on Highway Capacity and Quality of Service to discuss their views on the contents of this report. Those participating in the teleconference came to agreement that it is appropriate to have different freeway and multilane highway class LOS thresholds based on traveler perception. Classes should be based on a combination of interchange/intersection spacings, free flow speed, area type, and trip length. Specifically, it was agreed that:

Florida and the HCM should have at least be two classes for freeways: (1) generally characterized by interchange spacing of 6+ miles, 75 mph free flow speed, in a rural area, and typical 60+ mi. trip lengths, (2) generally characterized by interchange spacing of 2 miles, 60 mph free flow speed, in an urbanized area, and typical 10- mi. trip lengths. As appropriate agencies (e.g., FDOT) should have the flexibility to have more classes reflecting variances in these class characteristics (FDOT currently recommends four classes). On a preliminary basis FDOT's freeway research will concentrate on Class 1.

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APPENDIX A
Review of the Literature on Acceleration Noise as a Measure of Traffic Performance and Potential Measurement Techniques

Definition and Applications

Acceleration noise is a measure of traffic turbulence, defined as the root mean square deviation of the acceleration of a vehicle in the traffic stream. Acceleration noise was first described by Hermann in 1959 (Hermann, R. et al. *Traffic Dynamics: Analysis of Stability in Car Following.* Operations Research., 7, pp. 86-106.). A few years later, the concept was discussed in Highway Research Board Special Report # 79, *An Introduction to Traffic Flow Theory*, published in 1964.

It was first suggested as a level of service (LOS) measure by Drew in 1967 in:

Drew, DR; Dudek, CL and ;Keese, CJ, "Freeway Level Of Service As Described By An Energy- Acceleration Noise Model, Highway Research Record, Highway Research Board (now TRB), 1967

Abstract:
The standard deviation of the acceleration of a vehicle is called acceleration noise. Research is conducted on the theoretical and practical implications of the acceleration noise parameter and the energy model, as related to the level-of-service concept. A complete energy model of traffic flow is formulated which includes both kinetic energy and internal energy. Measurement was made of the acceleration noise on the gulf freeway to test the hypothesis that acceleration noise represents the internal energy of a traffic stream. The effects of such geometrics as grades of the facility on acceleration noise, and of operational control procedures such as ramp metering on acceleration noise are determined. It is concluded that acceleration noise can be a useful tool for measuring the changes in smoothness of flow resulting from on-ramp control and metering procedures. Since there is a good indication that acceleration noise is linearly related to the absolute difference in adjoining grades, it is apparent that this parameter might be useful in measuring the effects of geometric changes. Thus, acceleration noise has practical application in both operations and design.

Drew's Model was reviewed and critiqued in 1981 in the following reference:

Measurement Of Acceleration Noise And Discussion Of The Energy Model Developed By Drew, Winzer, T, *Transportation Research*. Volume: 15A Issue: 6 1981

Abstract:
To find relationships between acceleration noise and the characteristic features of the traffic flow, an investigation has been conducted including the measurement of relevant parameters. By means of the average-car method relationships between acceleration noise and traffic volume, density and mean-time speed have been found, which can be represented in form of nomograms. The results of this investigation show that the concept of internal energy of a traffic stream cannot be maintained.

Subsequent papers are found in the literature in which acceleration noise is investigated as a measure, or included among the measures, for evaluating specific conditions or improvement projects. Examples include:

Acceleration Noise And Level Of Service Of Urban Roads - A Case Study, Babu, YS;Pattnaik, SB, Journal of Advanced Transportation, Volume: 31 Issue: 3, 1997

Predictor Model Of Traffic Accidents In Consideration Of Acceleration Noise And Traffic Conditions. Noda, K; Ogino, H; Takahashi, M;Kurimoto, *Intelligent Transportation: Realizing the Future.* Abstracts of the Third World Congress on Intelligent Transport Systems.

Evaluation Of Steady Burn Lights For Traffic Control In Highway Work Zones, Phase Ii. Final Report, Pant, PD;Huang, XH;Krishnamurthy, SA, Cincinnati University Department of Civil and Environmental Engineering, 1992

Factors Affecting Traffic Operations On Seven-Lane Cross Sections: Final Report, Balke, KN;Fitzpatrick, K;Lienau, FHWA/TX-94/1293-2F ,1993.

Measurement Techniques

Acceleration noise is somewhat difficult to measure because it involves longitudinal observations of individual vehicles. In general, the measurement techniques reported in the literature reflect the state of the art in data collection methods at the time of the study. For example, the first tests to determine the acceleration noise distributions experimentally are reported in Herman et al. 1959. An accelerometer of an equipped test car was evaluated for trips under different density conditions and with different driving tasks for the driver.

Because of the microscopic nature of the measurements and the relatively primitive state of the art, the studies reported in the literature were based on a relatively small number of observations, generally using test vehicles with some degree of instrumentation. These studies could be repeated today with more productive instrumentation, but the need for specially instrumented vehicles with trained drivers would make the collection of adequate amounts of data extremely expensive. The cost of instrumenting each vehicle would be in the range of $1500, and several vehicles would be required.

Another data collection possibility involves the use of GPS-based instruments. The University of Florida Transportation Research Center has performed some preliminary experiments that suggest that inexpensive GPS receivers may be used to provide useful data for in-vehicular measurements. Studies conducted at Louisiana State University have explored this concept in more detail. The following reference appears to be directly related to traffic stream measurements:

“Results of Car Following Analyses Using Global Positioning System”. Wolshon, B;Hatipkarasulu, Y, Journal of Transportation Engineering, Volume: 126 Issue: 4, 2000.

Abstract:
One of the key elements in the evolution of traffic flow theory has been the development of the car following theory. Applications of this research can be seen in traffic simulation models, such as CORSIM, that use car following models to simulate traffic flow and predict operational performance characteristics on arterial roadways. Researchers at Louisiana State University have recently developed a technique using the global positioning system to record and analyze car following behavior. In this study, these procedures were used to collect vehicle motion data and compare aspects of driver behavior recorded in the field to those predicted by the General Motors car following models. These comparisons were also used to develop numeric values of driver sensitivity and time lag from field data.

Task 3, Phase I

Development and Validation of a Procedure for Estimating LOS on Rural Freeways

February 2003

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Abstract

The Systems Planning Office of the Florida Department of Transportation (FDOT) has been one of the national leaders in funding research to develop improved methods for determining level of service (LOS) on various roadway facilities. Fundamental to the determination of level of service is the selection of appropriate an appropriate service measure, or measures, and the determination of appropriate thresholds within the range of service measure values for LOS designations A - F.

There has been some debate in recent years within the Highway Capacity and Quality of Service (HCQS) committee about how service measures for a facility should be selected. In particular, the historical approach has been for the HCQS committee to select the service measure they think is most appropriate. However, some committee members have been suggesting that the selection of service measures should be based on research involving the driving public at large that either directly or indirectly obtains information on driver perceptions of quality and level of service. Additionally, the Systems Planning Office of the FDOT has questioned whether the use of a single service measure, density, for freeways and the use of a single set of thresholds for this service measure across freeways in different area types, particularly urban and rural is completely appropriate. Specifically, the FDOT feels that driver perceptions of quality/level of service on freeways in rural areas are distinctly different than those of drivers on freeways in urban areas.

This report documents an initial investigation into the determination of the factors that impact driver perceived quality of service on rural freeways, using in-field surveys of motorists traveling on a rural freeway.

Introduction

The Highway Capacity Manual (HCM) presents methods for analyzing capacity and level of service for various transportation facilities, such as signalized and unsignalized intersections, arterial streets, freeway segments, highway segments, and more. The HCM is produced by the Highway Capacity and Quality of Service (HCQS) committee of the Transportation Research Board (TRB).

Methods for assessing the level of service (LOS) of a facility has become a major foundation of the HCM. A level of service designation provides an indication of the quality of service that the facility is providing under the given roadway, traffic, and control conditions. LOS values range from 'A' to 'F', with 'A' representing very good service and 'F' representing very poor service. This allows the transportation engineering community an effective way to communicate with decision makers and other stakeholders about the general adequacy of a facility to meet its travel demands.

For each of the facility analytical procedures in the HCM, the LOS assessment is based upon one or more performance measures. The selected performance measure(s) for the LOS assessment are referred to as the service measure(s). In selecting the service measure(s) for a particular facility analytical procedure, the committee has followed the general principle that the chosen service measure should be one that the traveling public can perceive. For example, the chosen service measure for signalized intersection is delay, which the HCQS committee believes is a measure that the traveling public easily perceives and associates with their perceived quality of service for that facility. The chosen service measure for freeway and multilane highway segments is density, which again, the committee believes the traveling public highly associates with its perceived quality of service, as this is directly related to a driver's ability to maneuver within the traffic stream.

Recently, however, there has been some debate within the HCQS committee about whether this approach for choosing service measures is the best one. Some members have proposed an alternative approach to the current one where transportation experts (primarily the HCQS committee) select a measure that they believe is most appropriate and one that they *think* the traveling public perceives to be a major indicator of their quality of service. The proposed alternative approach is to find out directly from the traveling public what performance measure or measures they most associate with their perceived quality of service on a particular roadway facility.

This debate has also been fueled within the HCQS committee discussions by some FDOT concerns in regard to the freeway analysis methodology. The Florida Department of Transportation's (FDOT) Systems Planning Office has long questioned the validity of having both just a single service measure, density, and having a single set of LOS thresholds for freeways in all area types (e.g., urban, rural). The FDOT Systems Planning Office believes that motorist expectations and perceived quality of service on rural freeways are distinctly different than on urban freeways. This belief is based on the premise that urban freeway travelers are quite satisfied with relatively dense traffic conditions as long as the conditions are not oversaturated, while rural freeway travelers are less satisfied with dense traffic conditions. For example, whereas urban travelers would likely be very satisfied traveling with 40% of the facility's capacity used (approximately a density of 15 passenger cars per mile per lane) correlating to a level of service of B, in rural areas such conditions would be considered quite congested, perhaps a level of service of D. Furthermore, whereas urban freeway travelers typically incur trip times much smaller than rural drivers, they are more likely to tolerate heavy traffic densities (e.g., 80% of capacity) because they do not become fatigued with such conditions over time.

The concept of different service measures or different thresholds for a specific service measure for a certain facility type in areas with differing levels of development is nothing new. In fact, it is already being used for a couple of facility types. The two-lane highway analysis procedure currently defines two classifications of highway (as defined by primary trip type served), with differing service measures and thresholds. The urban streets analysis methodology uses one service measure, average travel speed, but four different sets of thresholds, corresponding to four different arterial street classifications.

The overall objective of this task (Task 3) of the research project is to investigate quality/level of service issues for rural freeways and make recommendations for preferred service measures and thresholds. The first phase of this task was to essentially perform a pilot test of one method for finding out directly from motorists what they feel to be the important factors/measures for assessing their experienced quality/level of service on a rural freeway facility. The second phase of this task (which is now under a separate contract) will include detailed analysis of the data collected from Phase I, as well as a continued investigation of the issue of appropriate service measures and thresholds for rural freeways.

Literature Review

The concept of trying to determine directly from the traveling public what the most salient performance/service indicators are has only received minor research attention in the past, but has recently gained momentum. While the current literature base is still quite small on this topic, there are a few noteworthy pieces of work on this topic. The abstracts of these published or working papers will be reproduced in this section.

Authors: Hall, Fred L.; Wakefield, Sarah; Al-Kaisy, Ahmed
Title: Freeway quality of service: what really matters to drivers and passengers?
Abstract: Although the concept of Level of Service for freeways is usually defined in terms of users' perceptions, there have been very few studies that have sought drivers' or passengers' views about what is important to them. Such information is particularly important for evaluating extended trips on freeways, as opposed to a single section or segment. Not only is such information valuable for improving the Highway Capacity Manual, but it is also important in establishing appropriate criteria for assessing ITS proposals. This paper reports on the results of focus group sessions in which a group of commuters discussed their views about determinants of the freeway quality of service they experienced. Total travel time is the most important determinant for them, but a number of other aspects of the trip also matter, including

safety, traveler information, and maneuverability (density). The importance of travel time is a reminder that travel is a derived demand, and not something commuters do for the pleasure of the drive.

Publication Info: Presented at the 80th Annual Meeting of the Transportation Research Board. Washington, D.C. 2001.

Authors: Hostovsky, Charles and Hall, Fred

Title: Freeway Quality of Service: Perceptions from Tractor-Trailer Drivers

Abstract: Trucks make up a significant and growing portion of the traffic on freeways. This paper deals with the perceptions of tractor-trailer drivers regarding the Quality of Service on freeways, with a focus on the factors that are important to this group of road users. Perceptions were determined using the standard qualitative inductive analysis approach through a focus group with professional tractor-trailer drivers. Freeway conditions in general were the most frequently mentioned factors, and encompassed a variety of considerations. The three variables that together describe traffic conditions were all mentioned with regard to QOS: travel time (or speed); traffic density (or maneuverability); and traffic 'flow'. Likely the most significant finding is that it is not traffic density that matters to them, rather it is traffic flow. It appears that there is a comfortable operating range of highway speeds that does not require much braking and acceleration related gear-changing. Other important themes included, weather, attitudes toward other drivers, and "road rage" (i.e., aggressive driving). Safety was an issue that transcended or overlapped with many other issues. Participants also responded to questions about regional differences in QOS. The results were also compared with QOS focus groups held for urban and rural freeway commuters.

Publication Info: Currently a working paper.

Authors: Hostovsky, Charles; Wakefield, Sarah; and Hall, Fred

Title: Mitigating Traffic Congestion Impacts: Users' Perceptions of the Quality of Transportation Service

Abstract: Traffic congestion has become an important issue in Canadian urban centers experiencing sprawl. To that regard, the Quality of Service (QOS) of different freeway user groups is examined in this study. One of the principal ways in which QOS is identified by transportation engineers and planners is to rely on the concept of Level of Service (LOS). Previous work on QOS and LOS research involving highways, on-ramps, signalized intersections, transit, bicycles and pedestrian facilities is reviewed. However, QOS perception of freeway users has received limited theoretical development. In order to conduct exploratory qualitative research, focus group sessions were held with urban freeway commuters who use the QEW from Toronto to Hamilton and with rural freeway commuters who use Hwy 403 from Brantford to Hamilton. A separate focus group session was held with tractor-trailer drivers. The findings of this research suggest that, although there is some commonality of interest among the three groups, each group values a characteristic of the trip that they do not have, or at least cannot be sure of, and that differs among them. Urban commuters were concerned about travel time, rural commuters about maneuverability and truck drivers about steady traffic flow and physical road conditions.

Publication Info: Currently a working paper.

Authors: Nakamura, Hideki; Suzuki, Koji; and Syunsei, Ryu

Title: Analysis of the Interrelationship Among Traffic Flow Conditions, Driving Behavior, and Degree of Driver's Satisfaction on Rural Motorways

Abstract: This study tries to assess the quality of service of a basic motorway section based on the driver's perception, which is one of the noticeable concerns in the discussion on the quality of service. A field driving survey in a rural motorway section is conducted in order to collect data on degree of driver's satisfaction under various uncongested traffic flow conditions. It is further analyzed how these measured values of degree of driver's satisfaction relate to the traffic flow conditions and driving behaviors, and the interrelationship among them is quantitatively described.

Publication Info: In *Transportation Research Circular E-C018: Proceedings of the Fourth International Symposium on Highway Capacity*. TRB, National Research Council, Washington, D.C., 322-335

Authors: Pecheux, K.K., Peitrucha, M.T., Jovanis, P.P.

Title: Evaluation of Average Delay as a Measure of Effectiveness for Signalized Intersections

Abstract: This paper describes the analyses of individual vehicle delay distributions of lane groups at two intersections in the Borough of State College, PA and 120 drivers™ quality-of-service ratings associated with a third intersection. The purpose of these analyses was to assess the appropriateness of using an average measure of delay (i.e., mean) as the primary measure of effectiveness (MOE) for signalized intersections. The observed delays consistently resulted in similarly-shaped distributions that varied with v/c ratio. At low v/c ratios, a large proportion of the vehicles passed through the intersection without experiencing delay, while the delay experienced by the remaining vehicles was more or less constant up to about the length of the red phase. At higher v/c ratios, the proportion of vehicles that experienced no delay fell, and the amount of delay experienced by the remaining vehicles increased. When the 26 delay distributions were subjected to criteria established to test if mean delay was an appropriate MOE, none of the cases met all of the criteria. In one case, two (33 percent) of the criteria were not met; in twelve cases, three (50 percent) of the criteria were not met; in twelve cases, four (67 percent) of the criteria were not met; and in one case, five (83 percent) of the six criteria were not met. These results suggest that the use of average delay does not adequately characterize delay at signalized intersections. Although the perceptual data could not be directly compared to the delay distributions, subjects' overall QOS ratings were lower for lane groups with higher average delays. More detailed QOS ratings (by lane group and time of day) would be needed to compare the distribution of the ratings to the distribution of delay. It has been hypothesized that users are likely to have two related concerns about the quality of service at signalized intersections: 1) What is the probability that I will be delayed? and 2) How long will the delay be? Considering this hypothesis and the resulting delay distributions, perhaps a more appropriate MOE for signalized intersections, in terms of operations and users' perceptions, would be the probability of no delay and the average or range of delays encountered by the remaining vehicles.

Publication Info: Presented at the 80th Annual Meeting of the Transportation Research Board. Washington, D.C. 2001.

Authors: Pecheux, K.K., Peitrucha, M.T., Jovanis, P.P.

Title: User Perception of Level of Service at Signalized Intersections

Abstract: The Highway Capacity Manual (HCM) defines level of service as "a qualitative measure describing operational conditions within a traffic stream and their perception by motorists and/or passengers." The concept of level of service is therefore meant in part to reflect operational conditions as perceived by users. The HCM delay level-of-service categories for signalized intersections, however, were not based directly on studies of user perceptions. The categories evolved, like most of the manual, as a combination of consulting studies and research and a solid dose of committee debate and discussion, and they were based on field-observed delays. There is some question, then, as to how accurately the categories represent the experience of users. The point of this paper is not to criticize the development of the HCM levels of service but to attempt to place level of service on a more solid research footing. Two issues are addressed in this paper. The first issue is how users perceive quality of service at signalized intersections. The assessment of this issue is based on 98 drivers' performance ratings of video-taped operations of actual intersections. The second issue, which is closely related, is the question of how many levels of service individuals are actually able to perceive based on a range of delays on various intersection approaches. This paper reports on analyses of the quality-of-service ratings that indicate that two and perhaps three levels of service are generally perceived. These results are preliminary and need to be treated with the appropriate caution. It seems very clear, however, that motorists do not perceive level of service as precisely as we have assumed (i.e., on six levels), particularly at high levels of service (e.g., A through C).

Publication Info: Presented at the 79th Annual Meeting of the Transportation Research Board. Washington, D.C. 2000.

Authors: Landis, B.W., Vattikuti, V.R., Brannick, M.T.

Title: Real-time Human Perceptions: Toward a Bicycle Level of Service

Abstract: The primary focus of this study by Sprinkle Consulting Engineers, Inc., is to develop a bicycle-quality, or level-of-service, model for applications in U.S. metropolitan areas. Although there are several model forms being used throughout the United States that attempt to quantify road suitability or the quality of service afforded bicyclists traveling the street and roadway networks of urbanized areas, to date there have been no statistically calibrated models published. The statistically calibrated level-of-service model described here is based on real-time perceptions from bicyclists traveling in actual urban traffic and roadway conditions. The study's participants represented a cross section of age, gender, experience level, and geographic origin of the population of cyclists that use the metropolitan road networks in the United States. The test course is representative of the collector and arterial street systems of North American urban areas. Although further hypothesis testing is being conducted and additional studies are planned to test the need for disaggregate models for central business district streets with high turnover parking, truck routes, and two-lane high-speed rural highways, the general bicycle level-of-service model reported here is highly reliable, has a high coefficient of determination (R-squared = 0.73), and is transferable to the vast majority of United States metropolitan areas. The study reveals that pavement surface conditions and striping of bicycle lanes are important factors in the quality of service.

Publication Info: Transportation Research Record 1578, Transportation Research Board, Washington, D.C. 1997.

Authors: Landis, B.W., Vattikuti, V.R., Ottenberg, R.M., McLeod, D.S., Guttenplan, M.

Title: Modeling the Roadside Walking Environment: Pedestrian Level of Service

Abstract: A method is needed to objectively quantify pedestrians' perceptions of safety and comfort in the roadside environment. This quantification, or mathematical relationship, would provide a measure of how well roadways accommodate pedestrian travel. Essentially, it would provide a measure of pedestrian level of service (LOS) within a roadway environment. Such a measure of walking conditions would greatly aid in roadway cross-sectional design and would help evaluate and prioritize the needs of existing roadways for sidewalk retrofit construction. Furthermore, the measure can be used to evaluate traffic-calming strategies and streetscape designs for their effectiveness in improving the pedestrian environment. Such a measure would make it possible to merge pedestrian facility programming into the mainstream of transportation planning, design, and construction. To meet the need for such a method, as well as to fulfill a state mandate to establish levels of service standards for all transportation modes, the Florida Department of Transportation sponsored the development of the Pedestrian LOS Model. The model was developed through a stepwise multivariable regression analysis of 1,250 observations from an event that placed 75 people on a roadway walking course in the Pensacola, Florida, metropolitan area. The Pedestrian LOS Model incorporates the statistically significant roadway and traffic variables that describe pedestrians' perception of safety or comfort in the roadway environment between intersections. It is similar in approach to methods used to assess automobile operators' level of service established in the Highway Capacity Manual.

Publication Info: Transportation Research Record 1773, Transportation Research Board, Washington, D.C. 2001.

Research Approach

After consideration of several potential methods for obtaining direct traveler input (e.g., focus groups, post simulation/video review interview, etc.), it was decided to use a survey-based approach for the initial phase of this task. The main advantage of a survey approach is the ability to collect a relatively large sample size with a reasonable level of effort. The main potential drawback is that the survey may have design deficiencies that result in not obtaining very useful input. In should be kept in mind, however, that one of the intents of this survey-based approach was to help guide a more focused follow-on study which might make use of an alternate method that will only allow for a relatively small sample size. In this case, it is desirable to have this pilot effort with a larger sample to focus in on the most important information. Thus, it is expected that not all of the information obtained from the initial survey effort will be useful.

Furthermore, it was decided to perform an 'in-field' survey data collection effort as opposed to a mail-back survey or something similar. This provides the advantage of obtaining input while the specific characteristics of the traveler's trip (which in the case of this project was typically still in progress) are still fresh in their mind. The details of the individual components of the research approach are described in the following sections.

Survey development

The survey instrument was developed to solicit driver opinions about various factors related to the perception of the quality of their trip on a rural freeway. The specific questions and their wording were developed over several iterations. The first iteration involved the drafting of questions by the UF research team. The second iteration incorporated suggested revisions to the initial draft based on input from FDOT project management staff. The third iteration incorporated further suggested revisions based on input from select members of the HCQS committee. A fourth iteration incorporated some minor revisions based on testing by a small group of graduate and undergraduate students. A copy of the final survey form is included in Appendix A.

The final survey form contained questions relating to the following general categories:

- Current trip information
- Personal information
- Traveler opinions

The first category asked questions such as the vehicle type being driven on this trip, the purpose of this trip, and the typical traffic flow conditions on this trip. The second category asked questions such as the traveler's gender, age, and education level. The third category asked travelers to rate the relative significance of 16 different roadway and traffic related variables to their experienced quality of service on this trip. It also asked questions related to speed and lane restriction issues of interest for rural freeways.

Survey distribution

It was desired to collect data from travelers that were in the process of, or just finishing, a trip on a rural freeway. Again, it was felt that this would result in higher quality data than input received from mail-back surveys that might get completed in a home some time removed from the respondent's last trip on a rural freeway.

The first effort in this regard was conducted on July 26, 2002 at a rest stop just south of Gainesville, on Interstate-75. Interstate-75 runs north-south and provides linkages to cities such as Atlanta, Lake City, Gainesville, Ocala, Orlando (via Turnpike), Tampa, and Miami within the State of Florida. This interstate is considered a rural freeway in all but the central Tampa and Miami areas.

The survey data collection was performed by a graduate student. This student set up a small table on-site, with a couple of chairs and clipboards for use by potential survey respondents. To alert stopping motorists to the data collection effort, a sign was developed (see Appendix B).

The student spent from approximately 10:00 AM to 1:00 PM on the west side (southbound traffic) of the freeway and from approximately 1:30 – 4:00 on the east side. This effort resulted in the collection of only 23 surveys. It was believed that this small number was attributable to several issues:

- The weather was very hot and humid (as is typical for Florida at this time of year). As a result, most people were trying to limit their time not in the comfort of air conditioning.
- The survey "advertising" sign did not get the attention of all stopping motorists. The sign was originally intended to be approximately 2.5' x 3.5' in size, but ended up being only about 1.5' x 2.0' due to a color printing technical issue.
- No immediate incentive was provided to the survey respondents. In light of the weather conditions, offering free refreshments might have enticed more travelers to fill out a survey.

After this effort, it was figured that this approach would probably not yield an acceptable number of surveys within a reasonable amount of time, at least for summertime conditions.

Another approach was developed, which sought to address each of the issues mentioned above. This approach involved conducting the survey data collection at a service plaza on the Florida Turnpike toll road. Utilizing a service plaza offered the following advantages:

- The data collection could be performed indoors with climate-controlled conditions.
- With traditional rest areas, such as the one used for the initial effort, there is one on each side of the freeway to serve opposing directions of travel. The Turnpike service plazas are located in the middle of the freeway; thus, the survey effort is exposed to a larger number of travelers for a single data collection location.
- The service plazas provide food vendors. This offered two advantages for our data collection effort. The first was that it was believed people would be more willing to spend the extra time filling out a survey at these locations since many were already committing a fair amount of time to stopping for food and/or gas. Secondly, this gave the researchers the ability to provide food discount vouchers that could be redeemed at this service plaza or others along the Turnpike.

Larger signs were developed for these data collection efforts—one posted on the entrance doors of each side of the service plaza (an entrance for each direction of vehicular traffic). Food discount vouchers were developed with the assistance of HMS Host Corporation staff. HMS Host manages the food vendors at all of the Turnpike's service plazas. After discussion with FDOT staff and HMS Host staff, it was decided that $2 would be a reasonable food discount. Subsequently, HMS Host staff provided us with 200 discount vouchers. Note that it is indicated on the voucher that it can be redeemed at any of the Turnpike's service plazas. This provided another advantage in case some potential survey respondents were only stopping for restrooms, telephones, or such, and planning to eat at a later stop. Another sign was posted on the entrances and at the data collection table that indicated survey respondents would receive a food discount voucher (see Appendix C).

Data collection at the service plazas was conducted during the month of October, 2002. Two different service plazas were utilized. One was the Turkey Lake plaza, which is about 10 miles north of Orlando. The other one was the Canoe Creek plaza, which is about 20 miles south of Orlando. A small number of additional surveys were collected from tailgating football fans on a Saturday game day at the University of Florida—persons who traveled on I-75 and other rural freeways the night or morning before.

The table below summarizes the data collection locations and dates and the number of surveys collected from each one.

Table 1. Survey Data Collection Summary

Date	Location	# Surveys Collected
Friday, 7/26/02	South Gainesville Rest Area	23
Friday, 10/11/02	Turkey Lake Service Plaza	62
Wed, 10/16/02	Turkey Lake Service Plaza	40
Sat, 10/19/02	Gator football game tailgating crowd	14
Tues, 10/22/02	Canoe Creek Service Plaza	18
Friday, 10/25/02	Turkey Lake Service Plaza	4
Friday, 10/25/02	Canoe Creek Service Plaza	8
Sat, 10/26/02	Turkey Lake Service Plaza	61
Sat, 10/26/02	Canoe Creek Service Plaza	3
	Total Surveys Collected	**233**

Results

Two-hundred and thirty-three collected surveys represent a good sample size. The following tables summarize the aggregate statistics for each of the questions.

Table 2 presents a summary of the demographic and socio-economic information for the survey respondents.

Table 2. Survey Respondent Demographics/Socio-economics Summary

Gender (232 responses)	
Male	54.7%
Female	45.3%
Education (231 responses)	
Some or no high school	5.2%
High school diploma or equivalent	36.4%
Technical college degree (A.A.)	8.7%
College degree	33.8%
Post-graduate degree	16.0%
Income (221 responses)	
No Income	9.5%
Under $25,000	19.0%
$25,000 – 49,999	27.6%
$50,000 – 74,999	20.8%
$75,000 – 99,999	10.0%
$100,000 – 149,999	8.6%
$150,000 or more	4.5%
Average household income	$53,000
Age (233 responses)	
16 to 25 years	32.2%
26 to 45 years	27.9%
46 to 65 years	29.6%
Over 65 years	10.3%
Average age	40

As this table indicates, there was a good mix of survey respondents by gender, education level, income, and age.

Table 3 is a summary of the first two digits of the survey respondents' primary residence. Appendix D contains a more detailed summary of geographic locations corresponding to these zip codes.

Table 3. First Two Zip-Code Digits Summary

Zip Code	Freq.	%
0 - 9	2	0.9%
10 - 19	4	1.8%
20 - 29	4	1.8%
30	10	4.4%
31	5	2.2%
32	71	31.1%
33	51	22.4%
34	50	21.9%
35	2	0.9%
36	1	0.4%
37	1	0.4%
38	0	0.0%
39	1	0.4%
40 - 49	8	3.5%
50 - 59	0	0.0%
60 - 69	2	0.9%
70 - 79	10	4.4%
80 - 89	3	1.3%
90 - 99	3	1.3%
Total	**228**	**100.0%**

Table 4 provides a summary of the responses to the current trip information questions.

Table 4. Current Trip Information

Primary Route Used*	
Interstate-75	143
Interstate-10	22
Turnpike	126
Interstate-95	10
Other	16
Roadway Familiarity (223 responses)	
Very	58.3%
Somewhat	28.3%
Not at all	13.5%
Role on Trip (231 responses)	
Driver	57.6%
Passenger	31.2%
Both	11.3%

Trip Purpose (221 responses)	
Business	20.4%
Leisure	64.7%
Other	14.9%
Weather (225 responses)	
Sunny	85.3%
Overcast	11.6%
Light Rain	2.2%
Heavy Rain	0.9%
Traffic Flow (231 responses)	
Very dense	3.0%
Dense	6.1%
Moderate	68.0%
Light	21.6%
Very Light	1.3%
Estimated Average Running Speed (mph) (232 responses)	
Mean	72.1
Median	70.0
Mode	70.0

* Numbers reported are frequencies, as some respondents indicated multiple routes, thus the percentages do not sum to 100.

As expected for the selected data collection sites, most survey respondents were traveling primarily on I-75 and the Turnpike. Most travelers were familiar with the freeways they were traveling on, and the majority of respondents were the vehicle driver. The trip purpose for the travelers was predominantly for leisure. Nearly all respondents were experiencing rain-free weather conditions on their trip. As is generally the case for rural freeways in the State of Florida, the traffic conditions that the travelers were experiencing were mostly moderate and lighter.

The mean response to average travel speed (without stops) was 72.1 mph. The median and modal responses were 70.0 mph. The 85th percentile was also calculated, which was 80 mph. The standard deviation was 7.37 mph. In the context of this study, the Highway Capacity Manual defines free-flow speed as "the average speed of passenger cars over a basic freeway or multilane highway segment under conditions of low volume."

For comparison purposes, the speed data statistics from an I-75 speed study are presented in Table 5. These data were collected (via radar) during a November 2002 afternoon from an I-75 overpass (SW 20th Ave) in Gainesville. Only the speeds of passenger cars were collected. These speeds are representative of free-flow conditions, as traffic volumes were fairly low during the data collection period.

Table 5. I-75 Speed Data Collection Summary

	Southbound	Northbound
Mean (mph)	74.8	72.5
Std. Deviation (mph)	5.37	4.39
85^{th} Percentile (mph)	81	78
Speed Limit (mph)	70	70
No. of Samples	222	384
Conf. Level (± 1 mph error)	99%	99%
Flow Rate (veh/hr/lane)	921	874

The self-reported speed data are surprisingly consistent with those collected for the speed study. These free-flow speed data are also generally consistent with the FDOT Systems Planning Office's assumption for its level of service planning methodologies that the free-flow speed is approximately 5 mph higher than the posted speed limit. It is interesting to note, however, that the 85^{th} percentile speeds are well above the posted speed limit, when it is generally desirable that these values be similar.

Table 6 presents the summary of the vehicle types being driven by the survey respondents.

Table 6. Current Trip Information, Continued

Vehicle Type (233 responses)	%
Sedan	43.8
Sports car	8.2
Pick-up truck	5.6
SUV	18.9
Mini-van	11.2
Full-size van	2.1
RV/Motorhome	0.9
Charter Bus	2.6
Sport motorcycle	0.0
Touring motorcycle	0.0
Delivery van/truck	0.9
Semi-truck	4.3
Other	1.7

Passenger sedans, sport utility vehicles, and mini-vans represent almost 75 percent of the various vehicle types driven by the survey respondents.

Table 7 provides the summary of the survey respondent rankings of the 16 traffic and roadway factors that were presented for consideration of their impact on perceived quality of service. The top six ranked factors are shown in bold type.

Table 7. Travel Quality of Service Factor Rankings

	Mean	Median	Mode	% Time Top 3
Ability to consistently maintain your desired travel speed	**6.09**	**7**	**7**	**64.3**
Ability to travel at a speed no less than the posted speed limit	**5.58**	**6**	**7**	**33.0**
Ability to change lanes and pass other vehicles easily	**5.79**	**6**	**7**	**33.3**
Availability of information on current traffic conditions (via radio or message signs)	4.61	5	7	6.1
Frequent freeway entrances and exits	4.65	5	5	5.6
Frequent rest areas	4.76	5	7	12.6
Infrequent construction zones	**5.37**	**6**	**7**	**23.4**
Infrequent steep grades and/or sharp curves	4.57	5	7	6.1
Noticeable presence of law enforcement (state patrol, etc.)	4.16	4	7	12.1
Other drivers' etiquette/courtesy	**5.38**	**6**	**7**	**22.1**
Small percentage of large commercial trucks in traffic stream	4.82	5	7	13.4
Small percentage of large personal vehicles (pickups, vans, SUV's) in traffic stream	4.00	4	7	2.6
Smooth and quiet road surface condition	**5.68**	**6**	**7**	**20.3**
Wide separation between opposing directions of traffic flow	5.13	6	7	10.4
Wide shoulders	5.00	5	7	3.0
Wide travel lanes	5.35	6	7	8.2

The top ranked factor was the 'ability to consistently maintain your desired travel speed'. This factor was also most frequently listed as one of the three most important factors for perceived quality of service. This factor description corresponds to what the researchers considered to be the 'cruise-control' factor, that is, the longer one can keep a constant speed, minimizing deceleration and re-acceleration, the more satisfied the driver will be. This may also be viewed as the speed variance factor (or alternatively acceleration noise). Thus, drivers that maintain a constant desired speed will be more satisfied with their trip than those that have considerable variance (decelerating/accelerating) about their desired average speed.

The second ranked factor was the 'ability to change lanes and pass other vehicles easily'. This factor description corresponds to what the researchers considered to be the 'density' factor. This factor is what is currently used by the HCM to define level of service on freeways, and its impact on driver satisfaction follows directly from the HCM discussion.

The third ranked factor was 'smooth and quiet road surface'. This factor description corresponds to pavement quality. This is not a factor that has traditionally been considered as one that impacts drivers' perceived level of service, but it is clear from this survey that it is definitely important to drivers.

The fourth ranked factor was 'ability to travel at a speed no less than the posted speed limit'. This factor description corresponds to what the researchers considered to be a 'percent of free-flow speed' factor. Free-flow speeds are typically higher than the posted speed limit, and thus having to travel at a speed less than the posted speed may be perceived as poor quality of service, for a majority of drivers. This factor ranked third in terms of the number of times listed in the top three.

'Other drivers' etiquette/courtesy' was the fifth ranked factor. It is believed this factor was ranked so highly because incidences of aggressive driving and road rage are becoming more common. This result is not surprising; however, this factor would be almost impossible to measure reliably. Certainly, driver education and law enforcement can impact the relative significance of this factor.

'Infrequent construction zones' was the sixth ranked factor. The high ranking for this factor likely indicates that drivers associate construction zones with significant delay. Given the temporary nature of construction zones, this is not a factor that would normally be considered for level of service evaluation. Nonetheless, its high ranking clearly reflects the effect construction zones have on driver perceived quality of service.

'Wide travel lanes' also had a relatively high rating, yet it was not frequently identified as one of the top three factors affecting trip quality.

Table 8 presents a summary of the responses to the travel lane and speed restriction opinion statements.

Table 8. Travel Lane and Speed Restriction Opinions

Opinion Statement*	Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
Vehicles should be in the left lane *only* if passing, even if traveling at or above the posted speed limit	37.8%	37.3%	11.6%	10.7%	2.6%
Large commercial trucks should be restricted from the left lane at *all* times	32.3%	25.9%	17.7%	18.1%	6.0%
Large commercial trucks should be restricted from the left lane *only* during peak periods	20.3%	28.1%	20.8%	19.0%	11.7%
Large commercial trucks should have a lower speed limit than automobiles	21.9%	19.7%	21.5%	22.7%	14.2%

* The number of responses received was 233, 232, 231, and 233 for statements 1-4, respectively.

The majority of survey respondents agreed that vehicles should be in the left lane only if passing, despite their speed. This seems to reflect the general belief that the left (inside) lane is the "fast lane", and unless you are passing other vehicles, you should not be in this lane, despite your speed. While some states have legislation to this effect, Florida is not one of them. In

Florida, drivers are free to use the left lane, like any other, whether or not they are passing other vehicles. Of course, many drivers that travel in Florida are from other states, and this belief may be based on the laws in their state. But regardless of the purpose of the inside lane, the speed limit applies just as equally to this lane as the other lanes, in all states. Many drivers understand the laws for Florida (or least have these beliefs), and feel that as long as they are traveling at or above the speed limit, they have every right to be in the inside lane. This appears to be a common situation that contributes to aggressive driving and/or road rage. States that allow travel in the inside lane only if passing often use signage that indicates 'slower vehicles keep right'. However, many drivers do not feel they are a 'slower vehicle' if they traveling at or above the speed limit, despite that fact that they may be impeding faster vehicles in the left lane.

A majority of respondents felt that commercial trucks should be restricted from the left lane at all times. The opinions were more balanced about whether commercial trucks should be restricted from the left only during peak periods. This is probably a result of some of the respondents that indicated trucks should be restricted at all times disagreeing that trucks should only be restricted during peak periods. The opinions were relatively balanced about whether commercial trucks should have a lower speed limit than automobiles. This result was somewhat surprising, and may indicate that truck speeds may not be nearly as important an issue to auto drivers as which lanes trucks are allowed to use.

Table 9 provides a summary of the respondent opinions concerning allowed travel speeds on rural interstates.

Table 9. Allowed Travel Speed Opinions

Opinion Statement*	Mean	Median	Mode
At what speed do you usually travel on rural interstates when not impeded by other traffic?	70.7	70.0	70.0
How many miles per hour above the posted speed limit do you feel it is safe to travel on the interstate?	8.0	6.0	5.0
What do you feel should be the speed limit on the interstate?			
For passenger vehicles	74.6	75.0	70.0
For commercial trucks	67.8	70.0	70.0

* The number of responses received was 233, 231, 228, and 221 for statements 1-3b, respectively.

The mean speed for the first question is a little lower than the speed reported for the current trip information (Table 4), but the 85th percentile was the same at 80 mph. However, there were nine responses of speeds between 30 and 45 mph, whereas the other speed question did not have any responses below 50 mph. This results in a higher standard deviation (10.7) for the speed data corresponding to Table 9. People driving at speeds below 50 mph on a rural freeway raises some safety concerns, but this issue is beyond the scope of this project.

Even though the responses to the opinion statement about commercial trucks having a lower speed limit than passenger cars being fairly balanced, it is clear from the table above that survey respondents felt on average that trucks should have a 5-7 mph lower speed limit.

Truck Drivers

This survey was targeted mostly at the general driving population, rather than commercial truck drivers. However, ten surveys were completed by truck drivers. Table 10 presents the five quality of service factors that were clearly identified as being important to trip quality of service.

Table 10. Truck Driver Rankings of Quality of Service Factors

	Mean	% Time Top 3
Other drivers' etiquette/courtesy	6.7	40
Ability to consistently maintain your desired travel speed	6.5	50
Wide travel lanes	6.5	10
Wide shoulders	6.4	10
Ability to change lanes and pass other vehicles easily	5.9	20

Not surprisingly, wide lanes and wide shoulders were ranked very high. Somewhat surprisingly, a smooth and quiet pavement surface was not one of the primary factors.

This sample, albeit quite small, provides some evidence that different factors may be more important to truck drivers than automobile drivers with regard to perceived quality of service. Additionally, these results are consistent with findings from Hall's focus group research with truckers that identified the ability to avoid frequent gear shifting being a primary factor in their evaluation of trip quality of service. However, a much larger sample size of trucker opinions obviously needs to be collected before any conclusions can be drawn.

All ten either agreed or agreed strongly that vehicles should only be in the left lane if passing. All ten either disagreed or disagreed strongly that commercial trucks should always be restricted from the left lane. As for being restricted during peak periods, four of the ten truck drivers actually agreed or agreed strongly that this should be the case. The remaining six all disagreed strongly to this statement.

All but two truck drivers felt truck and passenger car speed limits should be the same. One thought the truck speed limit should be 5 mph higher, while another thought the truck speed limit should 5 mph lower.

Conclusions and Recommendations

Overall, this field-based survey data collection effort met the objectives of the pilot study quite well. Opinions about various trip factors and how they impact perceived quality of service were obtained from a good sampling of travelers, while they were making a trip on a rural freeway. The use of the service plazas in particular was more successful than the outdoor rest stop, especially for summertime conditions. Overall traffic and survey interest levels were not as high at the Canoe Creek plaza as at the Turkey Lake plaza. This may also be a reflection of slightly different demographic and socio-economic characteristics for the two populations that visit those service plazas. For a future effort of this type, it would be desirable to get a little more representation from additional service plazas along the Turnpike towards south Florida.

When it comes to level of service, it is becoming clearer that drivers do not think in one dimension—they think multi-dimensionally. This is supported by the results of this survey effort that show a large majority of respondents giving three or more factors a rating of 7. A driver's overall perception of quality/level of service is likely a function of multiple roadway and traffic variables, and possible even safety/comfort related measures, much like what was found with the FDOT bicycle and pedestrian level of service research.

While density certainly appears to still be a primary factor affecting perceived quality of service, it appears that there are some additional factors that are just as important to travelers, such as speed variance and percent of free-flow speed. Additionally, some non-traffic performance measures were found to be important, such as pavement quality and driver etiquette.

Additionally, it appears that there are some factors unique to truck drivers and their perceived quality of service. And of the factors that were in common, they had different degrees of importance between the two groups of drivers. Truck drivers are a special group because of the characteristics of the vehicles they drive and their trip purposes. Consequently, it is reasonable to believe that truck drivers perceive the quality of their trip somewhat differently than passenger car drivers. A future study should focus specifically on quality of service issues for truck drivers.

Phase II of this task (under separate contract) will continue research into rural freeway level of service measures and thresholds. Initially, this will consist of some more detailed analysis of these survey results to help guide the direction of the additional research. Ultimately, it is intended to make a recommendation on the most appropriate service measure, or measures, and the corresponding thresholds. This could be in the form of a level of service 'function', analogous to that for the FDOT pedestrian and bicycle research. The research approach that will be used for Phase II will not be determined until further analysis and consideration of the Phase I results, but may include further field surveys, focus groups, study participant interviews after using a simulator or watching pre-recorded video, or more direct field observations.

Appendix A. Survey Form

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Transportation Research Center

Current Trip Information

Please provide the following information as it pertains to your trip on a *rural freeway* for *today* only.

Starting location (city, state): ____

Destination location (city, state): ____

Departure time (e.g., 8:00 AM): ____

Primary route used (e.g., I-75, SR-200): ___________________________________

How familiar are you with this roadway? ☐ Very ☐ Somewhat ☐ Not at all

Vehicle type: ☐ Sedan ☐ Sports car ☐ Pick-up truck ☐ SUV
☐ Mini-van ☐ Full-size van ☐ RV/Motorhome ☐ Charter Bus
☐ Sport motorcycle ☐ Touring motorcycle
☐ Delivery van/truck ☐ Semi-truck ☐ Other _____________

Role on current trip: ☐ Driver ☐ Passenger ☐ Both

Trip Purpose: ☐ Business ☐ Leisure ☐ Other

Your estimated average speed (not including stops) ___________ (mi/hr, km/hr)

Predominant weather condition: ☐ Sunny ☐ Overcast ☐ Light rain ☐ Heavy rain

How would you describe the typical traffic flow conditions you have experienced on this trip?

☐ Very dense ☐ Dense ☐ Moderate ☐ Light ☐ Very light

About Yourself

Gender: ☐ Male ☐ Female

Highest level of education:
☐ Some or no high school ☐ High school diploma or equivalent
☐ Technical college degree (A.A.) ☐ College degree ☐ Post-graduate degree

Approximate annual household income:
☐ No income ☐ Under $25,000 ☐ $25,000 – 49,999 ☐ $50,000 – 74,999
☐ $75,000 – 99,999 ☐ $100,000 – 149,999 ☐ $150,000 or more

Age:
☐ 16 to 25 years ☐ 26 to 45 years ☐ 46 to 65 years ☐ Over 65 years

What are the first two digits of the zip code at your primary residence? _____________

Your Opinions

From the list of 16 items below, rate each item on a scale of 1 to 7 (1-not at all important, 7-extremely important) as to how that item affects the quality of your trip on a *rural freeway*. After completing the ratings, please circle the item number of the 3 most important factors to you for a high quality trip.

1. ______ Ability to consistently maintain your desired travel speed
2. ______ Ability to travel at a speed no less than the posted speed limit
3. ______ Ability to change lanes and pass other vehicles easily
4. ______ Availability of information on current traffic conditions (via radio or message signs)
5. ______ Frequent freeway entrances and exits
6. ______ Frequent rest areas
7. ______ Infrequent construction zones
8. ______ Infrequent steep grades and/or sharp curves
9. ______ Noticeable presence of law enforcement (state patrol, etc.)
10. ______ Other drivers' etiquette/courtesy
11. ______ Small percentage of large commercial trucks in traffic stream
12. ______ Small percentage of large personal vehicles (pickups, vans, SUV's) in traffic stream
13. ______ Smooth and quiet road surface condition
14. ______ Wide separation between opposing directions of traffic flow
15. ______ Wide shoulders
16. ______ Wide travel lanes

For each of the following questions about travel restrictions on *rural freeways*, please mark the box that most closely describes your opinion.

	Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
Vehicles should be in the left lane *only* if passing, even if traveling at or above the posted speed limit	☐	☐	☐	☐	☐
Large commercial trucks should be restricted from the left lane at *all* times	☐	☐	☐	☐	☐
Large commercial trucks should be restricted from the left lane *only* during peak periods	☐	☐	☐	☐	☐
Large commercial trucks should have a lower speed limit than automobiles	☐	☐	☐	☐	☐

Please fill in your responses to the following questions on speed limits for *rural freeways*.

1. At what speed do you usually travel on rural interstates when not impeded by other traffic?

   ______ (mi/hr, km/hr)
2. How many miles per hour above the posted speed limit do you feel it is safe to travel on the interstate? ______
3. What do you feel should be the speed limit on the interstate (mi/hr, km/hr)?

   For passenger vehicles ________ For commercial trucks ________

Appendix B. Survey "Advertising" Sign

Actual Size was 2.5' x 3.5' for Service Plaza Sites

TRAVELER OPINION SURVEY

The Transportation Research Center at the University of Florida is assisting the Florida Department of Transportation in conducting a traveler survey related to travel on rural freeways (e.g., city-to-city interstate connections).

The Florida DOT would like to obtain your opinions on the relative importance of various traffic and roadway factors in how they affect your perception of the quality of your trip. Additionally, they would like to get your opinions on lane restriction and speed limit issues.

The Florida DOT wants to use this information to help better assess how it should measure the quality of service its rural freeways provide and how resources might be better allocated to improve traveler satisfaction with its roadways.

Your responses will be **completely anonymous**. Please place your survey form in the collection box when finished. Your assistance with this research project is greatly appreciated. *This survey has been approved by the University of Florida Institutional Review Board, which oversees research studies involving human subjects*. If you have any additional questions about this survey or research project, please contact the project supervisor, Dr. Scott Washburn, with the Transportation Research Center at the University of Florida (352-392-7575 x1453).

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Appendix C. Food Discount Advertising Sign

Actual Size was 1.5' x 2.5'

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STATE OF FLORIDA • DEPARTMENT OF TRANSPORTATION

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RECEIVE A COUPON FOR

$2.00 OFF
ANY FOOD
PURCHASE

FOR COMPLETING A SURVEY

Appendix D. Zip Code Geographic Location Summary

Out-of-State Zip Codes

00* - 09*****

Rhode Island
New Hampshire
Maine
Massachusetts
Vermont
Connecticut
New Jersey
New York

10* - 19*****

Delaware
New York
Pennsylvania

20* - 29*****

District of Columbia
Maryland
North Carolina
South Carolina
Virginia
West Virginia

37* - 39*****

Mississippi
Tennessee

40* - 49*****

Indiana
Kentucky
Michigan
Ohio

50* - 59*****

Iowa
Minnesota
Montana
North Dakota
South Dakota
Wisconsin

60* - 69*****

Illinois
Kansas
Missouri
Nebraska

70* - 79*****

Arkansas
Louisiana
Oklahoma
Texas

80* - 89*****

Arizona
Colorado
Idaho
Nevada
New Mexico
Utah
Wyoming

90* - 99*****

Alaska
California
Hawaii
Oregon
Washington

Zip Codes 30***

State: Georgia

<u>Counties</u>

BANKS
BARROW
BARTOW
BULLOCH
BURKE
BUTTS
CANDLER
CARROLL
CATOOSA
CHATTOOGA
CHEROKEE
CLARKE
CLAYTON
COBB
COLUMBIA
COWETA
DADE
DAWSON
DE KALB
DOUGLAS
ELBERT
EMANUEL
EVANS
FANNIN
FAYETTE
FLOYD
FORSYTH
FRANKLIN
FULTON
GILMER
GLASCOCK
GORDON
GREENE
GWINNETT
HABERSHAM
HALL
HARALSON
HART
HEARD
HENRY
JACKSON
JASPER
JEFFERSON
JENKINS
LAMAR
LAURENS
LINCOLN
LUMPKIN
MADISON
MCDUFFIE
MERIWETHER
MONTGOMERY
MORGAN
MURRAY
NEWTON
OCONEE
OGLETHORPE
PAULDING
PICKENS
PIKE
POLK
RABUN
RICHMOND
ROCKDALE
SCREVEN
SPALDING
STEPHENS
TALIAFERRO
TATTNALL
TOOMBS
TOWNS
TREUTLEN
TROUP
UNION
UPSON
WALKER
WALTON
WARREN
WHEELER
WHITE
WHITFIELD
WILKES

Zip Codes 31***

State: Georgia

Counties

APPLING
ATKINSON
BACON
BAKER
BALDWIN
BEN HILL
BERRIEN
BIBB
BLECKLEY
BROOKS
BRYAN
CAMDEN
CHARLTON
CHATHAM
CHATTAHOOC
CLAY
CLINCH
COFFEE
COLQUITT
COOK
CRAWFORD
CRISP
DE KALB
DECATUR
DODGE
DOOLY
DOUGHERTY
EARLY
ECHOLS
EFFINGHAM
EMANUEL
FULTON
GLYNN
GRADY
HANCOCK
HARRIS
HOUSTON
IRWIN
JASPER
JEFF DAVIS
JOHNSON
JONES
LANIER
LAURENS
LEE
LIBERTY
LONG
LOWNDES
MACON
MARION
MCINTOSH
MERIWETHER
MILLER
MITCHELL
MONROE
MUSCOGEE
PEACH
PIERCE
PULASKI
PUTNAM
QUITMAN
RANDOLPH
SCHLEY
SEMINOLE
STEWART
SUMTER
TALBOT
TAYLOR
TELFAIR
TERRELL
THOMAS
TIFT
TROUP
TURNER
TWIGGS
UPSON
WARE
WARREN
WASHINGTON
WAYNE
WEBSTER
WILCOX
WILKINSON
WORTH

Zip Codes 35***

State: Alabama

<u>Counties</u>

BIBB
BLOUNT
CHEROKEE
CHILTON
CLAY
COLBERT
COOSA
CULLMAN
DE KALB
ETOWAH
FAYETTE
FRANKLIN
GREENE
HALE
JACKSON
JEFFERSON
LAMAR
LAUDERDALE
LAWRENCE
LIMESTONE
MADISON
MARION
MARSHALL
MORGAN
PICKENS
SAINT CLAI
SHELBY
SUMTER
TALLADEGA
TALLAPOOSA
WALKER
WINSTON

Zip Codes 36***

<u>Counties</u>

AUTAUGA
BALDWIN
BARBOUR
BIBB
BULLOCK
BUTLER
CALHOUN
CHAMBERS
CHEROKEE
CHILTON
CHOCTAW
CLARKE
CLAY
CLEBURNE
COFFEE
CONECUH
COOSA
COVINGTON
CRENSHAW
DALE
DALLAS
ELMORE
ESCAMBIA
GENEVA
GREENE
HALE
HENRY
HOUSTON
LEE
LOWNDES
MACON
MARENGO
MOBILE
MONROE
MONTGOMERY
PERRY
PIKE
RANDOLPH
RUSSELL
SUMTER
TALLADEGA
TALLAPOOSA
WASHINGTON
WILCOX

In-State Zip Codes

Zip Codes 32***

Counties

ALACHUA
BAKER
BAY
BRADFORD
BREVARD
CALHOUN
CLAY
COLUMBIA
DIXIE
DUVAL
ESCAMBIA
FLAGLER
FRANKLIN
GADSDEN
GILCHRIST
GULF
HAMILTON
HOLMES
INDIAN RIVER
JACKSON
JEFFERSON
LAFAYETTE
LAKE
LEON
LEVY
LIBERTY
MADISON
MARION
NASSAU
OKALOOSA
ORANGE
PUTNAM
SAINT JOHNS
SANTA ROSA
SEMINOLE
SUWANNEE
TAYLOR
UNION
VOLUSIA
WAKULLA
WALTON
WASHINGTON

Zip Codes 33***

Counties

BROWARD
CHARLOTTE
COLLIER
DADE
DE SOTO
GLADES
HARDEE
HENDRY
HIGHLANDS
HILLSBOROUGH
LEE
MARTIN
MONROE
OSCEOLA
PALM BEACH
PASCO
PINELLAS
POLK
SUMTER

Zip Codes 34***

Counties

ARMED FORCES
CITRUS
HERNANDO
LAKE
LEVY
MANATEE
MARION
MARTIN
OKEECHOBEE
ORANGE
OSCEOLA
PASCO
PINELLAS
POLK
SAINT LUCIE
SARASOTA
SUMTER