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Roadway Level-of-Service Determination

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Roadway Level-of-Service Determination

Prepared for the
Florida Institute of Government

by the
Center for Urban Transportation Research

May 1991
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PREFACE

This technical study, "Roadway Level-of-Service Determination," was prepared by the Center for Urban Transportation Research, College of Engineering, University of South Florida. The study was proposed by the Florida Association of Counties (FAC) and coordinated by Stephen Hogge of FAC's staff. Funding was provided by the Florida Institute of Government under STAR Grant #90-058. The author is Reid Ewing, who worked under the general supervision of Edward Mierzejewski. Research assistance was provided by Edward Hannan.

We are grateful to FAC's Technical Advisory Committee for valuable comments on a draft of this report. Committee members were Bert Folce, Hillsborough County; David Harris, Florida Department of Community Affairs; Stephen Hogge, Florida Association of Counties; Herb Kahlert, Palm Beach County; Bill Lecher, Nassau County; Douglas McLeod, Florida Department of Transportation; Diane Salz, Florida League of Cities; and Clark Turner, City of Miami.

We are also grateful to the following individuals for clarifying methods of roadway level-of-service determination used by various jurisdictions, and for providing insights into the strengths and weaknesses of alternative methods: Bob Kamm (Brevard County); Ossama Alaschkow (Broward County); Mark Woerner (Dade County); Laura Firtel (consultant to Flagler County); Mark Gillis (consultant to Lee County); Tim Allen (Tallahassee); Clark Turner (Miami); Danny Pleasant (Orlando); Ali Atefi (Pasco County); Dick Thomas (Seminole County); and Mahdi Mansour (Tampa).

Mark Bevis of Seminole County, John Zegeer of Barton-Aschman Associates, and Glatting Lopez Kercher Anglin, Inc., supplied the traffic counts and travel time study results used in the quantitative sections of this report.

Gary L. Brosch
Director

May 1991
EXECUTIVE SUMMARY

Under Florida's 1985 Growth Management Act, adequate infrastructure must be available concurrent with the impacts of development. Adequacy is defined by level-of-service standards, adopted by local governments as part of their local comprehensive plans. No development order or permit may be issued if levels of service will be degraded below the adopted standards.

The focus in growth management is on level-of-service standards. However, the methods used to determine roadway levels of service affect conclusions about road adequacy as much as do the standards to which they are compared.

In this report it is shown that the specific technique used to analyze roadway level-of-service -- whether HCS, ART-PLAN, ART-TAB, or travel time studies -- can make at least a two-letter grade difference in the outcome. Likewise, the choice of analysis period or peak hour -- whether 30th highest hour, 100th highest hour, average peak hour of the peak season, or highest two consecutive hours on the average weekday -- can make a difference of two or more letter-grades. While harder to quantify, the effect of combining levels of service across facilities or modes could be of comparable magnitude.

Given the importance of methodology, this report seeks to provide guidance to public officials wrestling with the following four issues:

(1) **What methods should be used to assess roadway levels of service?**

Appropriate methods of analysis may differ from application to application since the consequences of error are more serious in some cases than others. Less precise methods are probably adequate for local comprehensive planning, while more precise methods of analysis are required for development review and approval.

To assess the precision of alternative methods, level-of-service estimates were compared to travel time study results. Highway Capacity Software (HCS) and ART-PLAN (formerly ART-ALL) proved better predictors of arterial levels of service than ART-TAB (formerly LOS). Since ART-PLAN is much easier to use than HCS, ART-PLAN appears to be the preferred method of arterial analysis.

All three methods are necessarily superior to generalized maximum volume tables. Generalized tables assume roadway, traffic, and signal characteristics averaged across the entire state rather than specific to a particular facility or locale.
All methods tested tend to **underestimate** travel speeds. Travel time studies can be used to better **calibrate** HCS, ART-PLAN, and other programs. Alternatively, travel time study results can be **correlated** directly with traffic volumes and other variables in statistically derived models.

To illustrate the latter approach, regression analyses were performed relating average peak-hour travel speeds on Seminole County roads to peak-hour traffic volumes and numbers of signalized intersections per mile. The explanatory power of the resulting model is probably inadequate for use in forecasting future travel speeds and levels of service. Nonetheless, with 55% of the variation in average travel speed explained by only two variables, a good predictive model could doubtless be developed with a richer data base (including such independent variables as the green ratio, arrival type, and % turns from exclusive lanes).

(2) **Should levels of service be averaged or aggregated across road facilities?**

Levels of service on roadway segments are routinely combined into one overall level of service for a facility end-to-end. The procedure for doing so is straightforward, and no difficult methodological issues arise. However, we find ourselves in uncharted waters when we begin to combine levels of service for different facilities into one overall level of service for a roadway network.

Three approaches suggest themselves: summing volumes and capacities, averaging levels of service, and adopting performance summaries. All three approaches have precedents in local comprehensive plans already approved by the Department of Community Affairs (DCA). All three enable local governments to finance the most cost-effective system improvements rather than isolated roadway improvements dictated by minimum operating standards.

Of the three, the **averaging** method may be preferred for growth management purposes. Travel speeds fall precipitously as traffic volumes approach capacities. With areawide averaging, local governments, concerned about maintaining average travel speed, will have ample incentive to fix localized traffic problems. Less incentive is provided by the other approaches.

Whichever approach is chosen, roadways must be assigned weights that reflect their contributions to areawide levels of service. The preferred weighting factor is vehicle-miles traveled on roadways, since it accounts for the volume of traffic exposed to different traffic conditions.
Also, meaningful analysis areas must be delineated if levels of service are to be estimated on an areawide basis. Transportation concurrency management areas (as DCA refers to them) should be drawn so as to encompass alternate routes available for common peak-hour trips. How this general guideline is operationalized is best left to local planners. The resulting areas could well coincide with pre-existing transportation impact fee benefit districts.

To ensure that localized traffic problems continue to be addressed, individual facilities could remain subject to level-of-service standards, albeit standards set at the absolute minimum acceptable level. At the same time, areawide average standards could set at a higher desirable level to encourage cost-effective system improvements.

(3) Should levels of service be averaged or aggregated across urban transportation modes (public and private)?

There are many problems with combining the levels of service for different modes into one overall level of service. The measures used to define levels of service are different for transit and private vehicles. Transit is a viable option only for auto users with trip ends in the transit corridor; commercial vehicles and other auto users cannot avoid roadway congestion by switching modes. Combined standards could have unintended consequences. Even if buses ran empty and roads were gridlocked, local government could approve new developments as long as they were “served” by transit.

Rather than combining levels of service across modes, transit availability may be reflected in relaxed roadway level-of-service standards in transit corridors. Relaxation of standards can be justified when transit offers a viable alternative to auto users. A commuter in a Miami Metrorail corridor can, by his individual choice of transit, avoid sitting in traffic. In contrast, a commuter facing the choice of auto or bus travel on congested city streets really has no choice.

The Florida Department of Transportation already accounts for transit availability in its level-of-service standards for state roads. Roadways parallel to exclusive transit facilities are subject to standards generally one letter-grade below the norm. Even lower standards might be justified in corridors where the vast majority of road users have viable transit options.
(4) For what time period or peak hour should levels of service be analyzed?

The choice of peak hour is ultimately a political rather than a technical decision. It involves balancing the public’s desire to hold down taxes (which means fewer road improvements and more traffic congestion) against their desire to avoid traffic congestion (which requires higher taxes for road improvements).

The same peak hour should be used for both design of new roads and management of existing roads, but that need not be the 30th highest hour of the year (that is, the hour with the 30th highest traffic volume of the year). While time-honored in highway design, the 30th highest hour has no special economic significance. An analysis of hourly volumes from FDOT’s permanent count stations shows that the 30th highest hour ordinarily does not correspond to the point of diminishing returns in roadway design.

FDOT is proposing a shift to the 100th highest hour. If it is necessary to settle on one peak hour for roads statewide, as FDOT has declared, the 100th highest hour may be the best choice. An analysis of hourly volumes from FDOT’s permanent count stations suggests that the 100th highest hour is roughly equivalent to the average peak hour of weekdays during the peak season in urban areas and weekends in recreational areas and other places with weekend peaking. Thus, the 100th highest hour reflects daily, weekly, and seasonal peaking of traffic; and given its rough equivalence to the average peak hour of peak days during the peak season, the 100th highest hourly traffic volume would be relatively easy to estimate and project.

Daily peaks tend to spread out as urban areas grow and traffic congestion causes motorists to adjust their travel hours. Indeed, the largest cities do not have a “peak hour” per se but rather a two- to three-hour period in the morning and afternoon when commuting is heaviest. A shift from peak hour to peak period analysis might be justified by local policies that encourage commuters to adjust their travel hours. With flex-time in place, government may be relieved of responsibility for accommodating every trip maker’s choice of travel hour.
I. INTRODUCTION

Roadway levels of service play a central role in Florida's efforts to manage growth. The 1985 Growth Management Act and implementing Rule 9J-5 embraced a "pay as you grow" policy, commonly referred to as concurrency. Adequate infrastructure must be available concurrent with the impacts of development. Adequacy is defined by level-of-service standards, adopted by local governments as part of their local comprehensive plans. No development order or permit may be issued if levels of service will be degraded below the adopted standards. Local concurrency management systems must be implemented to ensure that level-of-service standards are maintained in the face of development pressures.

As one writer noted: "Five of the infrastructure elements have posed few problems for local governments. But the sixth category, roads, is proving to be a nightmare." The state's 1987 comprehensive plan report projected a $53 billion infrastructure shortfall by the year 2000 unless growth slowed or infrastructure investment increased. Of that amount, nearly half was for transportation.

Roads are the infrastructure element most likely to trigger public dissatisfaction, growth moratoria, and legal challenges under the Growth Management Act. Thus, it is crucial that roadway level-of-service determinations be accurate and results be interpreted sensibly. This report explores alternative approaches to ensure that they will be.

A. SCOPE OF STUDY

Given the central role of roadway levels of service in growth management, one might expect to find volumes written about level-of-service determination and standard setting. Yet, a literature search uncovered only one published article that approaches the subject from a policy perspective. Other literature focuses on technical issues. How do progression adjustment factors for signalized intersections vary with intersection spacing? How do geometrics affect saturation flow rates? This is the stuff of the level-of-service literature.

The present study addresses four policy issues:

1. What methods should be used to assess roadway levels of service?
2. Should levels of service be combined across roadway facilities?
3. Should levels of service be combined across urban transportation modes (public and private)?
(4) For what time period or peak hour should levels of service be analyzed?

A host of other issues arise in the setting of level-of-service standards, the monitoring of levels of service, the approval of projects that degrade levels of service, and the treatment of roads that are backlogged to begin with. While important, these issues are beyond the scope of this study.

B. SOURCES OF INFORMATION

Policies and procedures for roadway level-of-service determination are in a state of flux. The Florida Department of Community Affairs (DCA) is revising its rules for local comprehensive plans (LCPs), the Florida Department of Transportation (FDOT) is revising its level-of-service guidelines, and many localities are switching to more sophisticated methods of roadway level-of-service determination. Adding to the confusion, DCA in its regulatory role often differs with FDOT in its role as advisor to DCA. DCA negotiates "creative" compromises with localities that are having difficulty meeting roadway level-of-service standards, while FDOT adheres to "professional" standards and practices that preclude such compromises.

To get a fix on current policies and practices, this study included:

(1) A review of pertinent rules of the Department of Community Affairs (DCA):


- A draft rule change to Chapter 9J-5, F.A.C.

- Chapter 9J-2, F.A.C., "Rules of Procedure and Practice Pertaining to Developments of Regional Impact."

- DCA's "Development of Regional Impact: Application for Development Approval" (referred to below as the DRI Applicant Handbook).
(2) A review of guidelines of the Florida Department of Transportation (FDOT):

- FDOT's Florida's Level of Service Standards and Guidelines Manual for Planning (referred to below as the Level of Service Manual).
- A draft revision of the Level of Service Manual.
- FDOT's Guidelines for the Review of Developments of Regional Impact (referred to below as DRI Guidelines).

(3) A review of Traffic Circulation Elements in 23 LCPs, and where applicable, Stipulated Settlement Agreements between DCA and local governments aimed at bringing LCPs into compliance with state law and regulations. Figure 1 contains a list of the 23 LCPs, plus summary information about their Traffic Circulation Elements.

(4) Interviews with transportation professionals responsible for roadway level-of-service determinations in selected localities (see the Preface for a listing). The localities were chosen for their diversity of approach from among the 23 whose LCPs were reviewed previously. The opinions of those interviewed are given much weight in the discussions that follow.
Figure 1

Roadway Level-Of-Service Determinations In Local Comprehensive Plans

<table>
<thead>
<tr>
<th>County</th>
<th>Methods of Analysis*</th>
<th>Facilities Aggregated</th>
<th>Peak Hour Analyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brevard County</td>
<td>v/c Ratios (1965 HCM)</td>
<td>Parallel Roadways</td>
<td>30th Highest Hour</td>
</tr>
<tr>
<td>Boca Raton</td>
<td>FDOT Tables</td>
<td>None</td>
<td>30th Highest Hour</td>
</tr>
<tr>
<td>Broward County</td>
<td>FDOT Tables</td>
<td>None</td>
<td>30th Highest Hour</td>
</tr>
<tr>
<td>Charlotte County</td>
<td>FDOT Tables (1979 UTPS ver.)</td>
<td>None</td>
<td>Avg. Peak Hr. of Peak Season</td>
</tr>
<tr>
<td>Cocoa</td>
<td>FDOT Tables</td>
<td>None</td>
<td>30th Highest Hour</td>
</tr>
<tr>
<td>Collier County</td>
<td>FDOT Tables</td>
<td>None</td>
<td>Avg. Peak Hr. of Peak Season</td>
</tr>
<tr>
<td>Coral Springs</td>
<td>Local Tables (Based on LOS Pgm.)</td>
<td>None</td>
<td>Not Specified</td>
</tr>
<tr>
<td>Dade County</td>
<td>FDOT Tables (1979 UTPS ver.)</td>
<td>None</td>
<td>Avg. 2 Highest Consec. Wkdy Hrs</td>
</tr>
<tr>
<td>Duval County</td>
<td>FDOT Tables</td>
<td>None</td>
<td>30th Highest Hour</td>
</tr>
<tr>
<td>Flagler County</td>
<td>FDOT Tables and Road-Specific Tables (Based on LOS Program)</td>
<td>None</td>
<td>30th Highest Hour</td>
</tr>
<tr>
<td>Ft. Lauderdale</td>
<td>FDOT Tables and Intersection Analysis with HCM Software</td>
<td>None</td>
<td>Not Specified</td>
</tr>
<tr>
<td>Hillsborough Cty.</td>
<td>FDOT Tables</td>
<td>None</td>
<td>30th Highest Hour</td>
</tr>
<tr>
<td>Jefferson County</td>
<td>FDOT Tables</td>
<td>None</td>
<td>30th Highest Hour</td>
</tr>
<tr>
<td>Key West</td>
<td>FDOT Tables and HCM Analysis of U.S. 1</td>
<td>None</td>
<td>30th Highest Hour</td>
</tr>
<tr>
<td>Lee County</td>
<td>FDOT Tables (1979 UTPS ver.)</td>
<td>Roads Within Traffic Districts</td>
<td>Average Peak Hour of Peak Season</td>
</tr>
<tr>
<td>Leon County/ Tallahassee</td>
<td>FDOT Tables</td>
<td>None</td>
<td>50th Highest Hour</td>
</tr>
<tr>
<td>Manatee County</td>
<td>FDOT Tables and Local Tables (Based on LOS Program)</td>
<td>None</td>
<td>30th Highest Hour</td>
</tr>
<tr>
<td>Miami</td>
<td>v/c Ratios (1965 HCM)</td>
<td>Roads &amp; Transit Fac. within Corridors</td>
<td>Average of 2 Highest Consecutive Weekday Hours</td>
</tr>
<tr>
<td>Orlando</td>
<td>FDOT Tables and Arterial Analysis with ART-ALL</td>
<td>Roads within Traffic Performance Districts</td>
<td>100th Highest Hour</td>
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<td>Palm Beach Cty.</td>
<td>FDOT Tables</td>
<td>None</td>
<td>30th Highest Hour</td>
</tr>
<tr>
<td>Pasco County</td>
<td>FDOT Tables and Local Tables (Based on LOS Program)</td>
<td>None</td>
<td>30th Highest Hour</td>
</tr>
<tr>
<td>Tampa</td>
<td>Local Maximum Volume Tables (Based on 1965 HCM)</td>
<td>Roads Within Districts and Citywide</td>
<td>30th Highest Hour</td>
</tr>
<tr>
<td>Volusia County</td>
<td>FDOT Tables</td>
<td>None</td>
<td>Not Specified</td>
</tr>
</tbody>
</table>

* Methods cited are those used in the adopted LCP; many localities have since switched to more sophisticated methods.
C. ROADWAY LEVELS OF SERVICE

Roadway levels of service are reported using the same grading scale as a school report card, with “A” being the highest grade a road can receive and “F” the lowest (see Figure 2). The 1985 Highway Capacity Manual (HCM) defines levels of service using numerical measures. The measures vary by type of facility (see Figure 3).

Level-of-service measures in the 1985 HCM emphasize the experience of motorists. This represents a departure from the 1965 HCM, which focused on the condition of facilities. In particular, before 1985, levels of service on arterials were defined by the volume/capacity ratios. They are now defined by the average travel speeds of motorists (see Figure 4).

This study focuses on urban and suburban arterials because so many arterials are already congested. The precise method of level-of-service determination may well determine whether these arterials are designated adequate or inadequate under adopted level-of-service standards, whether developments impacting them are approved or disapproved, and whether LCPs are found to be in compliance with state law and regulations.

![Figure 2: Roadway Levels of Service Become Newsworthy](image)

**Good grades for St. Petersburg roads**

St. Petersburg roads earned good grades in the county’s latest report card on traffic congestion. But highways in North Pinellas had the most failing grades.

“St. Petersburg earned relatively good marks on Wednesday’s report card. The city earned five A’s and had a B-minus average.”

The 1985 HCM provides the following descriptions of levels of service for arterials:

- **Level-of-service A (LOS A)** describes primarily free flow-operations at average travel speeds about 90 percent of the free flow speed of the arterial class. Vehicles are completely unimpeded in their ability to maneuver within the traffic stream. Stopped delay at signalized intersections is minimal.

- **Level-of-service B (LOS B)** represents reasonably unimpeded operations at average travel speeds about 70 percent of the free flow speed of the arterial class. The ability to maneuver within the traffic stream is only slightly restricted and stopped delays are not bothersome. Drivers are not subjected to appreciable tension.

- **Level-of-service C (LOS C)** represents stable conditions. However, ability to maneuver and change lanes in midblock locations may be more restricted than in LOS B, and longer queues and/or adverse signal coordination may contribute to lower average travel speeds of about 50 percent of the free flow speed of the arterial class. Motorists experience an appreciable tension while driving.
• **Level-of-service D** (LOS D) borders on the range in which small increases in flow may cause substantial increases in approach delay and, hence, decreases in arterial speed. This may be due to adverse signal progression, inappropriate signal timing, high volumes, or some combination of these. Average travel speeds are about 40 percent of free flow speed.

• **Level-of-service E** (LOS E) is characterized by significant approach delays and average travel speeds of one-third the free flow speed or lower. Such operations are caused by some combination of adverse progression, high signal density, extensive queuing at critical intersections, and inappropriate signal timing.

• **Level-of-service F** (LOS F) characterizes arterial flow at extremely low speeds below one-third to one-quarter of the free flow speed. Intersection congestion is likely at critical signalized locations, with high approach delays resulting. Adverse progression is frequently a contributor to this condition.

---

**Figure 4**

**Arterial Levels of Service**

<table>
<thead>
<tr>
<th>ARTERIAL CLASS</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of Free Flow Speeds (mph)</td>
<td>45 to 35</td>
<td>35 to 30</td>
<td>35 to 25</td>
</tr>
<tr>
<td>Typical Free Flow Speed (mph)</td>
<td>40 mph</td>
<td>33 mph</td>
<td>27 mph</td>
</tr>
<tr>
<td><strong>LEVEL OF SERVICE</strong></td>
<td><strong>AVERAGE TRAVEL SPEED (MPH)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>( \geq 35 )</td>
<td>( \geq 30 )</td>
<td>( \geq 25 )</td>
</tr>
<tr>
<td>B</td>
<td>( \geq 28 )</td>
<td>( \geq 24 )</td>
<td>( \geq 19 )</td>
</tr>
<tr>
<td>C</td>
<td>( \geq 22 )</td>
<td>( \geq 18 )</td>
<td>( \geq 13 )</td>
</tr>
<tr>
<td>D</td>
<td>( \geq 17 )</td>
<td>( \geq 14 )</td>
<td>( \geq 9 )</td>
</tr>
<tr>
<td>E</td>
<td>( \geq 13 )</td>
<td>( \geq 10 )</td>
<td>( \geq 7 )</td>
</tr>
<tr>
<td>F</td>
<td>&lt; 13</td>
<td>&lt; 10</td>
<td>&lt; 7</td>
</tr>
</tbody>
</table>

II. METHODS OF ANALYSIS

Methods of determining roadway levels of service may be arrayed in terms of data and analytical requirements, and corresponding precision of estimates. It is usually assumed that the simplest methods are the least precise, the most complex methods the most precise (as shown in Figure 5). This is believed to be the first study to systematically test this assumption.

From least to most complex, methods used in Florida include:

- FDOT generalized maximum volume tables based on “generalized” traffic, roadway, and signal parameters for the State of Florida. Levels of service are determined by comparing traffic flows to the maximum volumes at different levels of service for roads of a given type.

Figure 5
Alternative Methods of Arterial Analysis

<table>
<thead>
<tr>
<th>PRECISION</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Travel Time and Delay Studies</td>
</tr>
<tr>
<td>• Network Simulation Programs</td>
</tr>
<tr>
<td>• Arterial Analysis Programs</td>
</tr>
<tr>
<td>• Local Maximum Volume Tables</td>
</tr>
<tr>
<td>• Generalized Maximum Volume Tables</td>
</tr>
</tbody>
</table>

COMPLEXITY
• Local maximum volume tables based on traffic, roadway, and signal data for a specific area. The tables are generated with FDOT computer programs (LOS and ART-TAB). Again, levels of service are determined by comparing traffic flows to maximum volumes in the tables.

• Computer programs that analyze levels of service for individual roads based on methods in the 1985 Highway Capacity Manual (ART-ALL, ART-PLAN and HCS Arterial Analysis).

• Computer programs that estimate levels of service on individual roads by simulating traffic flows through road networks (NETSIM and TRANSYT-7F).

• Travel time and delay studies that measure actual levels of service in the field rather than estimating them, as other methods do, with formulas.

Methods in the last three categories apply only to urban and suburban arterials -- roads whose levels of service are defined by average travel speed. The 1985 HCM uses other measures to define levels of service for freeways and rural highways (again, see Figure 3).

A. STATE POLICIES

FDOT's Level of Service Manual

FDOT's Level of Service Manual features generalized maximum volume tables. FDOT recommends them for broad planning applications, where less field data are available, and in traffic impact studies with long planning horizons. For other applications, FDOT favors traffic operational methods based on local traffic, roadway, and signal data. “Where even more precise values are desired, more detailed methodologies and programs based on the 1985 HCM and traffic operation models such as SOAP84, TRANSYT-7F and NETSIM should be used.”

In a preliminary unpublished revision of the manual, FDOT also recognizes travel time studies as a more refined method of roadway level-of-service determination. “The primary LOS measure of effectiveness for arterials is average travel speed. Whereas, the models (i.e., ART-TAB, ART-PLAN, HCS, and TRANSYT-7F) theoretically determine average travel speed, travel time studies measure average travel speed directly. If done correctly, travel time studies are probably the most accurate method of determining LOS for arterials.”
FDOT's DRI Guidelines

These guidelines require a level-of-service determination for every intersection in the immediate area of a DRI, plus an arterial analysis for each arterial in the larger project study area. Intersection analyses are to be done with intersection capacity analysis procedures based on the 1985 HCM. Arterial analyses may be based on one of several methods, where the preferred method depends on the planning horizon. From 1 to 5 years into the future, planning and traffic operational methods are suggested. From 10 to 20 years, planning methods or generalized tables may be used.

DCA's DRI Applicant Handbook

The handbook provides for roadway level-of-service determinations based on "the most recent procedures of the Transportation Research Board (TRB) and FDOT." This is a reference to 1985 HCM procedures (developed by TRB) and the most recent maximum volume tables (developed by FDOT). Like FDOT, DCA is receptive to other methods, if agreed upon in advance.

In summary, current FDOT and DCA policies allow generalized maximum volume tables to be used in LCPs and DRIs. More precise traffic operational methods or travel time studies are favored in certain applications, but are not required except in DRI intersection analyses. The only methods specifically precluded by FDOT and DCA policies are those based on the 1965 Highway Capacity Manual or TRB's Circular 212, which have been superseded by the 1985 HCM.

B. LOCAL OPTIONS

Different Methods for Different Applications

Under the Growth Management Act and implementing Rule 9J-5, communities must analyze roadway levels of service in their local comprehensive plans. They must analyze levels of service before issuing development orders or permits as part of concurrency management. And to assess progress in implementing their comprehensive plans, localities must analyze levels of service on a "continuous" basis as part of a monitoring and evaluation process.

Methods of analysis may vary from application to application. Indeed, they probably should vary since the consequences of error are more serious for some applications than others. If level-of-service projections in the comprehensive plan are erroneous, a jurisdiction will probably catch the error later during roadway monitoring or detailed project review.
However, if errors are made in the development review process, a project may be approved without adequate mitigation or may be disapproved without justification, leaving a jurisdiction's decision open to legal challenge.

This suggests the following guideline: less precise methods of analysis are adequate for local comprehensive planning, while more precise methods of analysis are required for development review and approval. Roadway monitoring demands an intermediate level of precision.

From interviews with transportation professionals, we find that many jurisdictions follow this guideline. In their LCPs, they rely on FDOT's generalized maximum volume tables or local maximum volume tables generated with FDOT's LOS program (see Figure 1). In development review and approval, these same jurisdictions typically allow or encourage developers to use more precise methods to assess levels of service on impacted roadways.

The trick is to achieve a measure of consistency between roadway levels of service in LCPs and traffic impact studies conducted by different developers. When different analysts use different methods and make different traffic assumptions, consistency is sacrificed.

Jurisdictions have responded to the need for consistency in various ways:

- Tallahassee supplies developers with maximum volume tables for individual roadways generated with ART-ALL. These are the same maximum volume tables used in Tallahassee's LCP. Developers are required to use these tables in their traffic impact studies.

- Broward County supplies developers with projections of traffic volumes, including traffic generated by proposed developments assigned to the road network using the county's own travel model. Developers analyze roadway levels of service using county-prescribed methods of analysis and local traffic, roadway, and signal data. Roadway capacities derived by developers are then adopted by the county as replacements for the generalized capacities assumed in Broward County's LCP.

- Brevard County is integrating an arterial analysis procedure from the 1985 HCM into a regional travel model. The model will be run for each proposed development, yielding consistent estimates of traffic volumes and levels of service on major roads in the area.

- The City of Tampa plans to begin charging substantial fees for development review. The fees will allow the city to carefully check the assumptions and results of developer-prepared traffic impact studies.
At the very least, the need for consistency demands that localities promulgate assumptions about traffic, roadway, and signal characteristics for developers' use in traffic impact studies. Developers should be allowed to make a case for alternative assumptions. If the case is compelling, the developers' assumptions should be adopted by the locality for use in LCP updates and future traffic impact studies.

Consistency also demands that the methods used to analyze levels of service produce consistent results. It has been shown that even assuming the same traffic, roadway, and signal characteristics, FDOT's LOS program (the source of generalized and local maximum volume tables) may yield roadway level-of-service estimates that differ significantly from those obtained with software based directly on the 1985 HCM (HCS and ART-ALL software). Figures 6a-6c illustrate the magnitude of the differences.

FDOT is in the process of updating both LOS and ART-ALL. FDOT wants the resulting software packages, renamed ART-TAB and ART-PLAN, respectively, to be consistent with one another and with HCS.

Mixing and Matching of Methods

In the unpublished draft revision of the Level of Service Manual, FDOT raises a cautionary note:

FDOT does not regard mixing and matching of different evaluation techniques as an acceptable practice. For example, if the ART-PLAN computer model is being used in the preparation of a local government comprehensive plan, it should generally be used for all arterials and the generalized tables should not be used for some arterials....Some areas of the state are using the tables as a planning tool to identify potential problem sections of roadways and then using more refined techniques to analyze them to see if the problem is real, (in) a tiered approach. Certainly, this approach of using the tables and then using their deriving models has merit; however, there is a danger in the approach when applying it to cities with many road sections.

FDOT's concern is well-founded. Selective application of methods of analysis tends to minimize apparent traffic problems. One jurisdiction, for example, applies FDOT's generalized maximum volume tables to all roadways; if levels of service fall below adopted standards, the county then develops maximum volume tables for specific roadways that eliminate many of the apparent problems. Another jurisdiction allows developers to first analyze roadway levels of service based on generalized tables; for roads with apparent problems, developers may then apply more detailed methods of analysis; and for any roads that remain problematic, developers may conduct travel time and delay studies. If roads pass this final test, developments may proceed.
**Figure 6a**

**S.R. 50 LEVEL OF SERVICE COMPARISON**

<table>
<thead>
<tr>
<th>PRIMROSE DR.</th>
<th>MAQUIRE BLVD.</th>
<th>DRIVEWAY #2</th>
<th>HERHDON AVE.</th>
<th>BENNETT RD.</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.R. 50</td>
<td>2,150</td>
<td>2,606</td>
<td>2,345</td>
<td>2,875</td>
</tr>
</tbody>
</table>

**HCS ARTERIAL ANALYSIS**

<table>
<thead>
<tr>
<th>LOS</th>
<th>'E'</th>
<th>'E'</th>
<th>'C'</th>
<th>'E'</th>
</tr>
</thead>
</table>

OVERALL LOS = "D"

SPEED = 17.7 MPH

**LOS SOFTWARE SITE SPECIFIC MAX. VOLUMES**

<table>
<thead>
<tr>
<th>LOS</th>
<th>'D'</th>
<th>'D'</th>
<th>'D'</th>
<th>'E'</th>
</tr>
</thead>
</table>

**FDOT GENERALIZED MAX. VOLUMES**

| LOS | 'E' | 'E' | 'E' | 'F' |

---

**Figure 6b**

**S.R. 535 LEVEL OF SERVICE COMPARISON**

<table>
<thead>
<tr>
<th>PALM PARKWAY</th>
<th>HOTEL PLAZA BLVD.</th>
<th>I-4 WEST RAMPS</th>
<th>I-4 EAST RAMPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.R. 535</td>
<td>1,976</td>
<td>2,434</td>
<td>1,920</td>
</tr>
</tbody>
</table>

**HCS ARTERIAL ANALYSIS**

<table>
<thead>
<tr>
<th>LOS</th>
<th>'E'</th>
<th>'F'</th>
<th>'D'</th>
</tr>
</thead>
</table>

OVERALL LOS = "E"

SPEED = 14.8 MPH

**LOS SOFTWARE SITE SPECIFIC MAX. VOLUMES**

<table>
<thead>
<tr>
<th>LOS</th>
<th>'D'</th>
<th>'F'</th>
<th>'D'</th>
</tr>
</thead>
</table>

**FDOT GENERALIZED MAX. VOLUMES**

| LOS | 'D' | 'E' | 'D' |

Source: Reid Ewing, Antoine Khoury, Glatting Lopez Kercher Anglin, Inc. Paper delivered at the 1990 ASCE Florida Section Annual Meeting.
The selective application of methods creates a ratchet effect. Roadway levels of service can only improve as estimates are refined, since successive methods are only applied to roadways with apparent problems.

The solution is not to reject a "-tiered" approach to level-of-service determination. Rather, it is to apply more precise methods to all roadways identified as possible problems, whether they appear to operate above or below adopted level-of-service standards. In this manner, localities and developers can benefit from the efficiencies of a tiered approach, without biasing results.

Brevard County has designed a tiered approach along these lines. When road traffic reaches 85% of the generalized maximum acceptable volume, a road is designated "distressed." It is then subjected to a more detailed analysis using traffic, roadway, and signal data specific to that roadway. Minimal bias is introduced because the 85% threshold recognizes a margin of error in preliminary level-of-service estimates on both sides of the "true condition."
Generalized Maximum Volume Tables

While simple methods of analysis have their uses, the ultimate in simplicity -- generalized maximum volume tables -- may be too "general" to be useful. If estimated and actual levels of service are too far apart, even a tiered approach will not catch traffic problems.

To illustrate the limitations of generalized tables, we need only consider the experiences of three localities.

- Lee County switched from generalized maximum volume tables to local maximum volume tables derived with FDOT's LOS program. The result was a 6 to 7 percent increase in maximum volumes at level-of-service E.

- Flagler County developed maximum volume tables for state roads, after finding that the driving experience on those roads did not correspond to levels of service in FDOT's generalized maximum volume tables.

- Orlando began using ART-ALL to analyze state roads after planners found that level-of-service estimates with ART-ALL differed by one or two letter grades from those obtained with FDOT's generalized maximum volume tables.

Generalized maximum volume tables are based on "generalized" assumptions about traffic, roadway, and signal characteristics. It would be pure coincidence if the amount of green time devoted to arterial-through movements, the percentage of vehicles using exclusive turn lanes, the arrival pattern of vehicles at intersections, and other characteristics of a given roadway approximated the input values assumed in the generalized tables.

Of course, no method of analysis is as easy to use as generalized maximum volume tables. The tables require no traffic engineering experience, no time-consuming analyses, and no data other than daily traffic volumes, signal spacing, and number of through lanes.

Nonetheless, the additional effort involved in estimating levels of service with FDOT software (ART-TAB or ART-PLAN) may be justified by the increase in precision. The programs are user-friendly and the data requirements are modest. FDOT will provide traffic counts and estimated K-factors and D-factors for all state roads. City and county traffic engineers can provide information on traffic signal timing, spacing, and free flow speeds. Turning movement counts can be done at low cost for morning and afternoon peak periods. In a matter of minutes, data can be entered into a microcomputer, and the level of service determined for a given roadway.
Past Comparisons of Methods

The choice among methods should be based on the ease of use and the accuracy of their level-of-service estimates. To our knowledge, there have been no published studies comparing actual roadway levels of service to levels of service estimated by different methods. Reports and articles comparing traffic models and methods of analysis have stopped short of field testing.12

There have been some unpublished attempts to validate methods of analysis. A transportation consulting firm in Tallahassee compared average travel speeds on Apalachee Parkway to level-of-service estimates based on maximum volume tables and on ART-ALL. ART-ALL estimates came closer to actual levels of service than did maximum volume tables, but all estimated levels of service were lower than actual levels derived from travel time studies.13

The Dade County Planning Department compared travel time study results for eight county roads to levels of service estimated with HCS, ART-ALL, and FDOT's LOS program. According to preliminary analyses, none of the methods duplicates field data. Indeed, when methods predict LOS E or F, roadways are often at LOS C.14

An Orlando-based consulting firm compared peak-hour travel speeds on 12 arterial sections to level-of-service estimates generated with HCS, ART-ALL, and FDOT's generalized maximum volume tables. The generalized tables consistently produced the lowest levels of service; the travel time studies almost always produced the highest levels of service.15

These results have profound implications. If common methods of analysis underestimate average travel speeds, past LCPs and DIIs may have reached erroneous conclusions about roadway levels of service. Future LCPs and DIIs could be compelled to apply new methods or revamp existing methods.

A More Rigorous Evaluation

To assess common methods of analysis, traffic and speed data for three arterials were acquired from consulting firms. Two of the arterials, Kirkman Road and Turkey Lake Road, are in Orlando.16 The former has high traffic volumes and low signal density, the latter relatively low traffic volumes and higher signal density.17

Intersections were first analyzed with HCS, and results were fed into the HCS arterial analysis program to obtain estimates of overall average travel speed for each arterial.18 Assumptions from HCS runs were then carried over to ART-PLAN and ART-TAB runs.19 This meant that the three methods of estimating levels of service could be compared to travel time runs with some assurance that all were measuring the same conditions.
Estimated and actual average travel speeds and levels of service are compared in Figures 7 and 8. Given two arterials, two peak periods, and two directions, eight comparisons can be made. It appears that actual travel speeds are significantly higher than estimated speeds in nearly all cases. They are 5 to 10 mph higher in most cases than HCS-derived travel speeds.

**Figure 7**

**Average Travel Speeds and Levels of Service**

*Kirkman Road*

<table>
<thead>
<tr>
<th>Average Travel Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Northbound AM</th>
<th>Southbound AM</th>
<th>Northbound PM</th>
<th>Southbound PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCS</td>
<td>ART-PLAN</td>
<td>ART-TAB</td>
<td>Speed Study</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>C</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>C</td>
<td>B</td>
</tr>
</tbody>
</table>

**Levels of Service**

<table>
<thead>
<tr>
<th>AM</th>
<th>HCS</th>
<th>ART-PLAN</th>
<th>ART-TAB</th>
<th>Speed Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northbound</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Southbound</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Northbound</td>
<td>C</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Southbound</td>
<td>B</td>
<td>B</td>
<td>C</td>
<td>B</td>
</tr>
</tbody>
</table>
**Figure 8**

Average Travel Speeds and Levels of Service  
Turkey Lake Road

### Average Travel Speeds (mph)

<table>
<thead>
<tr>
<th>AM</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Northbound</th>
<th>Southbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HCS</td>
<td>ART-PLAN</td>
<td>ART-TAB</td>
<td>Speed Study</td>
</tr>
<tr>
<td>Northbound</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Southbound</td>
<td>B</td>
<td>B</td>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>Northbound</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Southbound</td>
<td>C</td>
<td>B</td>
<td>C</td>
<td>A</td>
</tr>
</tbody>
</table>

### Levels of Service
ART-PLAN predicts much higher speeds on Kirkman Road than does the more sophisticated HCS software, and slightly higher speeds on Turkey Lake Road. Thus, ART-PLAN is more in line with field data.

ART-TAB does not estimate average travel speeds but only maximum volumes at different levels of service. Still, comparing levels of service in Figures 7 and 8, ART-TAB seems to be the least precise of the three methods.

The other arterial analyzed was Broward Boulevard in Fort Lauderdale/Plantation. Compared to Kirkman Road, Broward Boulevard has higher traffic volumes on side streets and thus can claim a smaller portion of the signal cycle to accommodate its heavy traffic volumes.

Estimated travel speeds on Broward Boulevard are a fraction of actual speeds (see Figure 9). If results for Kirkman and Turkey Lake Roads suggest that methods of analysis underestimate travel speeds, results for Broward Boulevard indicate that methods break down entirely when demands are too heavy relative to intersection capacity.

Figure 9

**Estimated vs. Actual Travel Speeds**

Broward Boulevard

![Bar chart showing estimated vs. actual travel speeds on Broward Boulevard](chart.png)
Why Estimates Differ from Actual Travel Speeds

To help explain why actual travel speeds are higher than estimates, results for Kirkman and Turkey Lake Roads were analyzed by link and by component of total travel time, the components being delay at intersections and running time between intersections. Typical results (for northbound AM movements) are presented in Figures 10 and 11.

Stopped delays in the travel time runs are usually shorter than estimated with HCS and ART-PLAN. Differences are exaggerated for intersections with longer delays.

Figure 10
Average Stopped Delay (in Seconds)
Northbound AM Movements

<table>
<thead>
<tr>
<th></th>
<th>HCS</th>
<th>ART - PLAN</th>
<th>SPEED STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kirkman Road</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrier to International</td>
<td>10.0</td>
<td>11.4</td>
<td>12.15</td>
</tr>
<tr>
<td>International to Major</td>
<td>7.3</td>
<td>7.3</td>
<td>6.0</td>
</tr>
<tr>
<td>Major to Vineland</td>
<td>9.8</td>
<td>11.1</td>
<td>11.2</td>
</tr>
<tr>
<td>Vineland to Conroy</td>
<td>29.3</td>
<td>28.8</td>
<td>6.4</td>
</tr>
<tr>
<td>Average</td>
<td>14.1</td>
<td>14.7</td>
<td>9.0</td>
</tr>
<tr>
<td><strong>Turkey Lake Road</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand Lake to Wallace</td>
<td>3.4</td>
<td>3.4</td>
<td>12.3</td>
</tr>
<tr>
<td>Wallace to Panther</td>
<td>2.6</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Panther to Paw</td>
<td>1.0</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>Paw to Hollywood</td>
<td>1.9</td>
<td>1.8</td>
<td>0</td>
</tr>
<tr>
<td>Hollywood to Production</td>
<td>1.2</td>
<td>1.2</td>
<td>5.7</td>
</tr>
<tr>
<td>Production to Vineland</td>
<td>0.9</td>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>Average</td>
<td>1.8</td>
<td>1.8</td>
<td>3.5</td>
</tr>
</tbody>
</table>
The degree of chance inherent in a small sample of travel time runs causes actual delays to vary greatly from run to run and intersection to intersection. While the models predict some delay at all signalized intersections, no delay was actually experienced at certain intersections with high green ratios and good progression. This has a pronounced effect on average travel speeds, not directly but through its effect on running speeds (see below).

Running speeds in the travel time runs are significantly higher than estimated with either model, and as such, account for most of the difference between actual and estimated average travel speeds. Following convention, the posted speed limit was taken as the free flow speed in model runs. Yet, roads are often designed for safe speeds in excess of the posted speed limit, and as casual observation suggests, drivers have a tendency to drive at design speeds on long, uninterrupted segments with moderate traffic volumes.24
There is another reason why running speeds in travel time runs are higher than estimated with HCS and ART-PLAN. The models assume some stopped delay at all intersections, and hence some acceleration and deceleration which depress average running speed significantly on short segments. However, in the real world, vehicles do not slow down unless they have to stop at a traffic signal, and the free flow speed may be maintained over the entire length of a short segment or even a series of short segments.

It is easy to see why actual travel speeds would differ from estimated travel speeds. But why would HCS and ART-PLAN estimates differ? After all, they are supposedly based on the same equations from the 1985 HCM and the same assumptions (or at least consistent assumptions) about traffic, roadway, and signal characteristics.

Straight running times between intersections are the same for HCS and ART-PLAN, with one exception. HCS (Release 1.5, the latest) incorrectly extrapolates running times for segments of more than one mile when the free flow speed is 45 mph. Kirkman Road contains one such segment, which depresses the average travel speed on Kirkman Road in the HCS runs. This error went undetected until results were analyzed by link and by component of total travel time.

Adjusted stopped delays differ slightly between HCS and ART-PLAN. The reason is not obvious, since both are based on the intersection delay equation in the 1985 HCM (Equation 9-18). ART-PLAN's delay estimates are often lower than HCS', and therefore ART-PLAN's estimates of running speed and average travel speed are higher. This brings them slightly closer to travel time study results.

It appears, then, that ART-PLAN is at least as good a predictor of arterial levels of service as is HCS. And since it is much easier to use, ART-PLAN would appear to be the preferred method of arterial analysis.

Local Maximum Volume Tables

As previously noted, level-of-service estimates based on ART-TAB are less precise than those based on HCS and ART-PLAN (at least for the two arterials tested). ART-TAB estimates also tend to be lower than level-of-service estimates based on the other methods, two letter grades lower in one case than observed in the field (see Figures 7 and 8).

In one sense, ART-TAB is the mirror image of ART-PLAN. ART-PLAN predicts levels of service, given traffic volumes and characteristics of traffic, roadways, and signals. ART-TAB predicts maximum traffic volumes, given levels of service and characteristics of traffic,
roadways, and signals. ART-PLAN works through the intersection delay equation (Equation 9-18 in the 1985 HCM) from left to right; ART-TAB works through the same delay equation from right to left.

However, there is one fundamental difference between ART-PLAN and ART-TAB. With ART-PLAN, traffic volumes, % turns from exclusive lanes, signal cycle lengths, green ratios, and intersection arrival types are defined segment-by-segment. The overall level of service for a roadway is determined by summing the contributions of individual segments.

In contrast, with ART-TAB, traffic volumes, % turns from exclusive lanes, signal cycle lengths, etc. have to be averaged over an entire section of roadway. Average traffic volumes are then compared to maximum traffic volumes derived with ART-TAB, which also represent a kind of average, to determine the overall level of service. Valuable information is lost in the process of averaging, and the estimated level-of-service need not be the same for the two methods since the relationship between intersection delay and the characteristics averaged is not always linear.

This accounts for ART-TAB's lack of precision. But why are ART-TAB's level-of-service estimates apparently biased downward? The answer is that FDOT's Level of Service Manual requires the use of a weighted average green ratio (g/C ratio) when developing maximum volume tables, rather than a simple average. Green ratios of all intersections along an arterial are first averaged, and then this simple average is combined with the lowest green ratio of any intersection along the arterial to produce a weighted average. In this manner, the intersection with the lowest green ratio is given many times as much weight as any other intersection.

To determine how much effect this weighting has on levels of service, maximum volume tables were created for Kirkman and Turkey Lake Roads first using FDOT's weighted average green ratio, and then using the simple average. Average traffic volumes were compared to maximum volumes for each set of tables to determine levels of service.

Figure 12 presents the results. In many cases, the use of a simple average raises levels of service by one letter grade. Usually, this brings ART-TAB results in line with ART-PLAN results. However, in one case, it causes ART-TAB to predict better levels of service than does ART-PLAN. It is not clear from this preliminary investigation whether FDOT's weighted average green ratio, a simple average, or perhaps a different weighted average should be used in level-of-service determinations.
### Figure 12

**Level-of-Service Estimates**

<table>
<thead>
<tr>
<th></th>
<th>ART-TAB (Weighted Average g/C)</th>
<th>ART-TAB (Simple Average g/C)</th>
<th>ART-PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kirkman Road</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AM Northbound</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Southbound</td>
<td>C</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>PM Northbound</td>
<td>C</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Southbound</td>
<td>C</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Turkey Lake Road</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AM Northbound</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Southbound</td>
<td>C</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>PM Northbound</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Southbound</td>
<td>C</td>
<td>B</td>
<td>B</td>
</tr>
</tbody>
</table>

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**Application of Travel Time Studies**

Only three of 11 transportation professionals interviewed for this study said that their jurisdictions have conducted travel time studies, or plan to conduct them, as a method of determining levels of service. One reason is the relatively high cost of such studies; this factor may be rendered moot eventually by advances in automatic vehicle location (AVL) technology. The more important reason is the perception that travel time study results apply only to the specific time period when travel time runs are done -- that they cannot be used to project future levels of service, as required in growth management.
This perception is incorrect. Travel time study results could be used in at least two ways to predict future levels of service. Both warrant further study in light of the substantial disparity between actual travel speeds and estimates made with standard methods.

Travel time study results could be used to better calibrate HCS, ART-PLAN, and other programs. Default values assumed by these programs may not be applicable to a particular locale. HCS or ART-PLAN could be run with progressively higher saturation flow rates and free flow speeds until estimated intersection delays, running speeds, and overall travel speeds better approximate travel time study results. The better-calibrated models could then be used to forecast future levels of service.

Alternatively, travel time study results could be correlated directly with traffic volumes and other variables in statistically derived models. In its unique approach to level-of-service determination, Seminole County developed local maximum volume tables by averaging daily traffic volumes for all two-lane roadways whose average travel speeds placed them at a given level of service. For example, the daily traffic volumes on roadway sections operating at LOS C were averaged to obtain the "maximum" traffic volume for LOS C. Repeating this process for roadway sections operating at other levels of service, local maximum volume tables were developed that reflect actual travel speeds within the locale.

The approach taken by Seminole County could be improved upon with statistical techniques. Rather than averaging traffic volumes at different levels of service, which disregards the variability of traffic volumes within a given level-of-service grade, a technique such as multiple regression analysis could relate traffic volumes to average travel speeds in a continuous manner. Multiple regression analysis has the added advantage of allowing additional characteristics of roadways to be factored into equations as independent variables.

To illustrate the approach, average peak-hour travel speeds and traffic volumes were acquired for 17 two-lane roadways in Seminole County. With a.m. and p.m. peak hours, and northbound and southbound directions, speed and volume data were available for a total of 68 movements.

Average peak-hour travel speed was regressed on peak-hour traffic volume and two other variables, number of signalized intersections per mile and free-flow speed. Both linear and nonlinear forms of the regression equation were tested. The best fit to the data was obtained with a linear equation in two independent variables, peak-hour traffic volume and signalized intersections per mile (see Figure 13). Free-flow speed proved statistically insignificant. The other two variables were significant at the 0.01 level or beyond. Together they explain 55% of the variation in average peak-hour travel speed among roadways.

To use a model of this type in forecasting average travel speeds and associated levels of service, it would only be necessary to substitute projected values of the independent variables
into the regression equation. Alternatively, the model could be used to forecast changes in average travel speeds as peak-hour traffic volumes increase or other variables change.

The explanatory power of the model estimated for Seminole County is probably inadequate for use in forecasting future travel speeds and levels of service. The standard error of the estimate, 5.3 mph, could result in a one- or even two-letter grade difference between estimated and actual levels of service. Nonetheless, with 55% of the variation in average travel speed explained by only two variables, one has to believe that a good predictive model could be developed with a richer data base (including such independent variables as the green ratio, arrival type, and % turns from exclusive lanes).

The regression model’s simplicity may be a virtue. The complicated models and multitude of parameters in the 1985 HCM only give the appearance of precision. In light of results for Kirkman Road, Turkey Lake Road, and Broward Boulevard, the added complexity may not translate into added precision.

Figure 13

Regression Equation Relating Average Travel Speed to Peak Hour Traffic Volume and Signals Per Mile
Seminole County 2 - Lane Roads

\[
\text{Average Travel Speed} = 44.7 - 0.0087 \times \frac{\text{Peak Hour Traffic Volume}}{(3.12)} - 7.74 \times \frac{\text{Signals Per Mile}}{(6.65)}
\]

- \( R^2 = 0.55 \)
- Standard Error = 5.3
- Number of Observations = 68
- Degrees of Freedom = 65

\( t \) - statistics shown in parentheses
III. AREAWIDE LEVELS OF SERVICE

It is routine in traffic impact studies to determine levels of service for:

- a lane group at an intersection,
- an entire intersection,
- a roadway segment from intersection to intersection, and
- a section of roadway with multiple intersections along its length.

As we move up the hierarchy from intersections to entire roadway sections, we are averaging or aggregating levels of service. The procedure for doing so is straightforward, at least for urban and suburban arterials. For signalized intersections, levels of service are measured in terms of average stopped delay. Add to this the delay approaching intersections and the running time between intersections, and we obtain total travel time on a roadway segment. Divide this by the length of the segment, and we arrive at average travel speed, which determines the level of service. Do the same for several segments in a series, and we obtain an estimate of level of service for a roadway section.

No difficult conceptual issues arise, and no one questions the basic logic of averaging or aggregating levels of service in this context.

However, we find ourselves in uncharted waters when we begin to combine levels of service across facilities. There is no standard, professionally accepted method of averaging or aggregating levels of service within:

- a travel corridor,
- a traffic district, or
- an entire road network.
A. STATE POLICIES

FDOT's Level of Service Manual

FDOT's Level of Service Manual sets minimum operating levels of service for state roads and presents generalized maximum volume tables for state and local roads. Local governments and DRI applicants often assume that the standards and maximum volumes apply to individual roadway segments, from intersection to intersection. Typically, neither FDOT nor DCA challenges segment-by-segment analysis when it appears in LCPs or DRIs.

Yet the manual states explicitly at one point that maximum volume tables should be applied to "sections of roadways"; the sections should be at least one mile in downtown areas and two miles elsewhere. Either average or median traffic volumes for entire sections may be compared to maximum volumes in the tables to determine levels of service. In effect, several segments and intersections on a single facility are being aggregated. FDOT's rationale for combining them is: "Although directly related and important, congestion at individual intersections or links may be acceptable so long as the overall quality of flow is acceptable."

Rule 91-5

This rule requires the establishment of level-of-service standards for all roads in a local jurisdiction as part of the local comprehensive plan. Standards must conform to Subsection 91-5.005(3), which reads in part: "Each local government shall establish a level of service standard for each public facility. Such level of service standards shall be set for each individual facility or facility type and not on a systemwide basis." DCA has interpreted this rule to preclude LOS measurement and standard setting for collections of road facilities within corridors or districts.

Legislation introduced during the 1990 Florida Legislative Session would have allowed local governments to adopt average areawide level-of-service standards for "transportation concurrency management areas" (TCMAs). DCA was directed to establish criteria for delineating TCMAs and to develop methods of defining, measuring, and monitoring average levels of service within TCMAs.

The legislation containing this provision (Senate Bill 1794) was never enacted, but DCA is seeking a rule change toward the same end. Under a new section of Rule 91-5, local governments could designate TCMAs in their comprehensive plans and adopt an overall level-of-service standard for the transportation facilities and services within each TCMA.
Overall level-of-service standards for TCMAs would replace standards for individual facilities within TCMAs. As the draft currently reads: "Use of a transportation concurrency management area system shall allow development orders and permits to be issued within the transportation concurrency management area without consideration of the transportation level-of-service of individual transportation facilities or services so long as the overall level-of-service standard adopted for the transportation concurrency management area is maintained."33

Precedents

DCA has accepted averaging or aggregation of roadway levels of service as part of at least two stipulated settlement agreements with localities. The agreement with Brevard County allows the "averaging of parallel roadways to establish an acceptable level of service based on the maximum acceptable volume of the system [emphasis added]." This provision was written for the time when S.R. 520 crossing Merrit Island fails while parallel county roads continue to operate at acceptable levels of service. Until the average level of service becomes substandard, Brevard County can continue to approve developments that load traffic onto S.R. 520.

In DCA's agreement with Lee County, "the maximum allowable traffic growth on backlogged roads is to be determined on a district-wide basis rather than on an individual roadway segment basis [emphasis added]." Development affecting backlogged roads may be permitted as long as the percentage of surplus capacity in a traffic district is equal to or greater than the percentage of traffic growth in that district. District-wide aggregation may be used by the county until the end of the decade, when all roads will become subject to individual level-of-service standards.

B. LOCAL OPTIONS

Concepts Underlying Aggregation

Two distinct concepts are used to justify and guide the aggregation of roadway levels of service. The first is the concept of typical trips. Over the course of a day, a person may travel on scores of roadway links and dozens of different roads. Even a single peak-hour trip may involve travel on a myriad of facilities.

Presumably, a traveler's perception of roadway conditions is based on an entire trip or possibly even an entire day's worth of travel, not on the delay at one intersection or the congestion on one roadway segment. Therefore, roadway levels of service might reasonably be aggregated to reflect common travel patterns and trip lengths.
network exists, an individual may have many routes available for a given trip. Ordinarily, the routes will offer different levels of service since they are made up of segments with varying travel demands upon them from other trip makers. If any route provides an acceptable level of service, government may have met its responsibility to the individual trip maker. Hence, roadway levels of service might reasonably be aggregated within travel corridors.

The concept of alternate routes raises an important issue:

To what degree is government responsible for accommodating individual travel preferences?

This issue will surface again in the sections on “Multimodal Levels of Service” and “Choice of Analysis Period.” Have concurrency requirements been satisfied if a trip can be made at an acceptable level of service by some route, using some mode, at some time during the peak period? Or must acceptable levels of service be provided for every route, mode, and hour of travel that might be chosen by trip makers?

In effect, existing Rule 9J-5 interprets the Growth Management Act as requiring “adequate facilities” along every route, for every mode and hour of travel. The proposed amendment to Rule 9J-5 would relax this interpretation.

Methods of Aggregation

How can levels of service on individual facilities be aggregated into one areawide level of service? While there is no standard approach, three possibilities suggest themselves. All three have precedents in LCPs already approved by DCA. They are:

(1) summing volumes and capacities,

(2) averaging levels of service, and

(3) adopting performance summaries.

The first approach is to compare the sum of traffic volumes on roads in an area to the sum of roadway capacities (where capacities are equal to maximum volumes at adopted levels of service and both traffic volumes and capacities are weighted appropriately). If, in the aggregate, capacities exceed traffic volumes, the area might be deemed to meet level-of-service standards.
Under its settlement agreement with DCA, Lee County may aggregate traffic volumes and roadway capacities and use any surplus capacity to justify degradation of already “backlogged” roads. Aggregation is accomplished by:

1. Summing peak-hour traffic volumes on functionally classified roads in each traffic district,
2. Summing capacities of functionally classified roads in each district,
3. Subtracting aggregate traffic volume from aggregate capacity to obtain surplus capacity in each district, and
4. Comparing surplus capacity to the growth of traffic anticipated in each district (see Figure 14).

A second approach to aggregation is to average levels of service for facilities of a given type in a travel corridor or traffic district. While averaging in this context is novel, averaging travel speeds on arterials has been the norm since the 1985 HCM was released. It is not difficult conceptually or methodologically to go from averaging speeds of vehicles operating on different sections of an arterial to averaging speeds of vehicles operating on different arterials.

For arterials, the areawide average speed could be compared to minimum travel speeds at different levels of service (from the 1985 HCM) to determine the areawide level of service. If an area had arterials from more than one arterial class, minimum travel speeds for different classes could be weighted proportionally to produce one set of standards against which average travel speed could be judged.

For freeways and rural multilane highways, density in passenger cars per mile per lane could be similarly averaged and compared to level-of-service standards in the 1985 HCM. The only obvious limitation on averaging is that it cannot be done across types of facilities whose levels of service are measured differently.

Under its settlement agreement with DCA, Brevard County may average levels of service on a main arterial and parallel interconnected collectors. The prescribed procedure involves:

1. Dividing traffic volume on each road by the maximum volume at the adopted level of service, and
2. Weighting and summing the resulting ratios over all roads to arrive at the average proportion of maximum acceptable volume being utilized by traffic.
Figure 14
Traffic Volumes vs. Capacities (By District)
Lee County

Being among the first to prepare an LCP, Brevard County used volume/capacity ratios to define levels of service. However, the basic approach would be the same if travel times were averaged instead, consistent with the 1985 HCM.

A third approach to aggregation is to adopt a performance summary for roads in an area, which specifies the percentage of roads at or above level-of-service standards. Unlike the preceding approach, which applies an average standard to an average roadway, this approach retains individual standards for individual roadways. Roadway level of service is aggregated only in the sense that certain roadways are allowed to deteriorate as long as other roads are upgraded even more. It is the performance summary, not individual roads, that must show improvement over time.

At least three local governments have used performance summaries to meet concurrency requirements (see Figures 15 and 16). Orlando's approach is exactly as described above, while Pasco County and Tampa have accepted limits on aggregation in order to secure DCA approval. Pasco County agreed to bring all roads up to individual level-of-service standards by a certain date, and Tampa imposed ceilings on the volume/capacity ratios of all roads. The Orlando plan has been reviewed by DCA, and objections have been raised to the approach taken. It seems unlikely that this relatively pure example of geographic aggregation will prove acceptable under existing Rule 9J-5.

All three methods -- summing volumes and capacities, averaging levels of service, and adopting performance summaries -- allow individual roadways to operate below FDOT level-of-service standards as long as others are above. All three enable local governments to finance the most cost-effective system improvements rather than isolated roadway improvements dictated by minimum operating standards.

How to choose among them? One method -- the adoption of performance summaries -- conforms to professional standards, while the other two extrapolate from professional standards. There are no professionally accepted level-of-service standards and measurement methods for road networks, only for individual roads. By continuing to analyze roads individually, performance summaries avoid methodological leaps of faith.

Even so, the averaging method may be preferred for growth management purposes. Travel speeds fall precipitously as traffic volumes approach capacities. With areawide averaging, local governments, concerned about maintaining average travel speed, will have ample incentive to fix localized traffic problems. Less incentive is provided by the other methods of aggregation.

The fact that areawide averaging is not standard engineering practice may have little practical significance. Professionally accepted practices could change with a future update of the Highway Capacity Manual, as level-of-service standards are increasingly applied to growth
Figure 15

District Performance Criteria

<table>
<thead>
<tr>
<th>Traffic Performance District</th>
<th>1995</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>73%</td>
<td>75%</td>
</tr>
<tr>
<td>2</td>
<td>69%</td>
<td>73%</td>
</tr>
<tr>
<td>3</td>
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<td>52%</td>
</tr>
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</tr>
<tr>
<td>15</td>
<td>51%</td>
<td>58%</td>
</tr>
</tbody>
</table>

**Source:** City of Orlando Transportation Planning Bureau "Growth Management Plan Transportation Elements," Presentation to the Municipal Planning Board, September 11, 1990.
management. Even if level-of-service standards remain tied to individual facilities, areawide averaging will gain all of the legitimacy required for growth management if it is prescribed by DCA rule.

Weighting Factors

Whichever method is chosen, roadways must be assigned weights that reflect their contributions to overall levels of service. Lee County weighted traffic volumes and capacities of roadway segments by their respective lengths (i.e., by centerline miles). Brevard County also used segment lengths as a weighting factor. Pasco County weighted its performance summary by the number of vehicle-miles traveled on different roads; Orlando used the number of lane-miles; and Tampa used centerline miles in one performance summary and vehicle-miles traveled in another.

Use of vehicle-miles accounts for the volume of traffic exposed to different traffic conditions. Since it is the "average" experience of travelers we wish to capture in an overall level-of-service measure, not the average condition of roadways, vehicle-miles would seem to be the

Figure 16

System Performance Plan For All Districts
City of Tampa

Source: City of Tampa Comprehensive Plan Traffic Circulation Element, p. 3.
preferred weighting factor. Use of other weighting factors could encourage improvements to low-volume roads simply to meet concurrency requirements, while higher volume roads go unattended.

Delineation of TCMAs

Localities will require some guidance as they begin to delineate corridors or districts within which levels of service are aggregated. This discussion will refer to such areas generically as TCMAs.36

If TCMAs are too large, traffic problems will be glossed over and development decisions will be subject to challenge. We might expect property owners near the edges of large TCMAs, for example, to challenge project disapprovals prompted by traffic congestion at central locations or opposite edges.

If TCMAs are too small, flexibility to respond to systemwide needs will be sacrificed. In the extreme, TCMAs will cease to reflect motorists' experiences on typical trips or their choice of alternative routes and simply become surrogates for individual facilities.

Many criteria have been suggested for delineating TCMAs. Several seem intended to ensure that TCMAs capture the experience of motorists on typical trips. Transportation professionals interviewed for this study suggested that TCMAs be sized to reflect average trip lengths, be bounded by natural barriers or freeways, have few entry and exit points, and correspond to distinct communities within the metropolitan area. Where natural barriers exist between TCMAs, entry points are limited, or these other criteria are met, there is likely to be more trip making within TCMAs than between TCMAs. Thus, as intended, TCMAs will capture the experience on typical trips.37

Other criteria seem intended to ensure that TCMAs reflect the availability of alternate routes. In its draft rule, DCA has limited aggregation to roads that serve "related purposes." What this apparently means (from examples given) is that roads running in the same general direction may be combined since they serve as alternate routes. DCA also has limited TCMAs to areas containing "a complete, integrated network of arterial and collector roads." A complete, integrated network ensures that TCMAs will provide alternate routes for any given trip.

Two criteria proposed by DCA in its draft rule deserve special attention. At a public workshop on the draft rule, both criteria elicited strong reactions, pro and con.

The draft rule would confine TCMAs to special areas where development will assist in achieving state planning goals.38 Workshop participants who planned to divide up their entire
jurisdictions objected to this limitation. The City of Orlando, in particular, anticipates problems in justifying traffic performance districts throughout its jurisdictional area under the draft rule (see Figure 17).

Figure 17

Traffic Performance Districts
City of Orlando

Source: City of Orlando Planning & Development Department, Traffic Circulation Element: Growth Management Plan.
In effect, DCA’s draft rule would render TCMAs equivalent to FDOT’s special transportation areas (STAs). STAs are compact geographic areas in which growth management considerations outweigh roadway level-of-service objectives. STAs are designated by local governments and must be approved by metropolitan, regional, and state agencies. Within approved STAs, roadway level-of-service standards may be relaxed.

The state planning goals cited as justification for TCMAs relate principally to land use. However, the State Comprehensive Plan also contains goals related to transportation system efficiency. These goals might justify the designation of TCMAs throughout a jurisdiction, even if land use goals do not. After all, the purpose of aggregating levels of service across facilities is to promote cost-effective system improvements instead of isolated roadway improvements dictated by minimum operating standards.

Another point of contention at the workshop was the relationship between TCMAs and transportation impact fee benefit districts. Some workshop participants argued that TCMAs should coincide with impact fee benefit districts. In Lee County and Tampa, the two coincide for the most part. Other participants contended that TCMAs bear no relationship to impact fee benefit districts. Orlando’s impact fee benefit districts were said to be much too large to serve as traffic performance districts.

The draft rule applies the same basic requirement to TCMAs as the courts have applied to transportation impact fee benefit districts. Under the “dual rational nexus” test, impact fee benefit districts must be small enough to ensure that impact fees spent on transportation improvements anywhere in a district will be of benefit to fee-payers anywhere in the district. This test will be met only if fee-payers or their successors are likely to make use of transportation improvements in their routine trip making, that is, only if their typical trips take them all over their respective impact fee benefit districts. By this standard, impact fee benefit districts are conceptually no different from TCMAs.

For guidance in delineating TCMAs, the concepts of typical trips and alternate routes may be combined in the following general guideline: TCMAs should be drawn so as to encompass alternate routes available for common peak-hour trips.

How the general guideline is operationalized is best left to local planners. Let it suffice to say that the guideline could be operationalized. For example, regional travel models could be used to generate tables of trip interchanges between traffic zones, and from these, common origin-destination pairs could be identified. Because level-of-service standards apply to peak hours, primary consideration might be given to work trip interchanges. TCMA’s boundaries could be drawn so that traffic zones between which a majority of trip interchanges occur are part of the same TCMA.
Areawide and Tiered Standards

In a recent issue of the *Florida Engineering Society Journal*, two authors debated the merits of averaging roadway level of service within a corridor, district, or entire urban area. One author contended that averaging could result in a "glossing over of transportation problems." The other author countered that requiring each roadway link to operate at a minimum acceptable level of service could cause "short-term incremental improvements rather than long-term comprehensive improvements."

Both authors are right. The challenge is to devise level-of-service standards that will encourage a long-term comprehensive approach to transportation improvement programming while still addressing localized traffic problems.

One possibility is to establish areawide standards only but measure levels of service in a manner that gives considerable weight to localized traffic problems. As noted previously, averaging levels of service across facilities, and weighting facilities by the vehicle miles traveled on them, should have the desired effect.

Another possibility is to establish tiered standards. Standards for individual facilities could be set at the absolute minimum acceptable level, while areawide average standards are set at a higher desirable level. For example, the minimum standard for individual facilities could be LOS E or worse (say, 2 mph below the minimum travel speed for LOS E). At the same time, the minimum areawide average might be LOS B in rural areas, LOS C in urbanized areas, and LOS D in special transportation areas.
IV. MULTIMODAL LEVELS OF SERVICE

With so much of Florida's growth occurring in the age of the automobile, growth management has naturally focused on the adequacy of roadways. Low-density development patterns and poor transit service have left mass transit in most Florida urban areas with insignificant market shares.

Nonetheless, under certain circumstances, mass transit may represent a viable alternative to the automobile, and the adequacy of facilities may best be analyzed on a total transportation system basis. For example, in travel corridors with high-quality rail service, traffic congestion on parallel roadways may be of no public concern since auto users have an adequate alternative. Indeed, traffic congestion may be desirable since it encourages transit usage.

A. STATE POLICIES

Rule 9J-5

Under existing Rule 9J-5, traffic circulation and mass transit are usually dealt with in separate elements of LCPs, and a mass transit element is not even required in localities with fewer than 50,000 residents. However, a proposed rule change contemplates a combined level-of-service standard for autos and mass transit, and a precedent for such a standard has already been set in one LCP.

The original draft of the proposed rule change reads: “If justified by the local government as appropriate, the level-of-service standards for roads pursuant to Rule 9J-5.007(3)(c)1 and mass transit pursuant to Rule 9J-5.008(3)(c)1 may be integrated into one level of service standard [emphasis added].”

The reference to “integrated” standard setting has been deleted from the most recent draft, but localities are given latitude under the rule change (according to the draft’s author) to adopt a combined standard.

Precedent

The City of Miami’s LCP establishes the policy: “Within designated Transportation Corridors, the capacity of all transportation modes will be used in the measurement of future, peak hour level of service standards [emphasis added].”
Miami’s approach to level of service is based on the philosophy that “…‘roadway capacity’ and its derivative ‘level of service’ are functions not of how many person trips are being made, but rather of the collective decisions that choose by what manner they are made...within a reasonable range, traffic congestion exists as a matter of collective choice, not physical law.” In other words, if commuters wish to subject themselves to congestion by traveling in single-occupant vehicles during the peak hour, it is their decision, not local government’s. DCA seemed to agree when it found Miami’s LCP to be in compliance with state law and regulations.

B. LOCAL OPTIONS

Role of Transit

Nearly all of the transportation professionals interviewed for this study agreed that where better transit service exists, roadway levels of service need not be as high as elsewhere. However, they differed on just how good transit service must be before it compensates for roadway deficiencies. They also differed on whether transit availability should be reflected in relaxed roadway level-of-service standards or in combined level-of-service standards for autos and transit.

Some argued for consideration of transit availability only where it provides a level of service competitive with the automobile. Good transit service is not enough; the service has to be great. ‘‘Great’’ means that transit offers total trip times comparable to the automobile. Considering the out-of-vehicle time lost with transit, only systems with exclusive or semi-exclusive guideways are likely to measure up, and then only when congestion on the street system slows down automobiles.

Others felt that if transit systems have excess capacity, government has no responsibility to provide roadway capacity for every commuter who might choose the automobile. Miami’s LCP, and to some extent Dade County’s LCP, embrace this philosophy. To be free of the usual roadway level-of-service standards, roads need only lie within corridors served by bus lines with 20-minute peak-hour headways and excess bus capacity.

The two philosophies differ in their reading of where government responsibility ends and individual preferences begin. The capacity-oriented view holds that transit need only have the capacity to serve auto users, while the level of service-oriented view adds the requirement that transit service be good enough to attract auto users.
Where the level of service-oriented view may have a conceptual advantage is in its realization that an individual commuter has control only over his own mode choice decision, not over the collective decisions of other commuters. Metrorail in Miami offers a high level of service. A commuter in a Metrorail corridor can, by his individual choice of transit, avoid sitting in traffic.

In contrast, a commuter facing the choice of auto or bus travel on congested city streets really has no choice. True, if a large number of commuters were to switch to transit, reduced congestion would result in high levels of service for both modes. But an individual’s choice of transit will have no perceptible effect on congestion levels and leave him with a walk and a wait in addition to a long travel time.

**Alternative Approaches**

As indicated above, Miami defines levels of service for multimodal transportation corridors (see Figure 18). Where a transportation corridor contains a rail line or a bus route with a peak-hour headway of 20 minutes or less, the “practical capacity” of the corridor is estimated for all modes combined. The practical capacity of automobiles is taken as 1.6 persons-per-vehicle, higher than current auto occupancy. The practical capacity of transit vehicles is 150% of seated load for local buses, 125% for express buses, and 130% for rapid rail transit. Both autos and transit have “excess capacity” under these assumptions.

Once the practical capacity of a transportation corridor is known, it is divided into the person-trip volume within the corridor to obtain a volume/capacity ratio. The level of service is determined by comparing the volume/capacity ratio for the corridor to the following standards:

<table>
<thead>
<tr>
<th>v/c ratio</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>.01-.60</td>
<td>A</td>
</tr>
<tr>
<td>.61-.70</td>
<td>B</td>
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<tr>
<td>.71-.80</td>
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<td>.91-1.00</td>
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</tr>
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<td>F</td>
</tr>
</tbody>
</table>
Miami's companion government, Dade County, accounts for transit availability by relaxing roadway level-of-service standards in transit-served areas. Beginning in 1995, Dade County will apply a three-tiered standard to roadways in Urban Infill Areas:

- Where no transit exists, roads may not exceed LOS E traffic volumes.

- Where transit service with headways of 20 minutes or less is provided within 1/2 mile distance, roads may not exceed 120% of LOS E traffic volumes.
• Where "extraordinary" transit service such as commuter rail or express bus service exists, parallel roadways within 1/2 mile may not exceed 150% of LOS E traffic volumes.

Similar tiered standards will apply to roadways in Special Transportation Areas and roadways in rural areas.

Both approaches (Miami's and Dade County's) have been accepted by DCA. Both allow roadway levels of service to slip as transit service improves, and in so doing, both presumably encourage transit usage.

Miami's approach treats autos and mass transit as "equal partners in the trip moving business" (to quote the planner who devised the approach). A seat is a seat, whether in an automobile or on a bus.

Equating modes has theoretical appeal, but it must be reconciled with consumer preference for the automobile. Autos and transit are not equal partners in Florida's sprawling urban areas. Any system that treats them as equals could have unintended consequences. Transportation improvements might be funded on the basis of cost-effectiveness in meeting concurrency requirements, not cost-effectiveness in meeting travel demands. Even if buses ran empty and roads were gridlocked, local government could approve new developments as long as they were "served" by transit.

There is also the practical problem of combining levels of service for different modes. Miami measured levels of service in terms of volume/capacity ratios, as prescribed by the 1965 Highway Capacity Manual; it was a simple matter of relating the volume of person-trips in a corridor to the sum of the capacities of autos and transit.

With the arrival of the 1985 HCM, this methodology has been superceded. Levels of service on urban and suburban arterials are now measured in terms of average travel speeds, while transit levels of service continue to be measured in terms of load factors and the like (see Figure 19). Even if localities could develop average trip speed data for transit users, including walk, wait, and transfer times, the data could not necessarily be combined with average travel speeds for auto users since the two modes may be subject to very different level-of-service standards. A 15-mpg average travel speed may be unacceptable to auto users but perfectly acceptable to transit users who can work or read while they ride. The reverse could also be true. Without surveying public attitudes, it is impossible to say.
## Figure 19

**Transit Level-of-Service Measures**

<table>
<thead>
<tr>
<th>Local Comprehensive Plan</th>
<th>Measures</th>
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<tbody>
<tr>
<td>Jacksonville</td>
<td>Headway/load factor/route density</td>
</tr>
<tr>
<td>Orlando</td>
<td>Headway</td>
</tr>
<tr>
<td>Tallahassee</td>
<td>Route mileage</td>
</tr>
<tr>
<td>Tampa</td>
<td>Peak hour load factor</td>
</tr>
</tbody>
</table>

**Source:** Mass Transit Elements, Local Comprehensive Plans.

**FDOT’s Transit Corridor Standards**

The preceding sections may be summarized as follows: where transit service on exclusive or semi-exclusive guideways is available, it is reasonable to relax level-of-service standards for parallel roadways.

As it happens, this policy is already embodied in FDOT’s “Statewide Minimum Acceptable Operating Level of Service Standards for the State Highway System” (see Figure 20). In FDOT’s Level of Service Manual (draft revision), roadways parallel to exclusive transit facilities are subject to level-of-service standards generally one letter-grade below the norm. To qualify, roadways must be “parallel to and within one-half mile of a physically separated rail or roadway lane reserved for multi-passenger use by rail cars or buses serving large volumes of home/work trips during peak travel hours.”
Perhaps even lower standards (e.g., 2 mph below the LOS E standard) could be justified when high-quality transit service is available in the corridor. The only caveat is that some road users have no transit option; this is true of commercial vehicles and auto users with trip ends outside the transit corridor. A minimum roadway standard must be maintained for these users, if not for the auto users who choose gridlock when government has provided them with an attractive transit alternative.

**Figure 20**

**Statewide Minimum Acceptable Operating Level of Service Standards for the State Highway System**

<table>
<thead>
<tr>
<th>Roadway Type</th>
<th>Existing Urbanized Areas</th>
<th>Other Existing Cities</th>
<th>Transitioning Urbanized or Incorporated Areas</th>
<th>Rural Areas</th>
</tr>
</thead>
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<tr>
<td>Freeways</td>
<td>D</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Principal Arterials</td>
<td>D</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Minor Arterials &amp; Others</td>
<td>E</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
</tbody>
</table>

**SPECIAL CONSIDERATIONS**

<table>
<thead>
<tr>
<th>Roadway Type</th>
<th>Special Transportation Areas</th>
<th>Parallel to Exclusive Transit Facility</th>
<th>Constrained Facility</th>
<th>Backlogged Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeways</td>
<td>D</td>
<td>D</td>
<td>Maintain</td>
<td>Maintain &amp; Improve</td>
</tr>
<tr>
<td>Principal Arterials</td>
<td>E</td>
<td>E</td>
<td>Maintain</td>
<td>Maintain &amp; Improve</td>
</tr>
<tr>
<td>Minor Arterials &amp; Others</td>
<td>E</td>
<td>E</td>
<td>Maintain</td>
<td>Maintain &amp; Improve</td>
</tr>
</tbody>
</table>

V. CHOICE OF ANALYSIS PERIOD

Both Rule 9J-5 governing LCPs and Rule 9J-2 governing DRIIs require that peak-hour volumes be used to determine levels of service. Use of the peak hour is consistent with standard engineering practice in facility design, traffic operations, and traffic control. Whenever localities have sought to establish level-of-service standards based on daily rather than peak-hour traffic, DCA has objected.

It is not enough to prescribe the use of "peak-hour" volumes, though. As Bill McShane and Roger Roess note in Traffic Engineering, "...if peak-hour volume is to be used as a common focus of design, operations, and control analyses, it is critical to understand which peak hour is being used." Among the multitude of choices are:

- the single highest hour of the year,
- the 30th highest hour of the year,
- the 100th highest hour of the year,
- the average peak hour of the peak season, or
- the average peak hour of the entire year.

Which peak hour is selected could have a dramatic effect on estimated levels of service. From Brevard County's LCP, traffic in the 30th highest hour is 10% of annual average daily traffic (K30 = 0.10), traffic in the 100th highest hour is 9% (K100 = 0.09), and traffic in the average peak hour is 8%. Thus, the traffic volume during the 30th highest hour is 25% higher than the volume during the average peak hour; that extra traffic could make as much as a four letter-grade difference in the estimated level of service.

The K-factors of the preceding paragraph are called design hour factors. They represent the proportion of the annual average daily traffic occurring during the design hour, that is, during the hour of the future year which sets the standard for highway design. Customary practice in the United States is to base design on the 30th highest hourly volume in the 20th year of service. This means that facilities are expected to operate at acceptable levels of service all but 29 hours of that year.
A. STATE POLICIES

FDOT's Level of Service Manual

FDOT's current manual establishes level-of-service standards for the 30th highest hourly traffic volume of the year. The generalized maximum volume tables in the manual are also based on the 30th highest hour (actually, the highest 15-minute period of the 30th highest hour). Even the daily maximum volume tables are based on the 30th highest hour.\textsuperscript{46}

The revised manual will set standards and compute maximum volumes based on the 100th highest hour of the year. The 100th highest hour is said to approximate the typical peak hour of a day during the peak travel season.

While FDOT acknowledges that there may be valid reasons for using a time period other than the 30th (or 100th) highest hour, the agency insists that its choice is part of the FDOT's level-of-service standards not to be altered [emphasis added].\textsuperscript{47} Thus, local governments and DRI applicants would appear to have little latitude under FDOT's policy.\textsuperscript{48}

FDOT's DRI Guidelines

These guidelines call for the use of K30 (presumably to be replaced with K100 when the Level of Service Manual is revised). This policy has some built-in flexibility, though. The measured peak-to-daily ratio may be substituted for K30 in areas that do not experience heavy seasonal traffic.\textsuperscript{49} Also, the K-factor may be computed from traffic counts based on a method developed by James Bonneson.\textsuperscript{50} That method is estimated to yield the 145th highest hourly traffic volume, not the 30th; it disregards seasonal variations in traffic flow.

Precedents

Whatever the manuals might say, FDOT's peak-hour policy is not always followed. DCA has reached agreements with local governments on LCPs that provide for level-of-service determinations based on peak hours other than the 30th highest. DCA has accepted:

- The average of the two highest consecutive hours of an average weekday (in Miami and Dade County).

- The 100th highest hour or the average peak hour of days throughout the year, provided "the best engineering practices" suggest one of these is "more appropriate" than the 30th highest hour (in Brevard County).
• The average peak hour of days in the peak season (in several counties).

B. LOCAL OPTIONS

Interplay of Peak Hour and LOS Standards

The choice of peak hour cannot be divorced from the setting of level-of-service standards. The effect will be the same if we apply lower standards to a higher-volume hour, or higher standards to a lower-volume hour. In its LCP, Lee County adopted two standards -- LOS D for the annual average peak hour and LOS E for the average peak hour of the peak season. The lower standard (LOS E) applied to the peak season may be more restrictive than the higher standard (LOS D) applied to the entire year (as illustrated in Figure 21).

Figure 21

Level of Service Related to Choice of Peak Hour

HOURLY TRAFFIC VOLUME

Average Peak Hour of Peak Season

LOS E Maximum Volume

Annual Average Peak Hour

LOS D Maximum Volume

HIGHEST HOURS OF THE YEAR
Does this mean that there is no preferred peak hour for concurrency management purposes? Not hardly, but it does mean that the choice of peak hour must be made on some basis other than the desire to promote or restrict development (which can be accomplished with any peak hour by simply lowering or raising level-of-service standards).

**Relevance of the Design Hour**

FDOT presumes that the appropriate peak hour for concurrency management purposes is the same as the peak hour for design purposes. When DCA has allowed local jurisdictions to base levels of service on some peak hour other than the 30th highest, it has been out of expediency. Traffic conditions were so dire that the use of the 30th highest hour would have made it impossible to meet FDOT level-of-service standards, despite a "good faith" local effort.

But should the same peak hour be used for concurrency management and design purposes?

The transportation professionals interviewed for this study had mixed reactions. Some argued that we cannot afford to hold existing facilities to the same standard as new facilities. In their view, we design new facilities to desired standards but operate existing facilities at minimum standards because the resources required to upgrade them are limited. Others felt that the same standards must apply to new and existing roads for growth management policies to be internally consistent. In their view, roads identified as deficient by one standard in the Traffic Circulation Element of an LCP should be upgraded to the same standard in the Capital Improvement Element.

The latter view appears more defensible than the former. Once a community has decided how much congestion it is willing to accept, and has set a level-of-service standard for a particular peak hour to implement its decision, that standard would logically apply to both new and existing roads. If it is considered acceptable for new roads to operate below adopted standards for, say, 29 hours in the design year, it should be acceptable for existing roads to operate below adopted standards for 29 hours in the current year, but no more than 29 hours.

If jurisdictions cannot afford to maintain existing roads at the standard for new roads, the solution is not to establish a lower standard of existing roads but rather to re-evaluate the standard for new roads. Standards for new roads are based on theoretical considerations and professional dictates, but funding availability should be a factor, too. Indeed, it might be argued that the appropriate standard for new roads is that which is sustainable for existing roads, given funding availability.
New and existing roads differ in one fundamental respect -- traffic volumes are known for existing roads and only estimated for new roads. This difference has been used to argue for higher standards in roadway design than concurrency management, where roadways are designed for a "margin of error" in traffic forecasts. If the result of underestimating future traffic volumes (congestion) is more serious than the result of overestimating them (wasted capacity), it may be advantageous to make liberal assumptions in traffic forecasts. However, there is no reason for the choice of peak hour to reflect uncertainty in traffic forecasts, not when the forecasts themselves can be adjusted to reflect uncertainty.

The 30th Highest Hour

Use of the 30th highest hourly volume in roadway design dates back to the 1950 Highway Capacity Manual. Traffic studies of that era had observed extreme variations in traffic flow on facilities from hour to hour, day to day, and season to season. When hourly traffic volumes for an entire year were graphed in order of descending magnitude, the resulting curves often dropped sharply at first and leveled off quickly (as in Figure 22). The 30th highest hourly volume was found to fall on the "knee" of the curves, where the slope changed dramatically.52

Based on this early work, it has become conventional wisdom that:

- The 30th highest hourly volume is the point of

![Figure 22](Image)

diminishing returns in roadway design.

- It is uneconomical to design for volumes to the left of the 30th highest hour, since a great deal of capacity is required to meet demands that occur only a few times a year.

- It is shortsighted to design for volumes to the right of the 30th highest hour, since little additional capacity is required to accommodate demands that occur frequently.

The conventional wisdom may be wrong in this case. Traffic in many localities does not follow the pattern in Figure 22. Curves tend to flatten out rather than remain static as areas become more developed; the knee of the curve becomes a moving target. Even if the hourly volume curve has a predictable turning point, that point has no economic significance; the optimum design of a facility can only be determined by comparing the costs of alternative designs with the benefits to motorists.53

Plots of hourly traffic volumes for 20 representative FDOT permanent count stations in FY 1989 illustrate the arbitrariness of the 30th highest hour (see Appendix). Several of the curves never level off and/or have no point at which the slope changes dramatically. Even where there is a discernable "knee," it does not correspond to the 30th highest hour with any degree of consistency. The choice of design hour is ultimately a political rather than a technical decision. It involves balancing the public's desire to hold down road user taxes (which means more traffic congestion) against their desire to avoid traffic congestion (which means higher user taxes).

Consensus Choice?

If not the 30th highest hour, what peak hour should be used for level-of-service determinations? As previously noted, FDOT is proposing a shift to the 100th highest hour. Meanwhile, DCA is accepting and in some cases even requiring the use of the average peak hour of days in the peak season.

Are the two agencies at odds? In FDOT's unpublished draft revision of the Level of Service Manual, it is stated several times that the 100th highest hour of the year is "approximately equivalent to the typical peak hour of a day during the peak season." Studies in Collier County also suggest the two are equivalent. If true, FDOT and DCA are converging on a common peak hour.

To check for equivalency, we again analyzed hourly traffic counts for FY 1989 from the 20 FDOT permanent count stations. Figure 23 shows the 30th, 100th, and 200th highest hourly counts at each station, plus the average count for peak hours of days during the peak season (the peak season being the three highest-volume consecutive months). At all but two
Figure 23
Traffic Counts at Different Design Hours

<table>
<thead>
<tr>
<th>STATION</th>
<th>50TH HIGHEST HOUR</th>
<th>100TH HIGHEST HOUR</th>
<th>200TH HIGHEST HOUR</th>
<th>PEAK HOUR/PEAK SEASON</th>
<th>PEAK HOUR/PEAK SEASON/DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AVERAGE COUNT</td>
<td>EQUIVALENT DESIGN HOUR</td>
<td>AVERAGE COUNT</td>
<td>EQUIVALENT DESIGN HOUR</td>
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<td>1641</td>
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<td>2217</td>
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<td>1978</td>
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<td>3350</td>
<td>3123</td>
<td>2957</td>
<td>3056</td>
<td>130th</td>
</tr>
</tbody>
</table>

* Season average is lower than the 200th highest hourly count.

Source: FDOT hourly traffic counts for F.Y. 1988-89.
stations, the average count for peak hours during the peak season is less than the 100th highest hourly count. At 10 of 20 stations, it is even less than the 200th highest hourly count. The 10 stations are mostly in urban areas with stable commuting patterns and little seasonal peaking. At these stations, a single day (typically a Friday) may contribute several of the top 200 hourly traffic counts.

Clearly, the 100th highest hour is not equivalent to the average peak hour of days during the peak season. However, it may be roughly equivalent to the average peak hour of weekdays during the peak season in urban areas and weekends in recreational areas and other places with weekend peaking. Figure 23 shows average peak hour counts on weekdays or weekends (depending on when local peaking occurs) during the peak season at the 20 stations. The average count is less than the 100th highest hourly count at some stations, more at others, and probably about the same on average.

If it is necessary to settle on one peak hour for roads statewide, as FDOT has declared, the 100th highest hour may be the best choice. The 100th highest hour reflects daily, weekly, and seasonal peaking of traffic; this is apparent from the rough equivalence of the 100th highest hour and the average peak hour of peak days during the peak season.

The 100th highest hourly volume would be easy to estimate, assuming this rough equivalence is borne out. A locality could take a 24-hour count on a typical weekday or weekend (again, depending on when local peaking occurs) during the peak season and use the highest hourly count for that 24-hour period as its estimate of the 100th highest hourly volume. This approach would improve on the practice in many localities of applying a generalized K-factor to a single 24-hour traffic count.

Additionally, the 100th highest hourly volume would be relatively easy to project. Widely used regional travel models forecast traffic volumes for the average weekday during the peak season. To obtain estimates of the 100th highest hourly volume, it would only be necessary to apply a peak-to-daily ratio to model outputs. At present, modelers must first convert model outputs to annual average daily traffic volumes, and then apply a generalized K-factor to the result.

The Peak Period

Daily peaks tend to spread out as urban areas grow and traffic congestion causes motorists to adjust their travel hours. Indeed, the largest cities do not have a “peak hour” per se but rather a two- to three-hour period in the morning and afternoon when commuting is heaviest. Roads become capacity-constrained and K-factors come to be determined by supply rather than demand.\(^4\) We can expect even more spreading of the peak as traffic congestion worsens and communities seek to better manage transportation demands.
With DCA’s approval, Dade County and the City of Miami based levels of service in their LCPs on average traffic volumes for the two highest consecutive hours of the average weekday. While analysis of a two-hour peak period flies in the face of time-honored design convention (which utilizes a "design hour"), the convention may prove too limiting.

It will not be the spreading of the peak that, in time, justifies a shift from peak hour to peak period analysis. This spreading is already reflected in traffic counts and should be in the K-factors used in traffic projections. Rather, it will be the adoption of policies that encourage commuters to adjust their travel hours.

Let us say a locality adopts a trip reduction ordinance requiring all employers to institute flex-time. Employees would then have the option of commuting at less congested hours. Such a measure might justify the averaging of traffic volumes over flexible starting and ending hours. As when routing and modal choices are made available, a case could be made that with flex-time in place, government no longer has responsibility for accommodating every trip maker’s choice of travel hour.
VI. CONCLUSION

One observer has likened concurrency to "the engine of a car, the vehicle of growth management by comprehensive planning." Carrying the analogy one or two steps further, he states:

"The level of service (LOS) determination is analogous to the carburetor which feeds fuel to the engine. As with any carburetor, it must be capable of working well enough to start the engine and operate it at an efficient level....the LOS of the carburetor should not operate to choke the motor by setting LOS unrealistically high."

This observer and many others seem to assume that level-of-service standards determine whether the vehicle of growth management will operate efficiently. In fact, however, the methods used to determine roadway levels of service affect conclusions about road adequacy as much as do the standards themselves. Carrying the vehicle analogy to its logical extreme, installing a new carburetor may affect the performance of the engine as much as adjusting the fuel-air mixture on the old carburetor. The "new carburetor" in this analogy is a new method of level-of-service determination.

Our analyses suggest that the specific technique used to analyze roadway level-of-service -- whether HCS, ART-PLAN, ART-TAB, or travel time studies -- can make at least a two-letter grade difference in the outcome. Likewise, the choice of analysis period or peak hour -- whether 30th highest hour, 100th highest hour, average peak hour of the peak season, or highest two consecutive hours on the average weekday -- can make a difference of two or more letter-grades. While harder to quantify, the effect of averaging/aggregating levels of service across facilities or modes could be of comparable magnitude.

Thus, even adopting the same level-of-service standards, level-of-service determinations for, say, Miami and Jefferson County have entirely different implications for motorists. Jefferson County has opted for FDOT's "by the book" approach, comparing the 30th highest hourly traffic volumes on individual roads to the maximum volumes at different levels of service from FDOT's generalized maximum volume tables. In contrast, Miami has adopted an innovative but unconventional approach with DCA's approval, comparing person-trip volumes for the two highest hours on the average weekday to the practical capacities of multimodal transportation corridors.

To some extent, the different approaches reflect the different circumstances of the jurisdictions and therefore should be viewed in a positive light. Yet, there is a nagging concern that Florida's Growth Management Act may be undermined by lack of consistency
and comparability across the state. It is hoped that this report will provide some guidance to state and local officials searching for meaningful approaches to roadway level-of-service determination.

4 Ibid.
5 FDOT, Florida's Level of Service Standards and Guidelines Manual for Planning (1991 draft revision), Appendix D.
6 FDOT, Guidelines for the Review of Developments of Regional Impact, pp. 4 and 15-17.
7 Ibid., p. 17.
9 The ART-ALL program provides an estimate of roadway level of service for a given traffic volume and other input values. To generate maximum volumes tables using ART-ALL, it is necessary to employ an iterative procedure. ART-ALL runs are done with escalating traffic volumes to identify break points in level of service.
11 FDOT, Florida's Level of Service Standards and Guidelines Manual for Planning (1991 draft revision), Section 3.2.
13 These results were reported by Rick Hall of the Transportation Consulting Group, Tallahassee office.
The source of this information is Mark Woerner of the Dade County Planning Department.

John J. Moore and Antoine I. Khoury, "Level of Service Analysis: Urban and Suburban Arterials," Communication to the ITE Growth Management Subcommittee, Florida ITE.

Data were supplied by Glatting Lopez Kercher Anglin, Inc., an Orlando-based planning firm.

For each arterial, turning movement counts and travel time runs were done during the same peak hours on the same weekdays. Thus, by design, actual travel speeds (derived from travel time runs) and estimated travel speeds (dependent on turning movement counts) relate to the same time periods.

In a series of HCS intersection analyses, liberal assumptions were made about:

- the saturation flow rates at intersections on these arterials (1,850 vehicles per hour after adjustments),
- the amount of green time devoted to arterial-through movements (the maximum possible, given the timing plans of these semi-actuated traffic signals),
- arrival types of vehicle platoons (the best possible progression, given signal spacing and signal timing offsets), and
- the peak-hour factor (a value of 1.0 was assumed, as if flow rates were absolutely constant during the peak hour).

A peak hour factor of 1.0 was assumed to achieve a measure of consistency between HCS estimates and travel time runs. If actual peak-hour factors had been used instead, HCS estimates would have applied to the peak 15-minute period of the peak hour, while the travel time results were averaged over the entire peak hour.

While not yet accepted by FDOT, ART-PLAN and ART-TAB represent the latest generation of such programs and thus are more fittingly evaluated than are their predecessors, ART-ALL and LOS.

Data were supplied by John Zeeger of Barton-Aschman Associates, Inc., Fort Lauderdale.

Average travel speeds and peak hour volumes for Broward Boulevard were gathered on comparable weekdays of the same month. Portions of the cycle devoted to the through movements on Broward Boulevard (so-called green ratios) were observed at
the same time traffic counts were taken. They were subsequently confirmed from signal timing plans. Thus, while green ratios for Broward Boulevard appear very low, there is no reason to doubt the validity of the values supplied by the consulting firm.

22 The section of Broward Boulevard analyzed is between N.W. 18th Avenue and State Road 7. HCS runs could not be done for Broward Boulevard because information about cross-street traffic and signal timing is not available.

23 From travel time runs, the stopped delay at intersections and the total running time between intersections are known. From HCS runs, estimates of stopped delay, total intersection approach delay, and running time between intersections are available. Stopped delay from travel time runs can be compared directly to estimates from HCS runs. However, to compare total running time and hence running speed between intersections, an HCS estimate of running time must be inflated by the difference between total approach delay and stopped delay at the downstream intersection. This adjustment captures the extra running time associated with deceleration of vehicles approaching the downstream intersection.

24 This is not to sanction the practice of speeding but to acknowledge that it occurs. The problem lies with the level-of-service measure chosen for arterials in the 1985 HCM. Many alternative measures were considered during the update of the HCM. Perhaps a measure such as average delay would have been more suitable than average travel speed.

25 Delay associated with acceleration is incorporated into running time estimates for segments of less than one mile (see Table 11-4 in the 1985 HCM). Delay associated with deceleration is incorporated into intersection approach delay estimates.

26 From Table 11-4 of the 1985 HCM, the running time for a one-mile segment at a 45 mph free flow speed is 80 seconds. Properly extrapolated, the running time for a 1.08 mile segment (the segment in question) should be 86.4 seconds. HCS instead computes a running time of 110.2 seconds in the northbound direction, 106.9 seconds in the southbound direction. Extrapolation of running times seems to be a problem for HCS only at free flow speeds of 45 mph.

27 Recall that our estimates of average running speed incorporate intersection approach delays, which are set equal to 30% of stopped delays in HCS and ART-PLAN runs.

28 Not only were all of these parameters averaged in the ART-TAB runs, but free flow speeds were effectively averaged for Kirkman Road by interpolating between maximum volume tables representing different free flow speeds. Kirkman Road has one segment with 45 and 50 mph speed limits, while the other three segments have speed limits of 40 mph. ART-TAB will only recognize free flow speeds of 45, 40, or 35 mph for Class I arterials, and thus only by interpolation of maximum volumes was it possible to duplicate an average free flow speed of 43.5 mph.
29 A planner with the City of Miami wants to outfit the city's fleet of vehicles with transmitters that supply continuously updated travel speed data.


31 The speed-volume relationship is known to become nonlinear as road capacity is approached. Apparently, Seminole County roads operate in a flow range that is adequately approximated by a linear equation.

32 FDOT, Florida's Level of Service Standards and Guidelines Manual for Planning. p. 3.3 - 5.


34 FDOT defines backlogged roads as roads operating below level-of-service standards and not programmed for improvement in the first three years of FDOT's adopted work program or in the capital improvement element of any local government.

35 We would first divide vehicle-miles traveled (VMT) by average travel speed (ATS) for each road in an area to obtain vehicle-hours traveled (VHT) on each road; then, sum the result over all roads to arrive at total VHT; finally, divide total VHT into total VMT to arrive at average travel speed for all vehicles on all roads. Using mathematical symbols, the calculation is:

\[ VHT_i = \frac{VMT_i}{ATS_i} \text{ for each road } i \]

\[ VHT_t = \sum VHT_i, \text{ where } VHT \text{ is summed over all roads} \]

\[ ATS_t = \frac{VMT_t}{VHT_t} \]

36 DCA calls them "TCMAs" (transportation concurrency management areas). They are called "traffic performance districts" in Orlando, "traffic districts" in Lee County, and just "districts" in Tampa.
Of the criteria used to delineate traffic performance districts in the Orlando LCP, at least three appear aimed at keeping trips internal to districts:

- Major activity centers are contained within single districts.
- District boundaries generally follow geographic features, limited access facilities, or lightly traveled streets but generally do not follow arterial or collector roads.
- Districts generally are aligned along major commuting or traffic circulation patterns.

The goals specified in the draft rule are: discouraging the proliferation of urban sprawl, encouraging the revitalization of existing downtowns and designated redevelopment areas, protecting natural resources, and promoting mass transit. Examples of suitable areas cited in the draft rule are: community redevelopment areas, areas covered by approved downtown developments of regional impact, regional activity centers designated in a comprehensive regional policy plan, areas designated in a comprehensive regional policy plan as appropriate for increased development of regional impact thresholds, and central business districts.

Two policies of the State Comprehensive Plan particularly speak to the issue of system efficiency --

- Coordinate transportation investments in major travel corridors to enhance system efficiency and minimize adverse environmental impacts.
- Ensure that the transportation system provides Florida's citizens and visitors with timely and efficient access to services, jobs, markets, and attractions.

The draft rule states that a TCMA shall "not be larger than the area within which a development...that pays a development exaction could be reasonably assumed to receive a reasonable benefit from an improvement funded by the exaction if the improvement were constructed anywhere within the area."


City of Miami Planning Department, Transportation Corridors: Meeting the Challenge of Growth Management in Miami (1989), p. 5.

46 Maximum 15-minute peak directional volumes are divided by the peak-hour factor (PHF) to obtain peak-hour directional volumes; peak-hour directional volumes are divided by the directional factor (D) to obtain total peak-hour volumes; and finally, total peak-hour volumes are divided by the design hour factor (K30) to obtain daily volumes. Thus, all tables are based ultimately on peak-hour conditions and are internally consistent.

47 FDOT, Florida's Level of Service Standards and Guidelines Manual for Planning, p. 3.5-4.

48 The fact that everyone is required to use K30 (or K100) in level-of-service determinations does not mean that one K-factor fits all. K30 (or K100) varies from locale to locale, and even from roadway to roadway within a locale. Generally, the K-factor declines as a place becomes more urbanized; traffic congestion causes some spreading of the peak period.

The revised manual recommends the following K100s for arterials in different areas:

<table>
<thead>
<tr>
<th>Area</th>
<th>K100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td></td>
</tr>
<tr>
<td>Undeveloped</td>
<td>0.100</td>
</tr>
<tr>
<td>Developed</td>
<td>0.095</td>
</tr>
<tr>
<td>Urban</td>
<td></td>
</tr>
<tr>
<td>5,000-49,999 population</td>
<td>0.093</td>
</tr>
<tr>
<td>50,000-499,999</td>
<td>0.092</td>
</tr>
<tr>
<td>500,000 or more</td>
<td>0.090</td>
</tr>
</tbody>
</table>


50 Ibid.

51 FDOT's Level of Service Manual (current version) and FDOT's Roadway Plans Preparation Manual, Volume 1 (Roadway Design Criteria and Process) both use the 30th highest hour for their respective purposes, concurrency management and roadway design.


54 FDOT makes the distinction between "supply" and "demand" K-factors. From FDOT's analysis, the decline in K-factors with rising traffic volumes is entirely due to supply-side constraints. FDOT, Proposed Revisions to FDOT Traffic Data Processes (February 16, 1991 draft), pp. 5 and 23.

55 Since 1983, FDOT has been using a formula that relates the K-factor to AADT on a given state road.

Appendix
Urban route

St. Petersburg. SR 699. Station 66
Urban route
Tallahassee. US 27. Station 151
Small City route
Melbourne–Cocoa. SR 520. Station 113

Percent of AADT vs. Highest Hours of the Year
Small City route
Palatka, US 17, Station 105

Highest Hours of the Year

Percent of AADT

7 8 9 10 11 12 13 14 15 16
Rural route
Desoto County, US 17, Station 145

Percent of AADT

Highest Hours of the Year
Rural route

Escambia County, US 29, Station 159

Highest Hours of the Year

Percent of ADT
Rural route
Marion County. US 301. Station 118
Recreational route
Key West. US 1. Station 165

Percent of AADT

Highest Hours of the Year
Recreational route
Palm Beach, SR A-1-A, Station 87

Percent of AADT

Highest Hours of the Year