Evaluating Suitability of Roadways for Bicycle Use: Toward a Cycling Level-of-Service Standard

BRUCE EPPERSON

Since 1965, traffic engineers and planners have used a measurement known as level of service (LOS) to describe the operating conditions within a traffic stream and their perception by motorists, passengers, or both. Although the most recent edition of the publication that defines these standards, the *Highway Capacity Manual*, does contain a short section on bicycles, it is more concerned with the effects of bicycles on traffic flows within intersections than with the ability of various types of roads and traffic conditions to provide quality of service to cyclists. In the last several years, some researchers and planners interested in bicycling issues have made attempts to develop an index of roadway operational conditions important to bicycle users. Although there have been several different approaches to the problem, recent work has centered on a method based on five descriptive factors: per-lane traffic volume, speed of traffic, right-hand-lane width (including the width of bicycle lanes or road shoulders), overall pavement quality, and the generation of conflicting travel paths. Taken together, these efforts have come close to developing a practical and meaningful roadway LOS standard for bicycle use. Work remains to be done in several areas: the relationship between LOS values and the perception of various cyclists as to the quality of service provided by a roadway, the role of level of service in cyclist route selection, and the applicability of the methodology to bicyclists with different skills and use needs.

Since 1965, traffic engineers and planners have used a measurement known as level of service (LOS) to describe how well a roadway is operating. The LOS concept is an outgrowth of highway capacity analysis, and the publication defining these standards is still called the *Highway Capacity Manual* (*1*). Originally, researchers had hoped to create a mathematical formula to determine the capacity of roads to carry traffic loads. It quickly became apparent, however, that the ultimate capacity of a road was far less important than the quality of service it provided at various volumes of traffic. Therefore, level of service evolved from a measure of absolute traffic-carrying capacity into

> a qualitative measure describing operational conditions within a traffic stream, and their perception by motorists and/or passengers. A level-of-service definition generally describes these conditions in terms of such factors as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience, and safety. (*1*)

Level of service is broken down into six categories, denoted by the letters A through F. An LOS A road is free flowing with light traffic, whereas an LOS F road is totally jammed. Level of service is calculated using several variables, including type of road (freeway, arterial, collector); roadway geometrics and physical conditions (number of lanes, lane widths, severity of grades); traffic conditions (number of heavy vehicles, direction and distribution of traffic, weather conditions); and control conditions (frequency of driveways and intersections, traffic signal timing, special turn lanes). In fact, level of service is now such a complex measurement that computers are usually used to calculate it on a regional or citywide basis.

LOS standards have more recently been developed for transit and pedestrians. The transit LOS standards are based on the number of persons per seat in a bus or rail car, and the pedestrian standard is determined by the square feet per pedestrian on sidewalks and in elevators. Both are essentially measures of crowding, which affects comfort and, in the case of pedestrians, also affects the speed of forward travel.

The *Highway Capacity Manual* has a short section on bicycles, but it is more concerned with the effects of bicycles on traffic flows at intersections than with the ability of various types of roads to provide quality of service to bicycle users. There is no attempt to formulate an LOS standard for bicycles or to suggest what roadway or traffic conditions contribute to the safety, comfort, or convenience of cyclists.

DEVELOPMENT OF BICYCLING LEVEL OF SERVICE: A HISTORY

Davis Bicycle Safety Index Rating

The first systematic attempt to develop some sort of measurement of the operational condition of roadways for cycling was made in 1987 by Davis at Auburn University. He sought to "develop a mathematical model for indexing bicycle safety to physical roadway features and other pertinent factors" (*2*). His bicycle safety index rating divided roadways into segments with similar roadway and traffic conditions. Each segment was evaluated using a roadway segment index (RSI). Major intersections along the road were also evaluated using a separate intersection index.

Roadway Segment Index

The RSI was calculated using the following function:

$$RSI = [ADT/(L * 2500)] + (S/56) + [(4.25 - W) * 1.635] + \Sigma PF + \Sigma LF$$

Miami Urbanized Area Metropolitan Planning Organization, Office of the County Manager, 111 N.W. First Street, Suite 910, Miami, Fla. 33128.

where

ADT = average daily traffic,
L = number of traffic lanes,
S = speed limit (km/hr),
W = width of outside traffic lane (m),
ΣPF = sum of pavement factors, and
ΣLF = sum of location factors.

Pavement Factor Values Pavement factors are a series of points assessed for poor pavement surfaces and surface conditions that present a hazard to cyclists, such as rough railroad crossings, drainage grates, or potholes. Pavement factor values used in the RSI are as follows:

Factor	Value
Cracking	0.50
Patching	0.25
Weathering	0.25
Potholes	0.75
Rough road edge	0.75
Curb and gutter	0.25
Rough railroad crossing	0.50
Drainage grates	0.75

Location Factor Values Location factors are a series of points assessed against road segments that contain conditions that contribute to the generation of cross traffic, limit sight distance, or restrict the operation of bicycles. Location factor values used in the RSI are as follows:

Factor	Value
Angled parking	0.75
Parallel parking	0.50
Right-turn lanes	0.25
Raised median	−0.25
Center turn lane	−0.25
Paved shoulder	−0.75
Grades, severe	0.50
Grades, moderate	0.25
Curves, frequent	0.25
Restricted sight distance	0.50
Numerous drives	0.50
Industrial land use	0.50
Commercial land use	0.25

A lower RSI score indicates a better road for bicycling. To say that location factors are ''assessed against'' road segments is somewhat inaccurate because, unlike pavement factors, location factors are both positive and negative. Negative location factors indicate a feature that improves the quality of the roadway for cyclists, such as raised medians (which restrict left-turning cross traffic) and paved shoulders.

Intersection Evaluation Index

Davis also evaluated each major (i.e., signalized) intersection along a route using a function he called the intersection evaluation index (IEI), which was calculated using the following formula:

$$IEI = [(VC + VR)/10{,}000] + [(VR * 2)/(VC + VR)] + \Sigma GF + \Sigma SF$$

where

VC = cross street volume (ADT),
VR = traffic volume on route being indexed,
ΣGF = sum of geometric factors, and
ΣSF = sum of signalization factors.

Geometric Factor Values Geometric factor values used in the IEI are as follows:

Factor	Value
No left-turn lane	0.50
Dual left-turn lane	0.50
Right-turn lane	0.75
Two through lanes	0.25
Three or more through lanes	0.50
Substandard curb radii	0.25
Restricted sight distance	0.50

Signalization Factor Values Signalization factor values used in the IEI are as follows:

Factor	Value
Traffic-actuated signal	0.50
Substandard clearance interval	0.75
Permissive left-turn arrow	0.25
Right-turn arrow	0.50

As with the RSI, a lower IEI score is better. The geometric and signalization factors are analogous to the pavement factors and location factors in the RCI. There are no negative GF or SF terms.

Davis combined the RSI and IEI figures to achieve a final product, the bicycle safety index rating (BSIR). The BSIR is calculated using a weighted average of the means of the RCIs and the IEIs along the route under examination. For example, if Oak Street has three roadway segments with RCIs of 5.4, 4.8, and 6.1 and two signalized intersections with IEI scores of 6.8 and 4.6, the average of the three RCIs is 5.4 and the average of the two IEIs is 5.7. The BSIR would then be 27.6 ≈ 5 = 5.5.

This would place Oak Street in the middle of the ''fair'' category. A score of 0 to 4 would indicate an excellent rating; 4 to 5, good; 5 to 6, fair; and 6 and over, poor. The classification criteria used by Davis are given in Table 1.

The Oak Street example can also be used to point out some of the shortcomings in the Davis system. If Oak Street had only one signalized intersection but an IEI rating of 6.5, the BSIR rating for the entire street would climb to 5.7. This result conflicts with some studies of pedestrian accidents, which suggest that the number of conflicting travel paths (points where the permitted travel paths, pedestrians, and cars cross) is as important as the volume of vehicles or pedestrians traveling along those paths (*3*). If this is the case for bicycles, then an appropriate safety rating would include not only the average danger ratings of intersections, but also the frequency with which signalized intersections occur.

An analogous argument can be made for the RSI. Returning to the Oak Street example, assume that the street is divided into three segments with RSI scores of 5.4, 4.8, and 6.1. The BSIR weights these three segments equally, even though they may entail a much larger or smaller share of the road's total length. If, for instance, the roadway segment rated 6.1 made up most of Oak Street's length, the final BSIR rating of 5.5 is too low. The opposite would be true if the middle segment (RSI = 4.8) made up the bulk of Oak Street's length.

TABLE 1 Rating Classifications for Davis Bicycle Safety Index Rating

Index Range	Classification	Description
0 to 4	Excellent	Denotes a roadway extremely favorable for safe bicycle operation.
4 to 5	Good	Refers to roadway conditions still conducive to safe bicycle operation, but not quite as unrestricted as in the excellent case.
5 to 6	Fair	Pertains to roadway conditions of marginal desirability for safe bicycle operation.
6 or above	Poor	Indicates roadway conditions of questionable desirability for bicycle operation.

Another problem with the Davis model is the use of location factors and pavement factors in the RSI evaluation. Davis claimed to have structured the RSI so that "the coefficients were configured to give slightly more significance to the objective variables such as volume, speed limit, and lane width" (*2*). However, on the seven Chattanooga roads that Davis evaluated as a test of his method, the combined LF and PF values accounted for an average of 30 percent of the total evaluation score, with some road sections receiving as much as 53 percent of their total score in LF and PF values. This tended to dilute the focus of the evaluation model on the three critical factors of roadway speed, per-lane volume, and lane width. A similar problem exists with the use of geometric factors and signalization factors in the IEI.

In addition to these technical considerations, the Davis BSIR suffered from an inability to meet its stated goal: the prediction of major bicycling accidents. Davis did not attempt to calibrate his model by comparing the safety rating of roadways with their rate of bicycling accidents. An attempt to account for the location of bicycle and motor vehicle accidents in one Florida city using a variation of the Davis BSIR revealed that it explained less than 20 percent of the variation in accidents between different road segments (*4*).

These problems, however, should not detract from an appreciation of what was a significant conceptual leap. For the first time, Davis identified the three critical factors that affect the comfort, convenience, and perception of safety common to virtually all bicycle users: per-lane traffic volume, traffic speed, and lane width. He then used a quantitative method to distill these factors into a single rating. Although the Davis BISR may have left something to be desired as an accident prediction tool, it came very close to being a workable tool for describing a cyclist's perception of "the operational conditions within a traffic stream," and thus can lay claim to being the progenitor of a true LOS rating for bicycles.

Florida Roadway Condition Index

Since the mid-1980s, the state of Florida has maintained a system of county and local bicycle coordinators partially funded through, and guided by, a state bicycle coordinator's office within the Florida Department of Transportation (FDOT). In the late 1980s the coordinator's office circulated copies of the Davis monograph to its local counterparts. In 1991, the bicycle programs in Broward County and the city of Hollywood coordinated a joint application of two variants of the Davis index. (Hollywood is located in Broward County, which also includes Fort Lauderdale.)

The two projects were contrasts in terms of their scope. Broward County, with a population of over 1.2 million and a land area of almost 5,200 km^2, presented a much different problem than Hollywood, with its 125,000 population and 65 km^2. The roadway system in Broward County contained over 750 segments, many of which were over 2 km long. Hollywood, on the other hand, had fewer than 120 segments, only one of which was over 1 km long (*5*).

Both jurisdictions used similar variations of the Davis RSI, which eliminated both the IEI and the averaging of individual road segments into an overall roadway rating. Each road segment was identified by the cross streets that bounded it and retained an individual score. The final product for each segment was termed the roadway condition index (RCI), primarily to indicate that its goal was not to predict accident locations.

Also, the LF and PF values were modified so that they played a smaller part in the determination of segment scores. For the most part, this was successful, because the combined LF and PF values averaged 9 percent of total RCI scores in Hollywood and 11 percent in Broward County.

In addition to these changes, Hollywood alone modified the Davis RSI to place greater weight on segments where narrow lane widths and high vehicle speeds occurred simultaneously. This was done by multiplying the lane width term by the speed limit term, in effect doubly penalizing road segments that combined narrowness with high speeds. The denominator in the speed limit term was also decreased from 56 to 48, augmenting the effect. To compensate for the inherent tendency of the modified formula to inflate the final index, the denominator in the ADT factor was raised from 2500 to 3100, the upper limit of LOS C for two-lane collector roads in Florida. The so-called Epperson-Davis modification resulted in this formula:

$$RCI = [ADT/(L * 3100)] + (S/48) + \{(S/48) * [(4.25 - W) * 1.635]\} + \Sigma PF + \Sigma LF$$

The pavement factors and location factors used in the Epperson-Davis variation are given in Table 2. Broward County continued to use the less modified Davis RSI. As was explained earlier, the

TABLE 2 Epperson-Davis RCI as Applied in Hollywood, Florida

RCI = (ADT/(L*3100)) + (S/48) + (S/48*((4.25-W)*1.635)) + PF + LF

ADT	= Average Daily Traffic	W	= Width of Outside Lane (meters)
L	= Number of Travel Lanes	PF	= Pavement Factor
S	= Speed Limit (KPH)	LF	= Location Factor

Pavement Factor Values	
1. Cracking	.50
2. Patching	.25
3. Weathering	.25
4. Potholes	.25 to .50, depending on severity
5. Rough road edge	.25 to .50, depending on severity
6. Railroad Crossing	.25
7. Rough or Angled RR Crossing	.50
8. Drainage Grates	.50
Location Factor Values	
1. Cross-Movement Generation	
a. Angle Parking	.75
b. Parallel Parking	.25
c. Right-turn lane (full length)	.25
d. Raised median (solid)	-.50
e. Raised median (left turn bays)	-.35
f. Center Turn Lane (scramble lane)	-.20
g. Paved shoulder or bike lane	.75
2. Alignment	
a. Severe grades	.50
b. Moderate grades	.20
c. Horizontal curves, frequent	.35
d. Restricted sight distance	.50
3. Environment	
a. Numerous drives	.25
b. If Commercial, ADD	.25
or	
c. If industrial, ADD	.25

Evaluation Totals			
0-3	Excellent	4-5	Fair
3-4	Good	5+	Poor

city of Hollywood is contained within Broward County. Because of this, the road sections within the city were indexed independently by both jurisdictions, presenting an opportunity to compare the final results of the two derivations. In general, the differences were not large. Some examples of these differences are presented in Table 3. Overall, the Epperson-Davis version, as would be expected, was more sensitive to differences in lane width and speed and less sensitive to changes in ADT.

In general, the less altered Broward County version seems better suited to situations in which a large survey scope or limited resources make it difficult to get exact lane width measurements. In smaller areas with more frequent changes in the characteristics of road segments, the Epperson-Davis variant appears to more accurately capture the combined effects of small changes in two or more variables simultaneously.

As mentioned earlier, the Epperson-Davis RCI was tested for its ability to predict bicycle and motor vehicle accidents. For a 20-month period during 1990 and 1991, the location of all such accidents in Hollywood was plotted by road segment. Each accident was assigned a weight of 1 to 5 depending on the severity of injury to the cyclist (5 indicated a fatality). These scores were totaled for each segment and converted to a per-mile basis to compensate for different length segments. The accident score for each segment was then compared with its RCI rating using linear regression analysis. The analysis indicated that the RCI rating explained only 18 percent of the variation in accident scores between different road segments.

There are several explanations for this effect, the most likely being that different road segments had markedly different levels of bicycle use, with the pattern of accidents heavily influenced by the bicycle use patterns. A road segment with several accidents could be explained either as a very dangerous stretch of road or one that had a very high level of bicycle use. This suggests that the successful prediction of bicycle accidents must include bicycle traffic counts and an analysis of land use patterns as well as an evaluation of roadway characteristics.

TABLE 3 Comparison of Roadway Segments in Hollywood, Florida, Using Davis RSI (Broward) and Epperson-Davis RCI (Hollywood)

	No. Lns.	ADT	Speed Limit	Rt. Ln. Width	Holly-Wood	Broward County	Percent Difference
Taft Street (Collector)							
72 Ave to 64 Ave.	4	19900	56	3.7	4.44	4.66	5
64 Ave. to S.R. 7	4	27300	56	3.4	5.37	5.90	10
S.R. 7 to 56 Ave.	2	11400	56	3.4	5.26	5.95	13
56 Ave. to Park Rd.	2	8800	48	3.4	4.42	5.26	19
Park Rd. to I-95	2	12000	48	3.7	4.44	4.90	10
I-95 to 26 Ave.	2	13000	48	3.4	5.10	5.90	16
26 Ave. to 21 Ave.	2	7500	48	3.4	4.21	4.50	7
21 Ave. to US 1	2	6000	48	3.4	4.47	4.45	0
Pembroke (Major Arterial)							
66 Ave. to SR 7	4	30000	65	3.7	6.09	6.58	8
SR 7 to 56 Ave.	4	29900	65	3.7	5.58	6.07	9
56 Ave. to Park Rd.	4	35000	72	3.7	5.82	6.25	7
Park Rd. to I-95	4	42100	72	3.4	7.40	7.13	4
I-95 to 26 Ave.	4	31200	56	3.4	5.93	6.54	10
26 Ave. to 21 Ave.	4	31200	56	3.4	5.93	6.79	15

A second problem in accident prediction is the heterogeneous nature of bicycle users, resulting in distinct clusters of cyclist types, each experiencing widely different accident types. Children, occasional adult cyclists, and experienced recreational bicyclists have radically different operational characteristics, and as a result, the accidents experienced by each group result from very different causal circumstances (*6*). A safety evaluation methodology that yields good results for experienced, adult cyclists would probably be less accurate in predicting the location of accidents occurring to young children.

Dade County Bicycle Facilities Plan

In the summer of 1993, the Metropolitan Planning Organization of Dade County, Florida (which includes the Miami-Hialeah Urban Area), undertook a more ambitious application of the RCI. Whereas Broward County and the city of Hollywood used the RCI as a way of establishing existing cycling conditions in anticipation of future bicycle plans, Dade County's goal was the establishment of a true multimodal evaluation of the county's transportation network. Given Florida's growth management regulatory structure, such a methodology may prove critical to the future development of the area.

In 1985, Florida adopted the Local Government Comprehensive Planning and Land Development Regulation Act, which required local and regional plans to conform to the goals and objectives of both state and regional comprehensive plans. The state plan was based on the concept of guaranteeing the availability of public facilities and services needed to handle new growth and development. In short, if municipalities are at or approaching their maximum capacity in certain forms of infrastructure—including roads—they lose the ability to grant developers permission to build.

In the early years of the act, FDOT defined this mandate as requiring counties and municipalities to maintain LOS D or better on all arterials and on certain collectors designated by the state. Failure to meet this mandate usually led to development restrictions along the affected roadway links. However, realizing that this would eventually lead to a situation where most development would be driven to the urban fringe, Dade County proposed a two-tier system in which roadways inside a designated Urban Infill Area (UIA) would be allowed to degrade beyond the threshold between LOS D and E. The system, known as the Concurrency Management System, was accepted by the state in 1989 (*7*).

In 1992, the county wrote an updated comprehensive plan element that proposed a similar graduated scale but one that not only included location within the county (in or out of the UIA), but also incorporated the level of transit service available along a corridor. Transit service was broken down into two categories: standard, defined as line-haul service on headways of 20 min or less in peak periods, and extraordinary, defined as having very short peak period headways, express service, or rapid rail availability. A breakdown of these standards is presented in Table 4.

A primary goal of the 1993 Dade County Bicycle Facilities Plan was to incorporate the measurement of a roadway segment's suitability for bicycle travel into its overall capacity evaluation in a manner analogous to that for transit service. Thus, a roadway segment with good transit service and a high suitability for cycling would be defined as providing adequate transportation capacity, even if its vehicular level of service was below existing standards.

A modified version of the Epperson-Davis RCI function was used. Several of the changes were influenced by the work being done for a bicycle facilities plan for Hillsborough County, Florida, by Sprinkle Consulting Engineers of Tampa (see paper by Landis in this Record). The new function was of the form

$$RCI = [ADT/(L * 3100)] * (S/48) * (4.25/W) * [(1 + HV)]1.8 * [1 + (0.03 * PF) + (0.02 * LF)]$$

where the terms are as previously defined.

TABLE 4 Existing Long-Term LOS Standards for Dade County, Florida

Location	No Transit service	20 minute headway transit service within .8 km	Extraordinary transit service (rapid rail or express bus) within .8 km.
Outside UIA	LOS D	100% LOS E	120% LOS E
Inside UIA	100% LOS E	120% LOS E	150% LOS E

The pavement factors (weight 0.03) are as follows:

Factor	*Value*
Excellent pavement surface	0
Good pavement surface	1
Fair pavement surface	2
Poor pavement surface	3

The location factors (weight 0.02) are as follows:

Factor	*Value*
Little cross-traffic generation	1
Moderate cross-traffic generation	2
Heavy cross-traffic generation	3

The evaluation totals are as follows: 0 to 3, excellent; 3 to 4, good; 4 to 5, fair; 5+, poor.

Although the form of the equation appears much different from those used earlier by the city of Hollywood and Broward County, it functions in a similar manner and yields equivalent results in most circumstances. In general, there were three primary changes:

1. The pavement factors and location factors were each simplified to a single 0-to-3 scale, with each factor point assigned a weight of 0.02 or 0.03. The sum of the location factor and the pavement factor would then be multiplied by the remainder of the RCI term. For example, a roadway segment with a PF rated 2 and an LF rated 1 would score $(2 * 0.03) + (1 * 0.02) = 0.08$. If the remainder of the RCI function was 3.75, the final score for the link would be $3.75 * 1.08 = 4.09$. This change was made to prevent the location and pavement factors from weighing more heavily, in proportional terms, for roadway segments that had better characteristics of traffic speed, volume, and right-lane width.
2. The extra roadway width created through the placement of bicycle lanes or road shoulders was incorporated into the roadway width term instead of being included as a separate pavement factor value. As the role of pavement factors and location factors continued to be reduced, it became necessary to find an alternative method of incorporating these facilities in a manner that was more flexible and that accurately reflected the importance of these width-enhancing measures. To allow for this procedural change, the right-lane width term was modified so that it could consider widths greater than 4.25 m. In older versions, right-lane widths greater than 4.25 yielded nonsensical (i.e., negative) results. In the new version, an unlimited right-lane width input is possible, but combined lane and shoulder widths greater than 4.25 m yield proportionately less benefit. This accurately captures the effect of very wide lane-shoulder combinations offering a decreased advantage to cyclists because of the collection of road dirt and debris as one moves progressively away from the travel lanes.
3. Whereas previous versions of the index added the per-lane traffic volume, speed, and lane width terms together to achieve a final result, the new variant multiplied them. This increased the interaction of the three terms that was introduced in the Davis-Epperson version. Multiplicative terms also allowed the use of an exponential scalar: in this case, 1.8. The scalar was used to accentuate changes to the index at the top and bottom of its range, in effect "bending" the function line at values below 3 and above 5. This was done to improve the fit of the index on low-volume roads while not significantly affecting the evaluation of roads closer to the urban core. Although the method did inflate the index on roads rated above 5 or 6, this was of little concern since these roads were identified as being deficient in either case.

A roadway link rated 4.0 or lower was determined to provide an adequate level of service for less experienced cyclists or children and will be used in the future to evaluate roadways on the neighborhood level, to facilitate school accessibility planning, and to evaluate the potential for nonmotorized access to transit. A rating of 5.0 or lower was judged to provide an adequate level of service for more experienced cyclists and for travel on an intracounty scale, the scope of the present study. On the basis of this evaluation, the modifications outlined in Table 5 have been proposed to the Concurrency Management System to include bicycle accessibility considerations in the county's growth management strategy.

ISSUES FOR FURTHER CONSIDERATION

Is LOS Measurement for Bicycles Meaningful?

Given the great disparity of evaluation methodologies used in the relatively short history of the bicycling LOS procedure to date, one must ask: is there really such a thing as a meaningful level of service for bicycles?

One important difference between the level of service for motor vehicles and that for bicycles is the fact that the bicycling level of service is determined by exogenous variables such as roadway and traffic characteristics (particularly motor vehicle speed and volume), whereas the motor vehicle level of service is largely determined by the volume of the vehicles themselves. It would be hard to find a roadway in this country so heavily used by bicycles that the volume of bicycle traffic significantly affected the operation of other bicycles. However, recalling the full definition of level of service as given in the introduction to this paper, it becomes more apparent that level of service is a concept with specific meaning to bicycle operators. Most cyclists are able to identify—at least in a general way—which streets they consider "better" or "worse." In recent literature on bicycle planning, much has been made of a supposedly deep and irreconcilable

TABLE 5 Proposed Long-Term LOS Standards for Dade County, Florida

Outside Urban Infill Area			
Bicycle LOS	No Transit service	20 minute headway transit service within .8 km	Extraordinary transit service (rapid rail or express bus) within .8km.
Inadequate	LOS D	100% LOS E	120% LOS E
Adequate	100% LOS E	110% LOS E	130% LOS E
Inside Urban Infill Area			
Bicycle LOS	No Transit service	20 minute headway transit service within 1/2 mile	Extraordinary transit service (rapid rail or express bus) within 1/2 mi.
Inadequate	100% LOS E	120% LOS E	150% LOS E
Adequate	110% LOS E	135% LOS E	170% LOS E

schism in bicycle planning between casual and experienced cyclists (*8*). However, even a cursory survey of both groups reveals an agreement on the basic characteristics of a desirable riding environment: wider pavement surfaces to allow easy passing by overtaking motor vehicles, lower traffic volumes, and slower motor vehicle speeds. The so-called schism is not a debate about the virtue of these factors, but is instead a different propensity for various types of cyclists to trade off a pleasant riding environment for the higher average speeds, directness, and right-of-way preference accorded to roads with a high functional classification (*9*).

Much of the evolution in cycling-related evaluative methods has been the result of a refinement in thinking about what these methodologies are and what they are expected to do. Starting as a tool to predict accident exposure, the BSIR/RCI gained increased interest when it was used as a way of aggregating important roadway characteristics into a single, easily understood index number, and it has evolved into a method of replicating cyclists' own evaluative behavior in selecting travel path alternatives. As some researchers have noted (see the paper by Landis in this Record), this type of application functions much like the trip assignment module of a typical regional travel demand model. This could ultimately prove to be the most valuable application of an LOS-style method, with the development of an integrated travel demand model for bicycle use proving to be the breakthrough that ushers in a new era of nonmotorized transport planning. It is conceivable that such a model could be incorporated into the transportation forecasting models now used to plan roadway and transit networks, facilitating a true multimodal transport development framework.

What Further Work Is Required?

To facilitate such an application, work that more accurately relates the LOS standards to empirical data and the perception of cyclists will be required. One method of gathering these data would be to isolate a destination center that attracts a significant number of cyclists, such as a school, university, or employment center. Cyclists arriving at this location would be asked to identify the origin of their trip and the route that they chose to use, as well as the reason that led them to select this route over other alternatives. This method would allow the collection of both subjective and objective information. The subjective information would be revealed by the cyclists' responses to interview questions about the reasons behind their route choice. Objective data would be provided by measuring, either in time or distance, the deviation from the shortest or fastest route selected by a given cyclist. This method would thus have the advantage of allowing a pattern of subjective judgments to be somewhat quantified.

For example, with the destination interview, it would be possible to say that occasional cyclists are willing to make their trip X percent longer to gain a Y percent improvement in average trip level of service. Although this would be extremely useful knowledge for the planning of cycling route networks, it does go beyond the traditional use of the LOS methodology. For motor vehicles, level of service is assumed to affect route choice only in cases where the level of service on the preferred route is very low: E or F. On the other hand, bicyclists are exposed to impositions on their comfort and convenience to a much greater extent than are motor vehicle operators, who are primarily affected by trip length and time.

Another method would be to use a video camera to record conditions along several different road sections. These sequences could then be shown to groups of cyclists, who would be asked to evaluate them on, for example, a scale of 1 to 10. This method is being used to aid in the development of the next generation of motor vehicle LOS standards and would be an inexpensive method of comparing proposed standards with the perceptions of large groups. However, although such a method would be useful for comparing an overall roadway index for a road segment with the perceptions of cyclists, it would be harder (when compared with the destination interview) to use it as a quantification of the index itself.

CONCLUSION

As a result of the intervention of cycling activists and the adoption of recent legislation mandating a multimodal transportation approach, bicycling has gained new acceptance by mainstream transportation engineers and planners. However, these professionals are now demanding the development of the same type of quantitative tools that have long been the staple of traditional transportation planning. It is necessary that those involved with the development of alternative modes become familiar with these tools and work to adapt them to the needs of both cyclists and pedestrians.

Knowing bicycling is no longer enough. Just as cycling advocates have long been demanding that transport professionals broaden their vision, it is now time that bicycle advocates and planners become more catholic in their knowledge and learn the procedures and methods of transport analysis and use this new knowledge to develop the tools being demanded by the transport profession. The alternative to refusing to do so may prove to be either the removal of bicycle planning responsibilities from those with a particular interest in the field and a transferral to others with less understanding or sympathy for the area, or a continued neglect by municipal and state agencies of alternative modes planning.

REFERENCES

1. *Special Report 209: Highway Capacity Manual.* TRB, National Research Council, Washington, D.C., 1985.
2. Davis, J. *Bicycle Safety Evaluation.* Auburn University, City of Chattanooga, and Chattanooga-Hamilton County Regional Planning Commission, Chattanooga, Tenn., 1987.
3. Davis, S., H. Robertson, and L.King. *Pedestrian/Vehicle Conflicts: An Accident Prediction Model.* Transportation Publication Report 6. University of North Carolina at Charlotte, 1989.
4. Epperson, B. *Demographic and Economic Characteristics of Cyclists Involved in Bicycle/Motor Vehicle Accidents in the City of Hollywood, Florida: A Preliminary Research Report.* City of Hollywood Department of Growth Management, Hollywood, Fla., 1991.
5. *Bicycle Facilities Plan for Broward County.* Broward County Office of Planning, Fort Lauderdale, Fla., 1992.
6. Cross, K. D. *Bicycle Safety Education: Facts and Issues.* American Automobile Association, Falls Church, Va., 1978.
7. *Comprehensive Development Master Plan for Dade County.* Dade County (Florida) Office of Planning, 1989.
8. Forester, J. *Bicycle Transportation.* MIT Press, Cambridge, Mass., 1983.
9. Wilkinson, W., A. Clarke, B. Epperson, and R. Knoblauch. *The Effect of Bicycle Accommodations on Bicycle/Motor Vehicle Safety and Traffic Operations.* FHWA, U.S. Department of Transportation, 1992.

Publication of this paper sponsored by Committee on Bicycling and Bicycle Facilities.