unit average cost supply functions (Ontario may be one of the few Canadian sources for this information).

3. Although direct relations between the knee of the curve and the K-factor and cost-effective V/C ratios can be shown, the relation between economic level of service (supply) and DHV (demand) is still obscure and requires further research.

ACKNOWLEDGMENT

The observations and views presented in this paper are strictly our own. The design criteria presented are not formal Alberta Transportation policy.

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Freeway Level of Service: A Revised Approach

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Concepts, philosophies, and standards for freeway level of service presented in the 1965 Highway Capacity Manual are reviewed. A revised approach is developed that incorporates density in the definition of standards. Speed-flow relations under ideal conditions are approximated based on secondary source data and a limited number of pilot field surveys associated with current work. The recommendations made for new level-of-service standards for freeways are based on recalibrated speed-flow relations and incorporate density as a parameter.

The basis for any technique of capacity analysis is the definition of quality-of-service criteria and the correlation of these criteria with operational and design parameters. The 1950 Highway Capacity Manual (1) defined service in terms of "possible" and "practical" capacity. Practical capacity represented the maximum traffic volume that could be accommodated (under prevailing roadway and traffic conditions) while an acceptable quality of service was provided.

The 1965 Highway Capacity Manual (HCM) (2) introduced the concept of level of service, which allows for a more detailed treatment of service quality. The 1965 HCM defines level of service as "a qualitative measure of the effect of a number of factors, which include speed and travel time, traffic interruptions, freedom to maneuver, safety, driving comfort and operating cost" on operations. It also defines six levels of service—A through F—which describe a wide range of conditions, from totally free at level A to forced flow at level F.

CURRENT STANDARDS FOR LEVEL OF SERVICE

Current standards for freeway level of service are given in Table 9.1 of the 1965 HCM (2, pp. 252-253). Each level is a range of operating conditions for which the table defines boundary conditions in terms of two parameters: (a) volume-to-capacity (V/C) ratio, which may be stated as a volume, and (b) operating speed. Table 9.1 gives minimum values of operating speed and maximum V/C values for each level of service. The standards in the table apply under "ideal" conditions, which include (a) no trucks or buses in the traffic stream, (b) 3.6-m (12-ft) minimum lane widths, and (c) no obstructions in the median or roadside area closer than 1.8 m (6 ft) to the pavement edge. The standards for the V/C ratio depend on average highway speed, which is a weighted average design speed for the highway segment under study.

For a highway segment to be said to operate under a particular level of service, the criteria for both V/C ratio and operating speed must be met. This is an important point. The standards in Table 9.1 of the 1965 HCM do not, nor were they intended to, represent a correlation between speed and V/C ratio. The existence of a V/C ratio appropriate for level of service C does not guarantee that the operating speed for that level will also be met. This characteristic of the standards leads to a number of problems in their use.

QUESTIONS, ISSUES, AND ALTERNATIVES

In formulating recommendations for level-of-service standards, a number of critical philosophic and practical issues must be raised. The resulting recommendations should meet two primary objectives:

1. Levels of service must be defined in terms that are meaningful for the driver who experiences them and meaningful to the planners, analysts, and designers who will use the standard.
2. Definitions of level of service must be consistent with each other and consistent in application to the various types of subsections that occur on a freeway (i.e., open sections, weaving areas, and ramp terminals).

A number of key issues concerning the concept of level of service are treated here in the context of these general objectives along with practical questions about the state of the art and the availability of data.

Continued Use of the Level-of-Service Concept

The first major question is, Should the use of the basic concept of levels of service as quality descriptors be continued?

Essentially, there are only two alternatives to the concept of level of service: (a) a structure of capacity of the type found in the 1950 HCM (1) followed by design levels that represent "adequate" service quality or (b) a treatment of speed-volume relations as continuous functions. The first alternative is clearly a step backward and is really a level-of-service concept itself, modified by having only three levels. Such a structure might indeed be adequate in design [the American Association of State Highway and Transportation Officials (AASHTO) already specifies level of service as part of its design criteria] but would severely limit the use of procedures in analysis, where greater detail is needed.

The second alternative suggests a radical change and requires extensive calibration of generalized speed-volume curves. Although considerable speed-flow data are available, base conditions—e.g., percentage of trucks, number of lanes, and design speed—vary widely, which makes calibration of a full generalized speed-flow curve or curves difficult. In any event, where design is considered, standard or threshold levels would have to be established.

The two alternatives outlined are really extremes of a similar concept. The essential issue is how many threshold levels will be identified. In the 1950 HCM, the answer was three: possible, practical-rural, and practical-urban capacity. For the second alternative, the answer was infinite: a continuous relationship. Levels of service as they now stand define five boundary conditions in specific terms and a sixth to describe the entire range of unstable or forced flow.

An even more exotic alternative does exist. One might attempt to index level of service to various microscopic physiological parameters concerning driver experience and behavior. Studies have been made that relate such parameters as steering wheel reversals, heart rates, and blood pressure to traffic conditions. Such measures, however, although interesting, are not highly useful to designers, planners, and analysts who must deal in standard parameters of traffic flow and highway design. The state of the art in this area does not permit consistent correlation between standard flow measures and physiological factors.

Another approach would be to tie level of service to overall door-to-door trip convenience. This would permit multimodal evaluations but, again, the state of the art is insufficient to allow serious consideration of this option.

There are no compelling reasons to reduce or increase the number of levels defined. In the weaving procedure developed as part of project 3-15 of the National Cooperative Highway Research Program (NCHRP) (3), the researchers did divide level of service D into two sublevels called D1 and D2. This was done because an observed breadth of conditions occurred in level D. There is no evidence, however, to suggest that level D should be split for all freeway cases and, indeed, the observed breadth observed may have been an accident of calibration.

On the other hand, there are a number of compelling arguments for retaining the level-of-service concept in its current form:

1. The concept is now a familiar one that can be readily used and understood by professionals and many technicians in the field;
2. Many associated government standards, such as AASHTO design standards and recent government standards on traffic noise, are formulated in terms of level of service; and
3. Most of the extant material on freeway capacity analysis developed since the 1965 HCM was drafted is also based on level of service.

The level-of-service concept is a viable mechanism for describing service quality for freeways that is strongly established in the profession. Although the ultimate fate of level of service as a concept must await the results of other research in other areas of capacity, we endorse its use in the context of this work.

Table 9.1: Defined Standards or a Relationship

The V/C and speed specifications for freeway levels of service found in Table 9.1 in the 1965 HCM (2, pp. 252-253) are separately defined. Volumes and speeds in that table are not intended to be, nor are they in fact, correlated.

Chapter 5 of the 1965 HCM contains typical speed-flow curves from an early study by the U.S. Bureau of Public Roads. Our Table 1 compares volumes from Table 9.1 of the 1965 HCM and those depicted by the speed-flow curves shown in Figure 3.38 in that volume (2, p. 62).

Similar comparisons may be drawn for average highway speeds of 97 and 80 km/h (60 and 50 mph). Note that for levels A and B the standards given in Table 9.1 of the HCM agree closely with values taken from the speed-flow curves. At level C, volumes given in Table 9.1 appear to be higher than those from the curves. Level C volumes from Figure 3.38 do, however, agree closely with values in Table 9.1 for peak-hour factor (PHF) ≅ 0.95 (interpolating). Since the base conditions for Figure 3.38 include a "high PHF, approximating 1.00", a value of 0.95 is probably close to what the data represented.

The major discrepancy between Table 9.1 and Figure 3.38 occurs consistently at level of service D. At this level (for all values of average highway speed), volumes in Table 9.1 are considerably lower than those indicated by the speed-flow curves—lower by as much as 520

Table 1. Comparison of HCM volume levels for various operating speeds.

		Volume[a]					
		Four Lanes		Six Lanes		Eight Lanes	
Level of Service	Operating Speed (km/h)	Table 9.1	Figure 3.38	Table 9.1	Figure 3.38	Table 9.1	Figure 3.38
A	96	1400	1390	2400	2340	3400	3440
B	88	2000	2080	3500	3510	5000	5000
C	80	3000	2790	4800	4500	6600	6280
D	64	3600	3860	5400	5790	7200	7720
E	48	4000	4000	6000	6000	8000	8000
F	-	-	-	-	-	-	-

Notes: 1 km = 0.62 mile.
Average highway speed = 112 km/h.
[a]Peak-hour factor = 1.00.

vehicles/h (see Table 1). Note further that Figure 3.38 does not represent ideal conditions: The speed-flow curves include trucks and, in some instances, restrictive lane widths or lateral clearance or both. Thus, if they were corrected for ideal conditions (which is not possible from the data available), the volumes shown in Figure 3.38 of the HCM would be even higher, disrupting the apparent agreement at levels A-C and accentuating the discrepancy at level D.

More recent data seem to indicate that volumes for any given speed are even higher than those indicated by the HCM speed-flow curves. A study of the Southern State Parkway (4), for example, indicates the following volumes for the six-lane freeway (1 km = 0.62 mile):

Speed (km/h)	Volume (automobiles/h)	Speed (km/h)	Volume (automobiles/h)
48	6000	88	5500
64	5850	96	4950
80	5650		

These volumes are all considerably higher than those in Table 9.1 and Figure 3.38 of the HCM, strikingly so at the higher speed levels normally associated with levels A-C. The volume at 96 km/h (60 mph), for example, more than doubles those of either HCM source. The design speed of the Southern State Parkway is, moreover, 96 km/h, and the study was made well after the 88-km/h (55-mph) speed limit was in effect. In all other features, the Southern State Parkway is ideal: no trucks and good lane width and lateral clearance. The flows cited reflect a PHF of 1.00 but are based on 15-min intervals.

It appears that standards given in Table 9.1 in the HCM show volume levels that are below those that will actually occur at the operating speeds indicated, perhaps seriously so. The corollary to this is that, for the volumes shown in Table 9.1, operating speeds will be higher in practice than those shown.

Remember that Table 9.1 was not intended to reflect a speed-flow relation. The issue is clear: Should it reflect a relationship, or should both speed and V/C standards be defined?

The arguments for adopting a relationship base for Table 9.1 are strong:

1. In use, Table 9.1 often demands the assumption that speed and V/C are correlated. Designers select a level of service and design for it by using only V/C. They must presume that the indicated speeds will result. Many analyses are done without field measurements of speed, and level of service is determined, again, by V/C alone. In use, V/C is clearly the primary measure; most often the operating speed is assumed to follow.

2. If volumes in Table 9.1 are consistently lower than those that regularly occur in the field for the speeds shown, the implication is that V/C alone will determine level of service because the operating speed limits would never be the controlling factor. The two-parameter standard becomes a fiction since only one is ever effective. The fact that V/C is really the effective standard in Table 9.1 is, however, consistent with the use of the table, in which V/C is often the only value used.

3. The use of freeway capacity procedures in analysis is considerably hampered and restricted if the speeds and volumes in Table 9.1 do not correlate. No analysis could be properly done without data on operating speed, and such data are difficult to measure in the field and are far less available than volume data, which are more routinely collected.

We strongly believe that Table 9.1 should represent correlated values of V/C and speed and that such a relationship should be calibrated to the extent possible.

Speed Criteria

The 1965 HCM defines speed criteria for freeways in terms of operating speed, which is defined as "the maximum safe speed for given traffic conditions that an individual vehicle can travel at if the driver so desires, without exceeding the design speed at any point" (2, p. 246). Two alternatives to operating speed may be considered: (a) average running speed (space mean speed) and (b) percentile speeds (e.g., 85th percentile speed).

Operating speed is a difficult parameter to work with, particularly when speed-flow relations are to be calibrated. It is, most properly, a parameter measured by using runs by a test automobile (by the "maximum car technique") and is not a statistic that can be isolated from sample measurements of the traffic stream. When test-run measurements do not exist, operating speed can only be roughly estimated. Even when test-run results are available, they may vary considerably depending on the driver. Rarely are sufficient test runs made to statistically dampen this factor.

Average running speed is a statistical parameter that may be computed from sample observations of the traffic stream. Its relation to operating speed varies, but it is generally from 4.8 to 8 km/h (3 to 5 mph) lower at high levels of service and almost equal at capacity. Average running speed is more universally understood than operating speed, which is subject to frequent misinterpretation and is the standard used by AASHTO. Use of a stream statistic enables sample data to be used in calibrating relationships. It is also interesting to note that, in the basic traffic-flow relation,

$$\text{Volume (vehicles/h)} = \text{density (vehicles/km)} \times \text{speed (km/h)} \quad (1)$$

space mean speed (a statistical term for average running speed) is the parameter that must be used.

The use of an average running speed does present one philosophic problem. Table 9.1 in the HCM depicts speeds for ideal conditions—in particular, no trucks. Through the use of truck equivalencies and truck factors, service volumes for prevailing conditions are computed for various levels of service. Suppose, for example, that level of service C has a service volume of 2500 automobiles/h under ideal conditions for a given highway and a corresponding average running speed of 80 km/h (50 mph) (threshold values). It is further determined, by using truck factors, that a service volume of 2000 vehicles/h yields the same level of service. Is the corresponding speed still 80 km/h?

If the calibration of truck factors were based on finding volume levels that produce equivalent speeds, the answer would be yes. But none of the available methods for computing truck factors do this. As a result, the answer is no: The speed would probably be lower because of the percentage of trucks, which generally travel slower than automobiles. Thus, there is, at least on a philosophic level, a question as to the real meaning of the speed values in a recalibrated table in which average speed is used.

The 85th percentile speed is an intriguing alternative.

It is a statistic that can be isolated from stream data and, as a higher percentile (a positional value), may be expected to be relatively stable throughout the normal range of truck percentages. Operating speed also possesses this characteristic and would not vary widely with the presence of trucks at equivalent volumes.

All things being equal, we would recommend the use of the 85th percentile speed as a standard because it is (a) a stream data statistic, and (b) relatively insensitive to the presence of trucks at equivalent volumes.

Unfortunately, most extant data for calibrating speed-flow relations do not allow the 85th percentile speed to be isolated. To find the 85th percentile speed, individual vehicle speed would have to be recovered, or a computation of the standard deviation would have to be available. Because of this, it is recommended that average running speed be used as a criterion despite its sensitivity to the presence of trucks. The degree of sensitivity is not really known and might potentially be smaller than the normal spread of speed-flow data. Three overriding concerns dictate this choice (two of them have already been discussed):

1. A traffic stream statistic should be used to define levels of service to allow extant data to be used.
2. Average running speed is the proper statistic to use in speed-flow-density relations.
3. The NCHRP project 3-15 procedure for weaving areas on freeways also used average running speed.

The third point is important in terms of the consistency of procedures developed for freeways in current work.

Peak-Hour Factor

Table 9.1 incorporates the use of PHF at levels C and D. The meaning of the use of PHF in the HCM is not clear to many users and is confusing in that levels of service are defined for a peak 5-min period but are applied over a full hour during which flow may vary considerably.

Essentially, the HCM use of PHF allows that design and analysis at levels C and D are based on the peak 5-min rate of flow during the hour of interest (usually the peak). PHF is not used at other levels for two reasons:

1. At levels of service A and B, peaking within the hour will merely reduce the service provided for short periods and not cause any congestion or traffic backup.
2. At level of service E (capacity), PHF is 1.00 by definition.

The second point might be disputed. A PHF of 1.00 is never observed in the field whereas values of 0.95-0.97 are. Further, volumes of 2000 automobiles/h/lane have been observed at such PHFs. It is also true that a facility may reach capacity for a period of time less than 1 h, and according to the HCM this is not clearly identified.

The interpretation of Table 9.1 in the HCM for levels C and D is also unclear. Are the speeds given also for the peak 5-min period or for the whole hour? If the former, how can the hour as a whole be described? If the latter, then the same speed is associated with widely variant flow levels and distributions.

The difficulty is that few hours experience uniform operating conditions, even the peak hour. Operating conditions may vary by several levels within an hour. Consider the following situation: 2800 automobiles/h, a four-lane freeway, ideal conditions, and PHF = 0.77. According to Table 9.1, this is in level of service D for the full hour. Actually, during the peak 5 min, a flow rate of 3600 automobiles/h is experienced (level D). For the rest of the hour, the average flow rate is given by

$$[2800 - (3600/12)]/(11/12) = 2727 \text{ automobiles/h} \qquad (2)$$

Taken as an average, this is in level C. Obviously, this volume too will vary from period to period, but the point is clear: What Table 9.1 in the HCM labels as level of service D for an hour may be level C or better for a good portion of that hour. Perhaps Table 9.1 should not be geared to describing a full hour of operation but rather some shorter, reasonably stable period of time.

Were Table 9.1 to be based on peak flow rates (they do not actually have to be peak but simply uniform flow rates), the consideration of PHF could be greatly simplified. It would not appear as a factor in the table at all, and users would be instructed to enter the table with the volumes adjusted to peak flow rates by means of the following:

$$\text{Peak flow rate} = \text{volume/PHF} \qquad (3)$$

This implies that PHF will be considered at all levels of service. At levels A and E, this is of little importance. At level E, it will permit proper accounting for situations in which capacity is experienced for a portion of an hour and better levels exist during other portions of the hour. At level A, short periods of free flow may be identified even if other portions of the hour operate at poorer levels.

Level of service B, however, is used as a design standard for rural highways. Currently, level B does not consider a peak flow. However, once both the criteria for the standard and its use are adjusted to include a peak flow rate, the effect on design would not be significant because of this factor. It should be noted that many, if not all, designs based on a recalibrated Table 9.1 would be affected to some degree simply because of the calibration of new numeric limits at each level.

It is recommended that the recalibrated Table 9.1 in the HCM be based on peak flow rates and that, before the table is entered, the PHF expansion be applied directly to demand volumes.

RECOMMENDATIONS

As a result of these and other considerations, it is recommended that the development of recalibrated level-of-service standards for freeways be based on the following:

1. Table 9.1 should be representative of speed-flow relations and should be calibrated by using the best available data.
2. Average running speed should be used to establish speed criteria for the various levels of service.
3. Table 9.1 should be recalibrated by using a base of peak flow rates.
4. The effect of the 88-km/h (55-mph) speed limit must be accounted for in recalibrating Table 9.1, but there is no compelling reason to avoid showing speeds equal to or higher than 88 km/h in the standards.

The last point follows from the use of speed-flow correlations as the basis for the calibration of standards. If such calibrations showed speeds higher than 88 km/h, they would have to be accepted.

RECALIBRATION OF LEVEL-OF-SERVICE STANDARDS

To recalibrate level-of-service standards based on speed-flow relations, it is necessary to acquire a data base that consists of measured speeds and volumes under controlled conditions. Such data are sparse in the literature, particularly with regard to "controlled conditions". To calibrate speed-flow relations properly, underlying conditions must at least be known if not uniform. These underlying conditions include (a) the presence of trucks, (b) lane widths and lateral clearance, (c) the period of time over which flows are measured, and (d) average highway speed.

Where matched speed-flow data do exist in the literature, these underlying conditions are generally not specified; where they are specified, they vary considerably from study to study. Useful data were obtained from a relatively small number of sources:

1. The 1965 Highway Capacity Manual—The HCM shows typical speed-flow curves for a variety of freeway types, including stratifications by four-, six-, and eight-lane freeways; average highway speeds of 112, 96, and 80 km/h (70, 60, and 50 mph); the effect of speed limits; and the use of either operating or average running speed as a parameter.
2. Consultant studies—Data from the Southern State

Figure 1. Results of field survey.

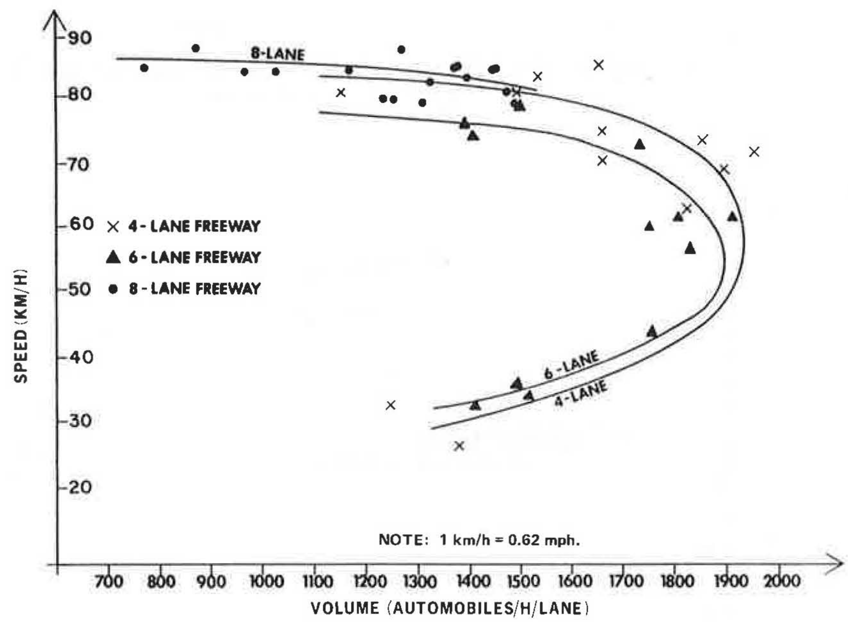


Figure 2. Speed-flow data for eight-lane freeways at 112 km/h.

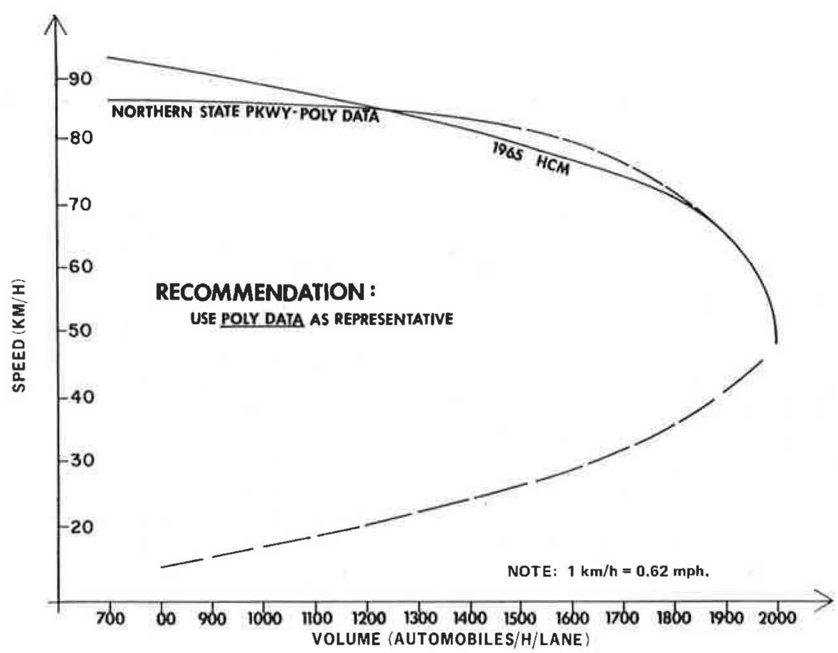


Figure 3. Speed-flow data for six-lane freeways at 112 km/h.

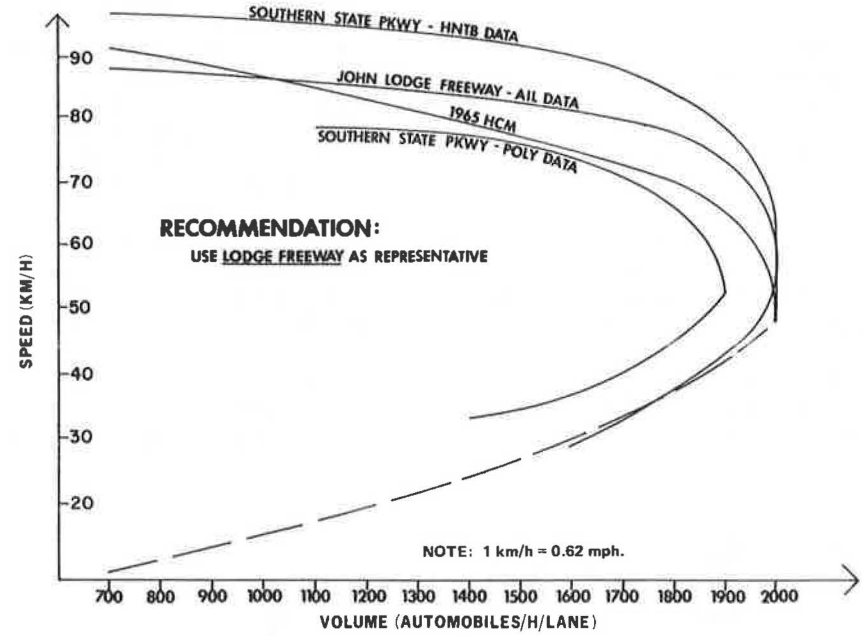
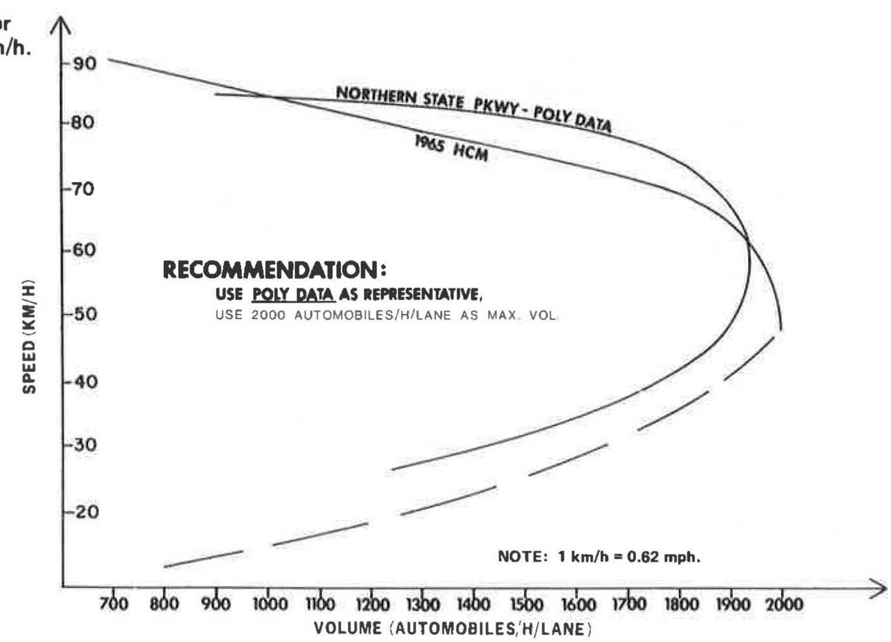


Figure 4. Speed-flow data for four-lane freeways at 112 km/h.



Parkway in New York (4) and the Lunalillo Freeway in Hawaii have proved to be most useful. A study of traffic flow models conducted by Airborne Instruments Laboratory (5) contains useful speed-flow data from the John C. Lodge Freeway in Detroit.

It had originally been thought that the several operational surveillance systems in the United States would be excellent sources of speed-flow data. Actually, few such systems even measure speed but rather use occupancy as a principal parameter. Where speed is observed, it is usually not at the same point for which volumes are available. Further, retrieval of surveillance system data in useful form is in itself a major effort that entails considerable expense.

Because of the small number of extant data sets that can be used in the establishment of general speed-flow curves, three field surveys were done on parkways in the New York area. These facilities come closest to providing truly ideal conditions—i.e., no trucks or buses, 3.6-m (12-ft) lane widths, and adequate lateral clearances. The results of these field surveys are shown in Figure 1. One survey each was conducted on a four-lane, a six-lane, and an eight-lane section of freeway.

Figures 2 through 6 show all available data and speed-flow relations stratified by type of freeway. In formulating recommendations for representative "general" curves, the HCM data were given the least weight because of their age.

Figures 2 through 6 illustrate a number of interesting points:

1. There are not enough data to suggest whether or not

Figure 5. Speed-flow data for 96-km/h freeways.

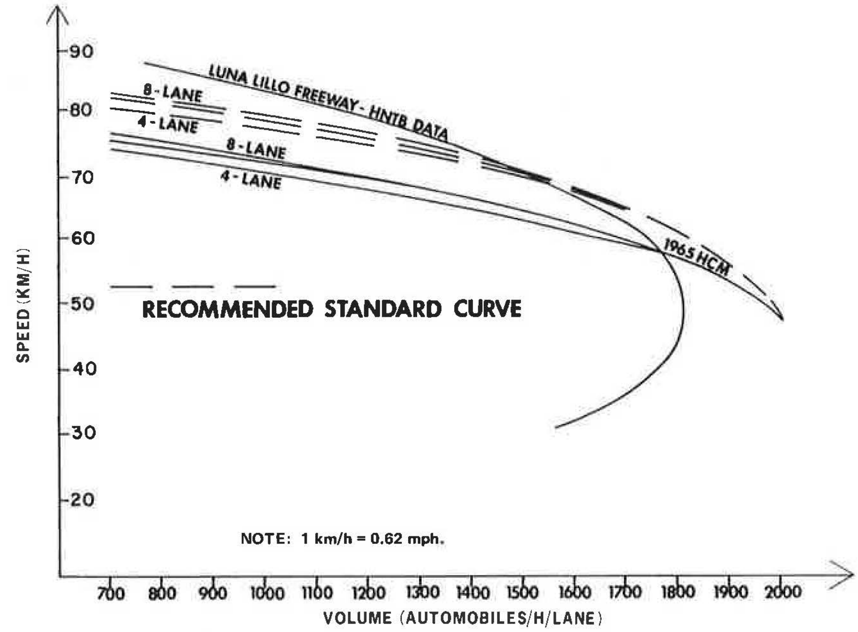
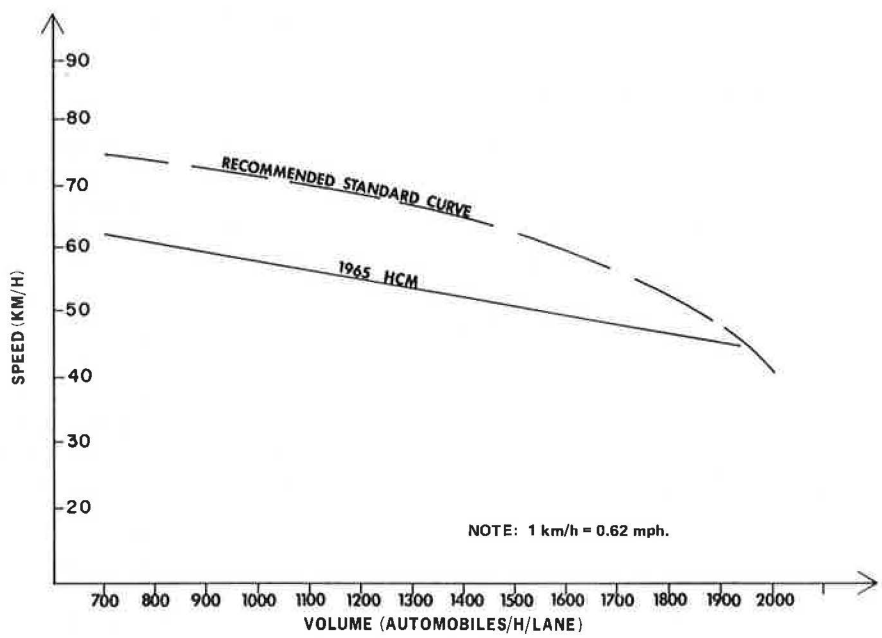


Figure 6. Speed-flow data for 80-km/h freeways.



2000 automobiles/h/lane is an appropriate value for maximum capacity under ideal conditions. Although none of our field studies reached that level, other sources did. Thus, there is no reason to either increase or decrease the 2000-automobiles/h/lane maximum at this time.

2. All of the more recent data show a wide range of volumes for which speed is relatively constant. This is not indicated in the HCM curves and will have to be dealt with in terms of level-of-service standards.

3. As a corollary to item 2 above, all of the more recent studies show a rapid deterioration of speed over a small range of volumes as the level of 2000 automobiles/h/lane is approached. This, too, has drastic consequences in the definition and interpretation of level-of-service standards.

On each of the curves, a general recommendation is made concerning the shape of a standard speed-flow curve. In Figure 6, the recommended curve for an average highway speed of 80 km/h (50 mph) is merely an extrapolation of the trends observed in other figures since there were no data available for this case.

Figure 7 shows the recommended standard curves for use in developing level-of-service standards. Because of the paucity of data, these curves are not adequately calibrated in the statistical sense but are "eyeball fits to the available data". But we believe that they are far more representative of current traffic characteristics than the curves that appear in the 1965 HCM.

Level-of-Service Standards Defined by Speeds

The most straightforward approach to defining levels of

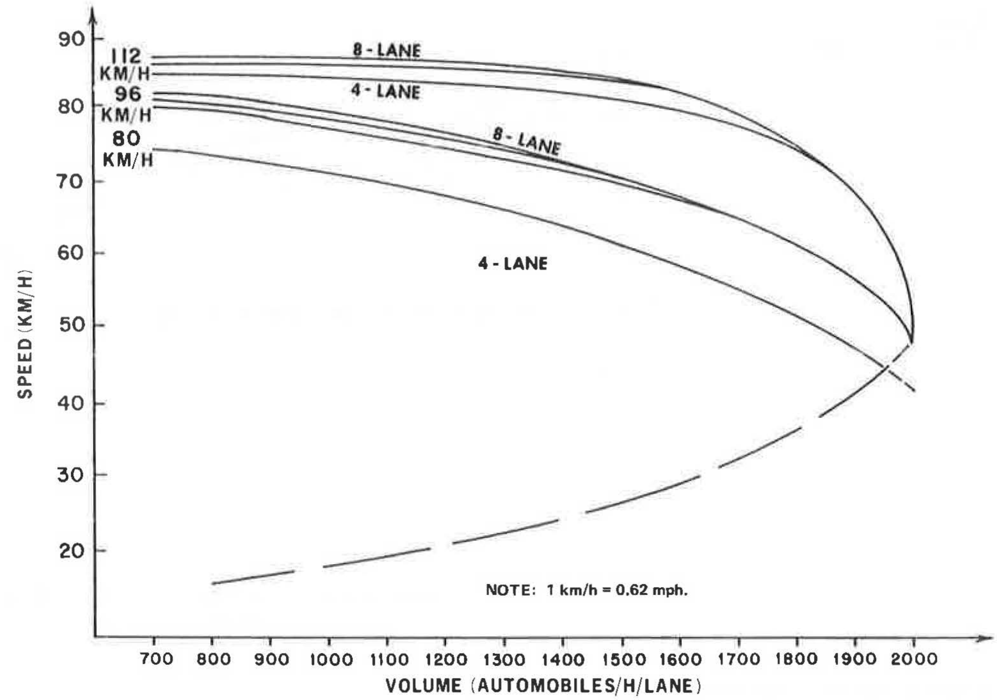


Figure 7. Recommended standard speed-flow curves.

Table 2. Level-of-service standards defined by speed.

Avg Highway Speed (km/h)	Level of Service	Avg Running Speed	Maximum Service Volume for PHF = 1.00			
			Four Lanes	Six Lanes	Eight Lanes	Each Additional Lane
112	A	96	3120	4980	6640	1660
	B	88	4680	5520	7360	1840
	C	80	3880	5820	7760	1940
	D	64	3970	5955	7940	1985
	E	48	4000	6000	8000	2000
	F	48	-	-	-	-
96	A	96	1400	2520	3680	940
	B	88	2680	4470	5960	1490
	C	80	3420	5130	6840	1710
	D	64	3800	5700	7600	1900
	E	48	4000	6000	8000	2000
	F	48	-	-	-	-
80	A	96	-	-	-	-
	B	88	1840	2760	3680	920
	C	80	2780	4170	5560	1390
	D	64	3360	5040	6720	1680
	E	48	4000	6000	8000	2000
	F	48	-	-	-	-

Note: 1 km = 0.62 mile.

service would be to define a speed range for each. Thus, service would be defined in terms meaningful to the user and would be correlated with volumes that may actually be anticipated. Since none of the speed-flow curves reach more than 83 to 85 km/h (52 to 53 mph), the most logical definitions would be those given in the table below (1 km = 0.62 mile):

Level of Service	Speed (km/h)	Level of Service	Speed (km/h)
A	≥ 80	D	≥ 56
B	≥ 72	E	≥ 48
C	≥ 64	F	< 48

Table 2 gives the level-of-service standards that result from these definitions. Volumes are taken from Figure 7. Note that the format of Table 2 follows previous recommendations. Volumes are shown only for a theoretic PHF of 1.00; that is, peak flow rates are shown. Figures 1 through 7 are also based on flow rates; the time period varies from 2 min for the John C. Lodge Freeway to 15 min for the Lunalillo Freeway and the Southern State Parkway (4).

Because of the peculiar characteristics of the recommended standard curves—i.e., a wide range of volume with constant speed followed by a rapid deterioration of speed as volume approaches 2000 automobiles/h/lane—the entire range of levels of service only covers a relatively small range of volumes. For average highway speed of 112 km/h (70 mph), this range is approximately 1660 to 2000 automobiles/h/lane, a range that is almost entirely within level of service E by current standards.

These standards, then, are not really useful to the designer, who could not reasonably design anywhere in the available range in most cases. Nor are they particularly useful to the analyst since they do not contain any description of what could reasonably be called free flow or anything approaching it. For these reasons, levels of service based on speed alone are not recommended.

A Philosophy of Level of Service

The three parameters that describe the state of a traffic stream are speed, volume (or flow), and density. Level-of-service standards are generally based on speed and volume because these parameters are easily observed and measured in the field. Density, which is difficult to measure directly and often must be measured by using aerial photography, can be computed from speed-volume data.

A level of service is a measure of quality that is intended to describe the quality of service being provided to the motorists who use a facility. The many parameters that affect the driver's perception of quality of service are all related to the ease and comfort with which the driver is able to proceed. In terms of the major parameters of

Table 3. Levels of service for basic freeway segments.

Avg Highway Speed (km/h)	Level of Service	Speed (km/h)	Density (automobiles/ km/lane)	Expected Service Volume[a] (automobiles/h) Four Lanes	Six Lanes	Eight Lanes	Each Additional Lane
112	A	≥80	≤9	1600	2400	3280	820
	B	≥80	≤16	2500	3900	5400	1350
	C	≥77	≤22	3400	5100	6800	1700
	D	≥64	≤29	3850	5775	7700	1925
	E	≥48	≤42	4000	6000	8000	2000
	F	<48	-	-	-	-	-
96	A	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]
	B	≥72	≤16	2300	3525	4800	1200
	C	≥69	≤22	3050	4575	6100	1525
	D	≥67	≤29	3600	5400	7200	1800
	E	≥48	≤42	4000	6000	8000	2000
	F	<48	-	-	-	-	-
80	A	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]
	B	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]
	C	≥64	≤22	2800	4200	5600	1400
	D	≥56	≤29	3300	4950	4950	1650
	E	≥48	≤42	4000	6000	6000	2000
	F	<48	-	-	-	-	-

Note: 1 km = 0.62 mile.

[a]One direction, for levels of service during uniform periods of traffic flow.
[b]Level of service not achievable because of restricted average highway speed.

Table 4. V/C values for use in design.

Avg Highway Speed (km/h)	V/C Ratio	Avg Running Speed (km/h) Four Lanes	Six Lanes	Eight Lanes	Density (automobiles/ km/lane) Four Lanes	Six Lanes	Eight Lanes	Level of Service Four Lanes	Six Lanes	Eight Lanes
112	0.20	83	86	86	5	5	5	A	A	A
	0.40	83	86	86	10	9	9	B	A	A
	0.60	83	84	86	14	14	14	B	B	B
	0.80	78	82	82	20	20	20	C	C	C
96	0.20	80	82	82	5	5	5	B	B	B
	0.40	78	80	80	10	10	10	B	B	B
	0.60	75	77	77	16	16	16	C	B	B
	0.80	67	69	69	24	23	23	C	C	D
80	0.20	75	75	75	5	5	5	C	C	C
	0.40	74	74	74	11	11	11	C	C	C
	0.60	69	69	69	17	17	17	C	C	C
	0.80	59	59	59	27	27	27	D	D	D

Note: 1 km = 0.62 mile.

stream flow, an interesting dichotomy develops:

1. The driver experiences (a) speed and (b) density (the relative proximity of other vehicles).
2. The designer or analyst is most interested in the volumes that can be accommodated.

Level of service should be defined in terms of the parameters directly experienced by drivers: speed and density. These should then be related to volumes for the use of designers, analysts, and planners.

Table 9.1 in the 1965 HCM is currently defined on the basis of constant speeds for each level of service. This leads to different V/C values for different highway types and markedly different densities, particularly for average highway speeds of 96 and 80 km/h (60 and 50 mph). For example, at 64 km/h (40 mph) (level D), density is approximately 28 vehicles/km/lane (45 vehicles/mile/lane) for an average highway speed of 112 km/h (70 mph); for an average speed of 80 km/h, density is 14 vehicles/km/lane (22.5 vehicles/mile/lane). Thus, two widely variant conditions of operation are labeled with the same level of service.

Of course, it is not possible to define both density and speed for a particular level because the two are related. The question, however, is whether or not defining level of service by speed alone, with no consideration of density, is proper or reasonable.

It is recommended that levels of service be established by considering both speed and density as defining parameters. Defining levels in this way considers both parameters of which drivers are directly aware (speed and density) and produces standards of a familiar form in a more meaningful way than does the current version of Table 9.1 in the HCM.

Recommended Standards for Freeway Level of Service

Table 3 gives the recommended standards for freeway level of service. They are in keeping with previous recommendations and have the following characteristics:

1. They are representative of observed speed-flow relations as shown in Figure 7.
2. They are based on average running speed as a speed parameter.
3. They are representative of peak flow rates, i.e., a PHF of 1.00.
4. Levels of service are defined by using both speed and density as parameters.

The principal defining parameter in Table 3 is density. Increments were chosen to be approximately representative of the six photographs in the 1965 HCM that illustrate the various levels of service. Speeds were established by using Figure 7. Since Figure 7 shows only volume and speed, the speed-volume point appropriate to a chosen density was determined by trial and error. Both the speed ranges and the density ranges given in Table 3 are approximate to within ±2 units. This is reasonable in view of the approximate nature of the Figure 7 calibrations and the known spread exhibited by most speed-flow data.

Note that the V/C ratio is not given in Table 3. As long as 2000 automobiles/h/lane remains the accepted maximum capacity for all types of freeways, V/C and volume are directly related on a one-to-one basis. Since volume is the parameter of direct interest to designers, analysts, and planners, its direct use in the standards simplifies their use and interpretation. It should also be noted that, for clarity, the standards shown for average highway speeds of 112, 96, and 80 km/h (70, 60, and 50 mph) are all in the same format.

The recommended standards in Table 3 result in nonuniform ranges of volume for the various levels of service. Again, this is a result of observed speed-flow characteristics in which speed remains relatively constant over a wide range of volumes and then deteriorates rapidly over a relatively small volume range as 2000 automobiles/h/lane is approached. Because of this, these standards do not give the designer a great deal of flexibility. Design at levels of service C, D, or E on a freeway with 112-km/h (70-mph) average speed could not be attempted because all are in a fairly unstable range of flow and a small error in estimated volumes would mean regular breakdowns. This leaves just two choices for a design level of service: A or B.

Since two design levels may not give the designer enough flexibility to achieve designs of optimal efficiency, it is recommended that a corollary table be developed for their use. Table 4 indicates, for uniform increments in V/C ratio of 0.20, the average running speed and level of service that could be expected if design at such a V/C value were attempted. In this table, the designer is presented with a wider range of feasible design levels.

IMPLICATIONS OF REVISED STANDARDS

Should the recommendations made here be adopted for freeway level-of-service standards, the manner in which such standards are used and interpreted would change even though their final form is very similar to standards in the current HCM. The standards given in Table 3 show speed ranges for the various levels of service that are not exclusive; i.e., several levels may have the same speed range. A field determination of level of service will require a determination of both speed (average running) and density. This, however, is no more complicated than current standards that require both speed and volume for such determinations. Density would not be observed directly but would be computed from speed and volume.

Further, it is hoped that the standards given in Table 3 are reasonably representative of what generally happens in the field under ideal conditions. Thus, where only volume data are available, it may be assumed that the speed shown in Figure 7 and the resultant density are in the range of what would be expected in the field. This statement could be considerably strengthened if the data base for Figure 7 were stronger. Clearly, more studies in this area, as well as closer control of underlying variables, are called for.

Finally, the traditional use of levels of service C and D for urban design would be altered because both are too close to the 2000-automobiles/h/lane mark for reasonable stability. A and B might be used as design levels or intermediate V/C points as indicated in Table 4. It is, however, clear that the design levels of service specified in AASHTO and other documents could not be used in conjunction with the standards recommended here.

Level-of-service standards are the very cornerstone of capacity analysis. It is believed that the recommendations made here result in a useful set of standards that both fulfill the requirements for such standards and more accurately reflect observed field conditions.

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The views presented here are ours. They do not necessarily represent the official views of FHWA or established policies or standard practices endorsed by FHWA.

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