

Synopsis of the Revised Highway Capacity Manual

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INTRODUCTION

It is a pleasure to be with you today to present a synopsis of the revised Highway Capacity Manual. I am a new Kentuckian and I welcome this opportunity to meet with you and to get to know you better.

The original Highway Capacity Manual was published in 1950. It was based on research of a few years earlier. Since 1950, a considerable mileage of freeways and other high type highways, roads and streets have been built. They have, in effect, broadened our laboratory for research and study.

Certain capacity data not available in 1950 have been developed and refinements have been made in the previous approaches to capacity. Further, some new procedures, particularly as related to intersection capacities, have been developed. Highway capacity research since 1950 has shown the 1950 Manual to be a sound and well conceived document.

The Highway Research Board determined that the more recent data should be made readily available to the highway and traffic engineers and other users of the manual, and instructed its Highway Capacity Committee to proceed with a revision of the 1950 Highway Capacity Manual. The Bureau of Public Roads provided a Task Group of five engineers for three months last summer to assist the Highway Capacity Committee with its revision of the manual. It was my privilege to serve as a member of that Task Group.

The Highway Capacity Committee presented drafts of the several chapters in the revised manual at the 43rd Annual Meeting of the Highway Research Board last January.

The publication and distribution of the revised manual is a matter for determination by the Highway Research Board, and I do not have specific information about their plans. There is reason to believe that the revised manual may be distributed in mimeographed form in the near future and that the manual may be available in final published form later this year.

MAJOR REVISIONS

The original manual defined three levels of capacity; basic, possible and practical. In the discussion of practical capacity the original manual included the idea of level of service, though perhaps in a somewhat obscure manner.

The revised manual is built around the concept that each route or route segment has only one capacity. In place of the concept of varying degrees of capacity, the Committee has used different levels of service that would be provided when the section is carrying various volumes.

The major changes in the revised manual consist of the introduction of the new capacity and level of service concept, a new procedure for intersection capacities,

additional data on traffic characteristics basic to the study of capacity, updating and expanding the sections on factors affecting capacity, weaving, and ramps, and a new chapter on transit.

My chapter by chapter resume of the new manual will stress the level of service concept and the changes from the original manual.

CHAPTER BY CHAPTER RESUME

The revised Highway Capacity Manual has eleven chapters, as introduction and ten other chapters, as follows:

Chapter I	Introduction
Chapter II	Definitions
Chapter III	Traffic Characteristics
Chapter IV	Capacity and Level of Service
Chapter V	Factors Affecting Capacity and Service Volumes
Chapter VI	Intersections
Chapter VII	Weaving
Chapter VIII	Ramps
Chapter IX	Freeways and Other Expressways
Chapter X	Non-controlled Access Highways and Streets
Chapter XI	Transit

The chapters to be used in the revised manual will serve as a basis for our discussion from here on, and as we consider each chapter, mention will be made of the revision from the original manual.

Chapter I—Introduction

The original manual had an introduction which included some historical background data found in previous studies. These data have been moved to another chapter and this chapter has been restricted to a general introduction to the material in the manual.

Chapter II—Definitions

In most technical publications, definitions are buried in the back of the report and are there only to assure that there is a common understanding of the written word in the main section of the report. In the case of the revised capacity manual, definitions play a very important role because they are the focal point of some basic concepts, primarily with respect to capacity and level of service.

It has been difficult for some people to understand how a particular route can, day in and day out, exceed its capacity even though "practical" had been tacked onto the word "capacity." The Committee decided after a great deal of deliberation that since most people use the word "capacity" to designate an upper limit, that they should do the same.

Capacity as defined in the revised manual is the same as "possible capacity" in the original manual. It is simply the maximum rate of flow that has a reasonable expectation of occurring. In the absence of a time modifier capacity in an hourly volume. Note that I did not say the maximum rate of flow that might ever occur, but the maximum rate of flow that has a reasonable expectation of occurrence.

In place of the concept of varying degrees of capacity employed in the original manual, the Committee decided to use different "levels of service."

The manual defines "level of service" as a term which denotes the different operating conditions that occur on a given lane or roadway when accommodating various traffic volumes. It is 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 convenience, and operating costs.

A given lane or roadway may provide a wide range of levels of service. The various levels for any specific roadway are a function of the volume and the composition of traffic. A given lane or roadway designed for a given level of service at a specified volume will operate at many different levels of service as the flow varies during an hour, during a day, during a year, and as the volume varies during different years with traffic growth. Further, different types of highways, roads and streets, such as freeways, expressways at grade, major streets, major highways, and local rural roads provide different levels of service that cannot be directly related to one another because each must be measured by a different standard or scale.

The revised manual includes some narrative descriptions of traffic conditions which represent varying levels of service. These levels of service cover a volume range between a free flow condition and capacity.

A new term has been employed because of the new concepts of capacity and level of service. It is "service volume." The revised manual defines "service volume" as the maximum number of vehicles that can pass over a given section of a lane or roadway in one direction on multi-lane highways (or in both directions in a two- or three-lane highway) during a specified time period and still maintain operating conditions corresponding to the selected or specified level of service. In the absence of a time modifier "service volume" is an hourly volume. In other words, "service volume" is that volume of traffic that can be handled by a given roadway under certain traffic conditions corresponding to a specified level of service. It will replace what has been called "design capacity," "satisfactory capacity," "tolerable capacity," "practical capacity," and similar terms used in the past.

The revised manual has added definitions for about 35 to 40 terms not included in the original manual, and it has deleted about 65 definitions that were in the original manual.

There are three new definitions to which I invite your attention, in particular. One is "peak hour factor," the second is "load factor," and the third is "average highway speed." They are defined as follows:

"Peak Hour Factor"—A ratio of the volume occurring during the peak hour to the maximum rate of flow during a given time period within the peak hour. Its maximum attainable value is one.

"Load Factor"—A ratio of the total number of green phases that are fully utilized by traffic during the peak hour to the total number of green phases for that approach during the same period.

"Average Highway Speed"—The weighted average of the design speeds when each subsection of a section of highway is considered to have an individual design speed.

Peak hour factor is used to reflect variations in rates of flow during an hour. This term, along with "load factor" has special application in the intersections chapter.

Design speed represents the highest continuous speed at which individual vehicles can travel with safety upon a highway when weather conditions are favorable, traffic density is low, and the design features of the highway are the governing conditions for safety. A five mile section of highway all on level terrain with one 50 MPH curve, has a design speed of 50 MPH. A second five mile section of highway having continuous 50 MPH curves also has a design speed of 50 MPH. Yet,

under the conditions described for design speed, one could average, say 69 MPH on the first five mile section (assuming a 70 MPH speed limit) and only 50 MPH on the second. The term "Average Highway Speed" is used to express the speed-ability difference of such highways.

Chapter III - Traffic Characteristics

The original manual did not have this chapter as such. Part VIII of the original manual has been incorporated here. Much of the background data relating to capacity have been brought together and developed further in this chapter.

Chapter III treats volume, speed and spacing of vehicles and their interrelationships in some detail. An understanding of these elements and their interrelationships is fundamental to an understanding of capacity.

This chapter also presents data concerning time variations. These are particularly important since our concept of capacity recognizes the variability of demand. The hourly capacity is not 60 times the maximum minute flow, any more than the annual capacity is 8,760 times the maximum hourly volume. The capacity of a roadway is that flow or volume which will result in loading the roadway for only a percentage of the total time when demand is the highest. Capacity is normally computed on an hourly basis.

The relationship between speed and volume is a fundamental one in any discussion of capacity and level of service. As the traffic volume on a roadway increases both mean speed and the distribution of individual speeds is reduced. Investigations conducted on an extensive scale have shown that a straight line is a reasonable representation of the speed/volume relationship provided that critical density is not reached and the speed limit effect is not controlling.

Figure No. 1 shows a speed/volume relationship for certain 2-lane rural roads. Both the slope and the relative positions of these curves have an important bearing on capacity. In general, the speed/volume curves for freeways and other expressways tend to be flatter than for two-lane rural roads or for city streets.

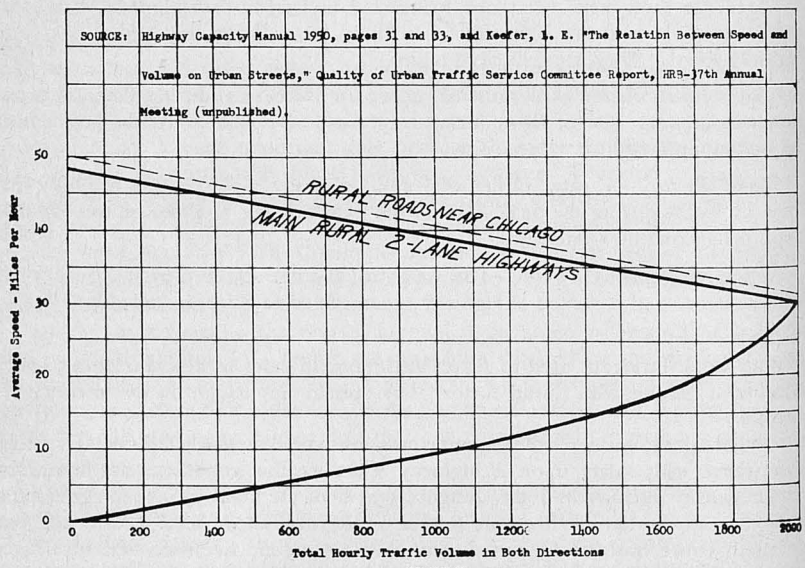


FIGURE I
Average Speeds of all Vehicles on level, Tangent sections of two-lane rural highways

Chapter IV—Capacity and Level of Service

Portions of the material in Parts III and IV of the original manual have been included here.

This chapter sets forth capacities under ideal conditions for two-lane, and multi-lane highways as follows:

Capacities under Ideal Conditions

Two-lane two-way roadway	2000 passenger veh./hr.-total
Multi-lane roads	2000 passenger veh./hr./lane

These values for capacity represent maximum volumes under ideal conditions.

It must be remembered, however, that these values were determined from studies of many highways under a variety of conditions. In all cases it would be impossible to state that the volume measured was the absolute maximum that could be carried since observed maximum volumes at one point will show a range of values. Rather, the capacities shown should be considered the attainable maximum volume, or a maximum volume that has a reasonable expectation of frequently occurring on the various highways under ideal conditions.

Chapter IV sets forth the premise that ideally "level of service" should include a numerical evaluation of each speed and travel time, traffic interruptions, freedom of maneuvering, safety, driving comfort and convenience, and economy. It also recognizes that such data are not currently available and that the best measure of level of service that can presently be identified is operating or average overall speed.

This chapter recommends six levels of service for application in identifying the conditions existing under various speed and volume conditions. These six levels are designated A through F and cover the entire range of traffic operations that may occur on any street or highway.

The descriptions presented in this chapter are generalized with definite values for the several levels given in Chapters IX and X for each type of highway.

Level of Service A describes a condition of free flow accompanied by low volumes and high speeds. Traffic density will be low with speeds controlled by driver desires and physical roadway conditions. There is little or no restriction in maneuverability due to the presence of other vehicles, and drivers can maintain their desired speed with little or no delay.

Level of Service B is in the zone of stable flow with operating speeds being restricted somewhat by traffic conditions. Drivers still have reasonable freedom to select their speed and lane operation. Reductions in speed are not unreasonable, with the probability of restrictions to traffic law. This level has been associated with the value used in the design of rural highways.

Level of Service C is still in the zone of stable flow, but speeds and maneuverability are closely controlled by the higher volumes. Most of the drivers are experiencing restriction in their freedom to select their own speed, change lanes or pass. A relatively satisfactory operating speed is still obtained, at least for urban design practice.

Level of Service D approaches unstable flow with tolerable operating speeds being maintained but sensitive to changes in operating conditions. Fluctuations in volume and temporary restrictions to flow may cause considerable drops in operating speeds. Drivers have little freedom to maneuver, and comfort and convenience is low, but these conditions can be tolerated during short periods of time.

Level of Service E cannot be described by speed alone, but represents operations at or near the capacity of the highway.

Level of Service F describes a forced flow operation at significantly low speeds by volumes not approaching capacity. These conditions usually happen when queues of vehicles back up from a restriction downstream, and the section under study is forced to act as a storage area. Speeds are reduced substantially and stoppages may occur for short periods of time caused by congestion.

Chapter IV sets forth four classes of highways for which levels of service are identified separately. They are (1) freeways and other expressways, (2) other multi-lane highways, (3) two and three-lane highways, and (4) urban arterial streets.

Chapter V—Factors Affecting Capacity and Service Volumes

Part IV of the original manual included a section discussing factors that affect capacity. These factors may be divided into two general categories, roadway factors and traffic factors.

The revised manual includes the roadway factors in the original manual and has added auxiliary lanes. In addition to commercial vehicles, the traffic factors now include a peak hour factor. The manual will include lane distribution data which will be valuable in the solution of many capacity problems, especially relating to ramps and weaving.

Chapter VI—Intersections

Fundamentally, the revised manual presents a new procedure for determining intersection capacities in which greater emphasis is placed on environmental conditions. The new procedure is based on research since 1950. The revised manual divides the factors affecting intersection capacity into four general groups. They are (1) physical and operating conditions, (2) environmental conditions, (3) traffic characteristics, and (4) control measures.

The physical and operating conditions include the approach width, parking conditions, and the type of operation with respect to one-way or two-way movements on the street.

The environmental conditions include peak hour factor, load factor, metropolitan population size, and location within a city.

The traffic characteristics include left turns, right turns, and commercial vehicles.

The control measures include bus stops as related to their location and usage, length of green phase, effect of lane width and type of signal control.

This chapter includes a series of charts covering the several physical condition factors for various parking conditions and one and two-way street operations which show approach width as the abscissa and vehicles per hour of green as the ordinate. The charts have a series of lines for a constant peak hour factor and population size, but with a variable load factor. The data thus obtained can then be corrected from a table for the specific peak hour factor and the city size.

Figure 2 shows such a chart for one-way streets with parking on one side. Table No. 1 presents a basis for correcting the data from the chart for different metropolitan area populations and peak hour factors. It is probable that this series of tables also will include a separate small table presenting the factors for location within a city.

The vehicles per hour of green so obtained must then be further adjusted for the traffic and control factors, namely, left turns, right turns, bus stops, etc. These factors are handled in much the same way as in the original manual although the values have changed slightly.

Chapter VII—Weaving

The revised edition is essentially the same as the original issue except (1) the

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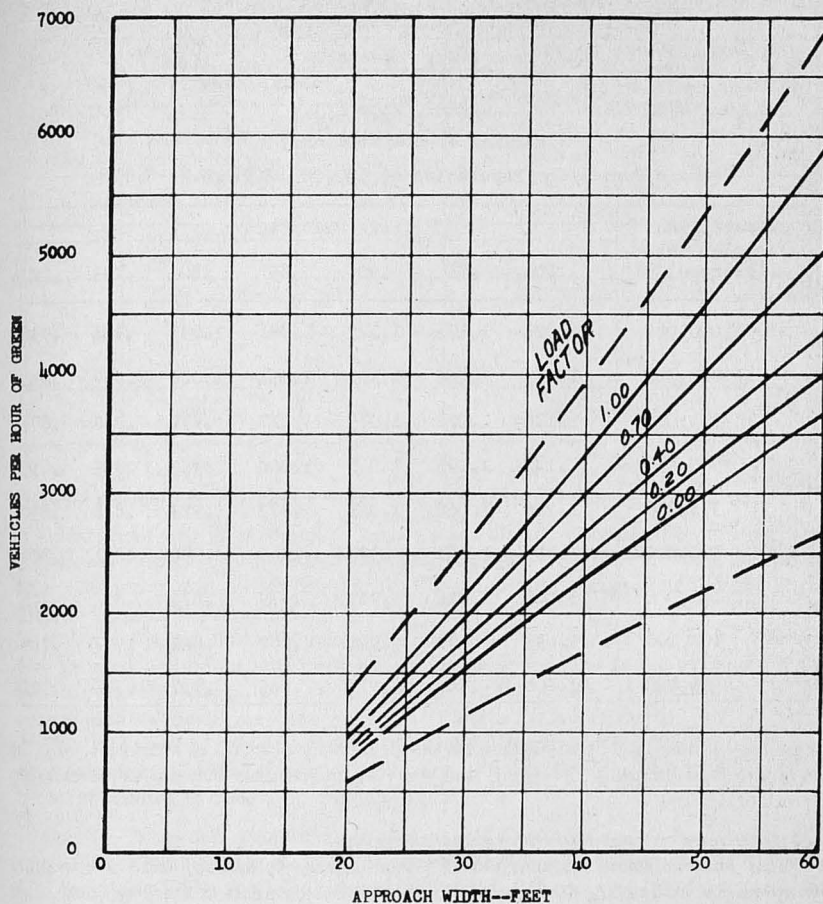


FIGURE II - One-way Streets - Parking one side

concept covered in the original manual under "operating speed" has been broadened, (2) the use of the charts and the limitations on their use have been more fully discussed, (3) all references to specific weaving sections have been deleted, (4) additional material has been added to show the effect on weaving by other factors, such as grades and pedestrians, and (5) a new procedure has been added for multiple weaving sections.

Chapter VIII - Ramps

The original manual really had very little on ramps. It presented the idea that lane distribution near ramp terminals is a factor and some information which was useful in some instances. The revised edition offers a procedure for determining a volume that will provide a comfortable operating condition on the ramp and for evaluating the possibility of critical conditions occurring upstream of the ramp on the main line of the freeway. This chapter includes information concerning

FACTORS FOR ADJUSTING VEHICLES PER HOUR OF GREEN

AT INTERSECTION APPROACHES

One-Way Streets

TABLE NO. 1

Parking on one side only

(Basic Curves for Population of 500,000 and P.H.F. 0.85)

Metropolitan Population (Average)	Peak Hour Factor						
	1.00	.95	.90	.85	.80	.75	.70
Over 1,000,000	1.224	1.176	1.129	1.081	1.033	.986	.938
1,000,000	1.197	1.149	1.102	1.054	1.006	.959	.911
750,000	1.170	1.122	1.075	1.027	.979	.932	.884
500,000	1.143	1.095	1.048	1.000	.952	.905	.857
375,000	1.116	1.068	1.021	.973	.925	.878	.830
250,000	1.089	1.041	.994	.946	.898	.851	.803
175,000	1.062	1.014	.967	.919	.871	.824	.776
100,000	1.035	.987	.940	.892	.844	.797	.749
75,000	1.008	.960	.913	.865	.817	.770	.722

auxiliary lanes, lane distribution data on the freeway near ramp terminals, and the evaluation of merging, diverging and weaving movements between adjacent ramp terminals.

Chapter IX - Freeways and Other Expressways

This chapter furnishes information either directly or through reference to other chapters for evaluating the capacities of the various elements of freeways and other expressways. These include not only the through lanes but also critical areas of operation; up grades, weaving areas, ramp entrances and exits, and, in the case of other expressways, intersections at grade.

This chapter ascribes definitive values in terms of prevailing traffic flow conditions, service volume/capacity ratios and maximum service volumes under ideal conditions for each of the six levels of service defined in Chapter IV. These data are presented in Table 2.

Chapter IX presents some narrative material explaining the basis for the numerical values shown in the table. You will note that the values in the last or right hand column under the heading "Each additional lane" are greater for levels of service A, B, and C than the average service volume per lane shown in the column immediately adjacent and to the left. For example, for level of service A, the maximum service volume under ideal conditions for two lanes is shown as 1400 vehicles per hour which represents an average of 700 vehicles per hour per lane. The table shows that the third and each additional lane could carry 1,000 vehicles per hour at level of Service A.

Table II
Levels of Service and Maximum Service Volumes
for Freeways and Other Expressways
Under Uninterrupted Flow Conditions

Level of Service	Prevailing Traffic Flow Conditions		Service Volume Capacity Ratios	Maximum Service Volumes under Ideal Conditions in Vehicles per hour	
	Description	Operating Speed, MPH		2 Lanes	Each Additional Lane
A	Free Flow	≥ 60	≤ 0.35	1400	1000
B	Stable Flow Upper Range	≥ 55	≤ 0.50	2000	1500
C	Stable Flow Middle Range	≥ 45	≤ 0.75	3000	1800
D	Stable Flow Lower Range	≥ 35	≤ 0.90	3600	1800
E	Unstable Flow	< 35	> 0.90	4000	2000
F	Forced Flow	< 35	> 0.90	<i>Below 4000 (Varies)</i>	<i>Below 2000 (Varies)</i>

When there are three or more lanes in one direction the opportunity for passing slower vehicles is greater. Therefore, at level of service A, each additional lane will accommodate approximately 1.5 times the average lane volume of the first two lanes in one direction.

It can be noted that this relationship tends to decrease so that at level of service D each additional lane carries only the same amount as the average for the first two lanes. This is because the opportunity for passing slower vehicles is not present to the same degree when the higher volumes are experienced.

This table will provide the user of the manual with valuable definitive information concerning levels of service and service volumes from which he can make decisions relating to design, operations or planning.

Chapter X - Non-controlled Access Highways and Streets

Chapter X treats three main types of uncontrolled access highways and streets: (1) multi-lane highways, divided and undivided, (2) two-lane highways, and (3) urban arterial streets.

This chapter includes three tables, one each for multi-lane, two-lane, and urban arterial streets presenting service volume/capacity ratio and operating condition information for the six levels of service similar to that shown in Table 2 for Freeways and Expressways. These data have not been included here in the interest of keeping this synopsis of the manual within the time specified for presentation.

In Chapter IV the factors considered in determining level of service are set forth. Level of service, by definition, must apply to a section of roadway and is the average accumulative effect of operating levels at each point along the roadway.

Since the ability to pass other vehicles is such an important part of level of service on two-lane highways, the percentage of passing sight distance greater than 1500 feet has been introduced for each of the several levels of service defined and the service volume/capacity ratio has been included for the several passing sight distance categories.

Capacity calculations for specific locations on an urban street, such as at an intersection, are often used by operating traffic engineers. It is considered to be

unreasonable, however, to analyze an urban arterial solely as separate segments between intersections. Interrupted flow capacity is normally controlled by such factors as (1) the total width of street and lane widths provided, (2) traffic control devices and their settings, (3) speed limits, and (4) other mid-block frictions.

The new manual provides a speed-volume approach for arterial street conditions which allows the calculation of capacity over a long section of street rather than only at the intersections. This approach would not preclude the presence of a few "bottleneck" intersections operating at a lower level of service than the overall street section. However, it would be essential that all intersections within the longer section operate below capacity.

Chapter XI- Transit

The treatment of transit as a separate chapter is now in the revised edition. It includes bus loading and unloading times and the length of loading zones required by various length buses.

SUMMARY AND CONCLUSIONS

In order to cover a rather large volume of material about capacity in a relatively short time, my remarks have been limited to the more salient features in the revised manual. I do not presume to have presented enough material to make you thoroughly conversant with what the revised manual contains. If I have whetted your appetite for the revised manual, I shall be amply rewarded.

The revised manual, like the original one, is a research document. It presents data and information the Highway Administrator, the Highway Engineer, the Traffic Engineer, the Planner, or other users of the manual can utilize in making decisions. It will not tell the designer the level of service and the corresponding service volume he should select. It will, however, tell him the type of operation he could expect when his road is operating at a given volume.

The level of service to be provided through design or through operations is a policy matter appropriate for determination by the Administrator, the Highway or Traffic Engineer, or the Planner. The revised manual can serve as a valuable tool to aid them in policy decisions, but it will not make those decisions.

In conclusion, my remarks may be summarized as follows:

1. The manual about to emerge is a revised edition of the 1950 Manual. It is not a new manual. Research since 1950 has shown the original manual to be a sound and well conceived publication. Research also has provided additional data which have served as a basis for updating or changing material in the previous manual.

2. The major revisions consist of a new definition for "capacity," the introduction of the concept of the level of service, a new procedure for intersections, additional data on traffic characteristics basic to the study of capacity, and updating and supplementing the data on factors affecting capacity, weaving, ramps and transit.

3. The revised Highway Capacity Manual can serve as a valuable tool to aid the Administrator, the Highway and Traffic Engineer, and the Planner in making policy decisions. It will not, in itself, make those policy decisions.

4. The manual is expected to come out in mimeographed form in the near future. Photographs and additional illustrative examples will be added prior to publication which is scheduled for later this year.

5. The manual has been revised for you. The proof of the pudding is in the eating. We hope that in the years to come you will find the revised Highway Capacity Manual has added something to the highway technology of value to you.