Traffic Capacities on Streets and Highways

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There is little doubt that those of us who are involved in the great industry of motor vehicle transportation—whether it be along the lines of design, maintenance, or operations—have come to recognize that street and highway capacity considerations are indispensable.

It is unfortunate, however, that too often there is a lack of clear understanding of what we mean by capacity and how it actually is used. I am quite certain that many of us have, at one time or another, used the term capacity rather loosely without fully realizing just what phase of capacity we have meant to describe. Hence, our first approach to the subject should be a definition of terms. Simply stated, capacity is a generic term applied to the ability of a highway facility to accommodate traffic. This ability, in turn, is dependent upon prevailing conditions which may be either certain physical conditions, a traffic condition or perhaps both.

The committee of highway capacity of the highway research board has fixed upon three terms: basic capacity, possible capacity, and practical capacity. The first (or basic capacity) is defined as the maximum number of passenger vehicles that can pass a given point during one hour under the most nearly ideal roadway and traffic conditions. An example of this might be the closely controlled flow in the Holland Tunnel or on the Oakland Bay Bridge.

Possible capacity differs from the basic level in that it is described as the maximum number of vehicles that can pass a given point in one hour under prevailing roadway and traffic conditions.

The third level and the one we will deal with at this time is practical capacity. This is defined as the maximum number of vehicles that can pass a given point in one hour without causing unreasonable delay, hazard, or a restriction of the drivers' freedom to maneuver under prevailing conditions.

While the subject of capacity has been studied for several years, not until the recent report of the highway research board committee was released was anything so extensive or exhaustive available to the engineering profession. O. K. Normann, chairman of that committee, aided by well-informed consultants, city engineers and state engineers and with the facilities of the Bureau of Public Roads at his disposal, delved deeply into the fundamentals of the subject and came up with many basic factors that insure far far more accuracy than any work done before or since.

Capacity considerations are generally applied in two ways. One is the determination of design details so that the finished facility will be assured of all the essential features necessary to carry the traffic imposed upon it efficiently and safely. In this use, no short-cut or simplified system has yet been devised. Most designers must use every scrap of information available in order that they may not be judged guilty of gross over-design or unfortunate under-design.

The second main use of these data is for the purpose of appraising existing deficiencies and the determinating needs. For instance, knowing a given set of prevailing traffic conditions and the existing physical characteristics, it is possible to determine within a fair degree of accuracy just what is the maximum practical carrying capacity. Then, knowing the number of vehicles actually using the facility, proof of adequacy or of overloading is within easy grasp.
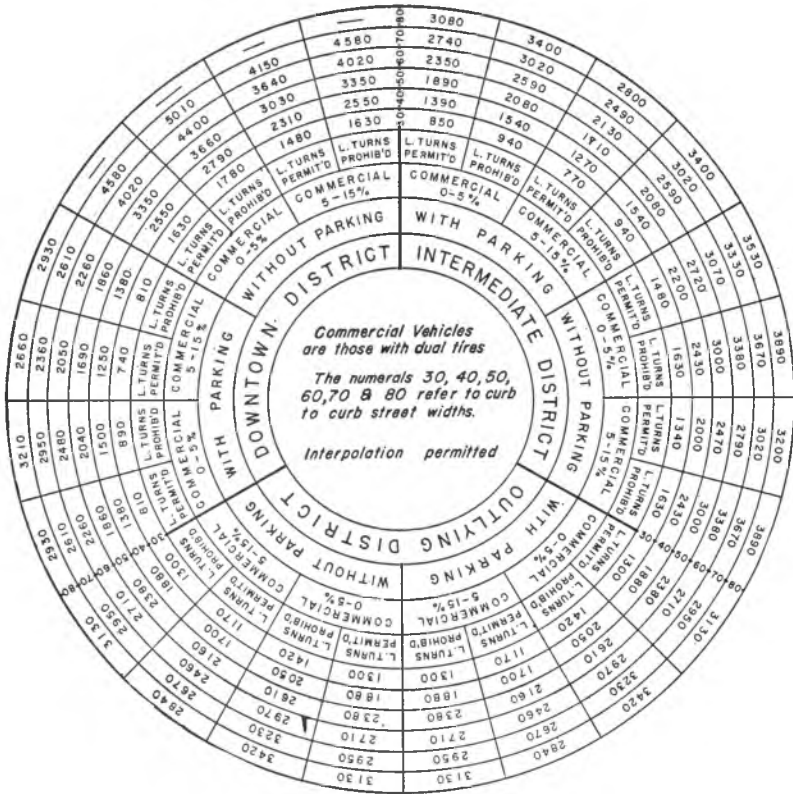
As many of you know, in my state (Ohio) there is now underway a statewide study to determine street and highway needs. Obviously, such a survey demands a careful check to determine whether a given street or highway is seriously overloaded and also to point the way to the correction of known deficiencies. Since much of the work in Ohio was to be done by local engineers, it soon became evident to the staff that there was little practicality in expecting each local engineer to be thoroughly conversant with the theory and application of capacity determinations as reported by the Research Board Committee. Neither was it practical to expect them to interrupt their regular work to acquaint themselves with those findings. It was equally unlikely that there would be any unanimity of interpretation of the methods so carefully developed by the committee. The task, therefore, became quite evident. It would be necessary to arrive at a method of applying the basic factors in a generalized and simplified manner without sacrificing accuracy. After a thorough study of the committee's report and the methodology of presentation, it was decided that some type of graphic chart should be devised wherein several of the more common variables could be included with a minimum of complexity. Nomographic means

were considered but discarded in favor of a more direct method. Final decision was made on a circular chart which appeared to have most of the qualities desired.

   The first chart or diagram (Figure 1) was designed for urban streets which normally carry bidirectional traffic. Mr. Normann's

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FIGURE I   PRACTICAL WORKING CAPACITIES FOR TWO-WAY STREETS

IN TERMS OF TOTAL VEHICLES PER HOUR

Commercial Vehicles
are those with dual tires

The numerals 30, 40, 50,
60, 70 & 80 refer to curb
to curb street widths.

Interpolation permitted

ADDITIONAL COMPUTATIONS REQUIRED

1. If Commercial Vehicles exceed 15% of Total traffic - subtract from the value shown for 5-15%
    Commercial, 1% for each percent of Commercial Vehicles over 15%.

2. If a Bus route - multiply final value by 0.88.
    If a Streetcar route, regardless of district, use values for "DOWNTOWN- WITH PARKING"

3. If fixed time signal is used, multiply by fraction $\dfrac{\text{Seconds of Green}}{\text{Seconds of Total Cycle}}$

    If Streetcar turns - deduct time from seconds of Green.

data showed clearly that different values existed depending upon the character of the location. For instance, traffic capacities on streets in the central business district were found to be different from those in "fringe" areas that are neither wholly commercial nor wholly residential. Values were still different in the outlying areas. Hence, the first subdivision of our circle was into three segments representing the three geographic locations.

Each of these three segments are further subdivided into two smaller segments representing parking characteristics. A further breakdown into two subdivisions, representing commercial vehicle composition followed, and that, in turn, into still smaller segments relating to left turning movements.

The small concentric circles (of which there are six) provide spaces for the values of curb-to-curb street widths ranging from 30 to 80 feet. Not including interpolated values for odd street widths, there are on this chart 144 direct readings for as many sets of conditions. These were still insufficient to care for the other important factors such as the presence of bus lines, unusually heavy concentrations of commercial vehicles and the effect of fixed-time traffic signals. Hence, additional multiplying factors were devised for those conditions.

The basic data of the highway capacity committee as condensed in this chart illustrates dramatically the amazing increases in practical capacity that can be secured by comparatively inexpensive and simple methods instead of the alternative of expensive widening or other major construction.

For example—the practical capacity of a 40-foot street in a downtown district carrying 10 per cent commercial traffic, when both parking and left turns are permitted, is 1,250 vehicles per hour. If parking were eliminated during the rush hours and left turns also prohibited the practical capacity could be doubled to 2,550 vehicles per hour.

It is recognized that public support for corrective measures of that type is often a problem. However, such facts as these enable public officials to decide intelligently whether or not the added capacity and its resulting freedom of movement and lessened congestion is economically sound.

In appraising the capacity of existing streets by means of such charts as these, engineers are shown specifically the results that can be expected by the application of various traffic engineering techniques. Without this evidence in some cases it might be wrongfully assumed that expensive construction is the only solution.
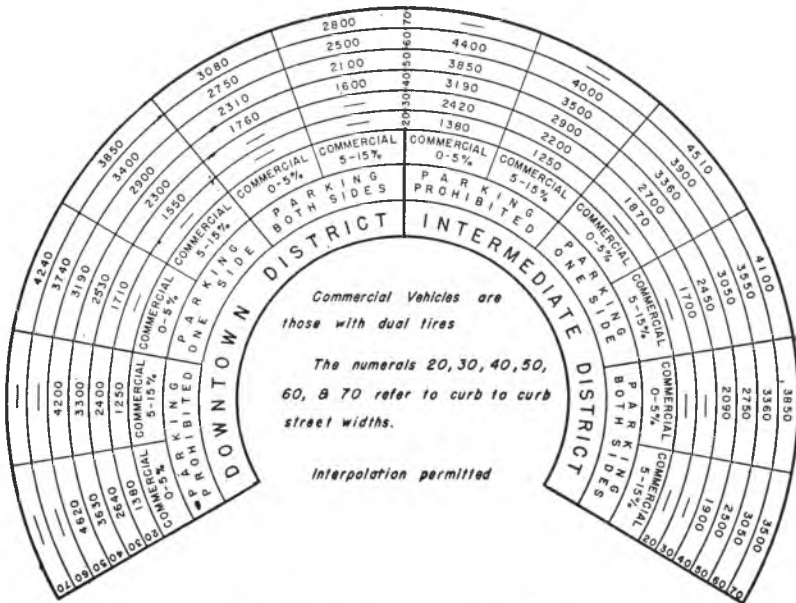
Although the major increases in capacity that are possible through these steps are important and substantial, it must be recognized that

such steps will not solve all problems and, under some conditions, major construction of freeways or other high volume facilities may still be the only answer. However, proper application of these data does insure that all practical steps will be considered and that the resulting program will be both conservative and sound.

It should be noted that there is a very narrow margin between the practical working capacity as shown on the chart and the existence of undersirable, or almost unbearable congestion.

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FIGURE 2 PRACTICAL WORKING CAPACITIES FOR ONE-WAY STREETS

IN TERMS OF TOTAL VEHICLES PER HOUR

Commercial Vehicles are those with dual tires

The numerals 20, 30, 40, 50, 60, & 70 refer to curb to curb street widths.

Interpolation permitted

ADDITIONAL COMPUTATIONS REQUIRED

1. If Commercial Vehicles exceed 15% of Total traffic— subtract from the value shown for 5-15% Commercial, 1% for each percent of Commercial Vehicles over 15%.

2. If a Bus route— multiply final value by 0.88.
   If a Streetcar route— regardless of district, use "DOWNTOWN— WITH PARKING".

3. If fixed time signal is used, multiply by fraction $\dfrac{\text{Seconds of Green}}{\text{Seconds of Total Cycle}}$
   If Streetcar turns— deduct time from seconds of Green.

In a moment a hypothetical problem will be worked out to demonstrate the use of this chart. But before so doing your attention is called to the second chart. (Figure 2.)

This second chart is of similar design but intended only for use on one-way streets. You will observe that one segment has been deleted. This is due to the general lack of need for mono-directional operation in outlying residential grids. This chart, when used in conjunction with the preceding one produces some startling results clearly illustrating the added capacity to be realized by one-way operation. For example, a 40-foot street in a central business district under the same basic conditions and having a capacity of 2,550 vehicles per hour as a two-way street could, as a one-way street, carry 3,630 vehicles per hour or an increase of 42 per cent.

Now let us go back to the first chart and work through a typical problem.

HYPOTHETICAL PROBLEM SOLUTION

Up to this time our attention has been directed to urban street considerations. We will now shift to the rural problem which obviously has a slightly different perspective.

The variable conditions that exist on rural roads have been limited to only the basic factors including the design speed, operating speed, terrain, lane width, passing distance, and commercial concentration.

Terrain has been divided into two groups—flat and hilly. In those cases where topographic conditions go beyond the hilly into a mountainous category these data cannot be safely relied upon.

Lane widths of 10, 11 and 12 feet have been shown since most of our modern roads have been constructed on the basis of one of these widths. Furthermore, facilities using 8 and 9-foot lanes are, by today's standards, deficient and potentially hazardous; for purposes of this study they are therefore ignored.

The passing distance just mentioned refers to the percentage of a given stretch of road having less than the required 1,500 feet of sight distance as prescribed by the A.A.S.H.O.

The chart (Figure 3) covering capacities for two-lane rural roads sets up practical capacities under 252 sets of conditions. These conditions include design speed, operating speed, terrain, lane width, and sight distance. Additional simple calculations can be made for variations in the percentage of commercial vehicles which further refine the answers.

To illustrate the use of this chart let us assume that the problem

FIGURE 3 PRACTICAL WORKING CAPACITIES FOR TWO-LANE RURAL ROADS

IN TERMS OF VEHICLES PER HOUR IN TWO DIRECTIONS
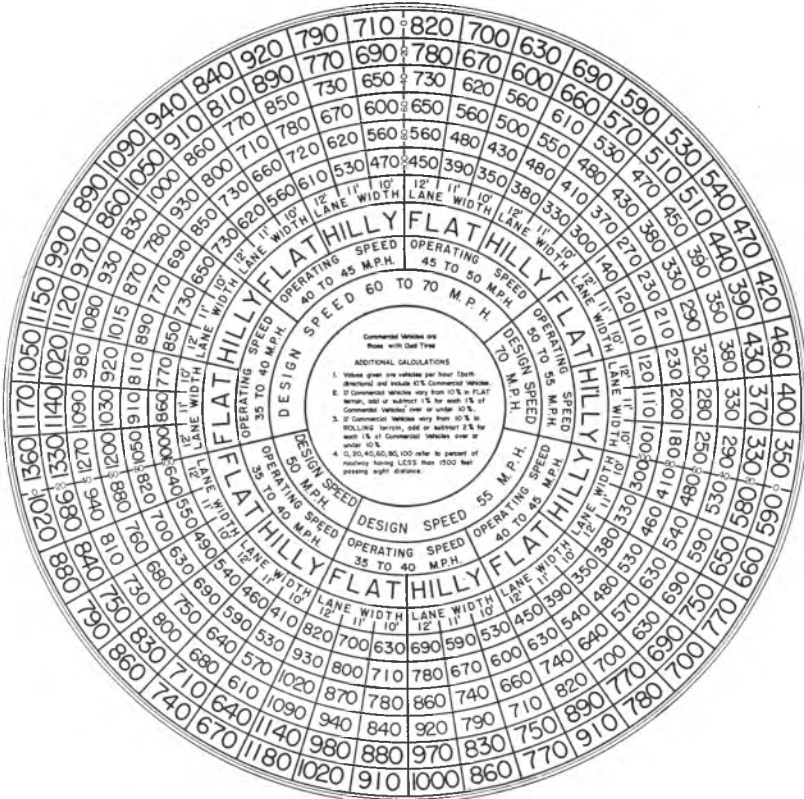
is to determine whether a specific section of a two-lane highway is adequate for existing traffic volumes. The volume in peak hours is 580 vehicles per hour for both lanes with 10 per cent of the vehicles being of the commercial type. It is desired to maintain an operating speed of 45 to 50 miles an hour since the highway under consideration is a main state highway. The following conditions prevail:

60 to 70 miles an hour design speed flat terrain.

11' lanes.

60 per cent of the road having less than 1,500 feet passing sight distance.

Referring to the chart, we find that the practical working capacity of the section under the prevailing conditions is 560 vehicles per hour

or slightly under the existing volume. This indicates that the highway is reasonably adequate from a capacity standpoint for the existing traffic load.

Another example might be a section of two-lane rural highway that is deficient structurally and also operating beyond practical working capacities. The problem then is to determine the type of facility required to carry the maximum traffic volumes during the life of the facility.

Let us assume the following conditions:

60 to 70 miles per hour design speed.

40 to 45 miles per hour operating speed, hilly terrain.

850 vehicles per hour required practical working capacity.

Referring to the chart we find that under the stated conditions this volume could be carried on a two-lane highway with 12-foot lanes and not more than 40 per cent of the length of the roadway having less than 1,500 feet passing sight distance. Thus, at least some of the more important design features can be fixed.

It is significant to note that depending on the lane width and percentage of 1,500 feet passing sight distance available the capacity of a two-lane rural road in flat country with an operating speed of 45 to 50 miles per hour can vary from 350 to 820 vehicles per hour or more than double. Similar wide variations in capacity are found for other sets of conditions. The significance of the true economy of proper design has never been better illustrated.

Some rural roads are known to carry more vehicles per hour than are shown on this chart and are not considered congested in terms of vehicle density. However, when conditions reach the point that drivers are no longer able to operate at their normally desired speeds a higher accident potential is created which, of course, lowers the net efficiency of the facility. It could, then, be termed congested. Generally it will be found that the chart values shown are very near to the point at which congestion begins.

For those of you who are primarily involved in design or in traffic engineering, I highly recommend to you to take time out to carefully review the committee's report published in October and December (1949) issues of *Public Roads*. You will, thereby gain a much clearer conception of the background or foundation upon which the method described today was based. You may also discover a need for quickly applying these very important facts to practical problems that are placed before you.