Operation of Weaving Areas

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● A KNOWLEDGE of the capacities of weaving sections has become an extremely important requirement in modern highway design and traffic operation, especially for freeways, channelized intersections, and other designs where the crossing of two or more traffic streams is not controlled by traffic signals. Failure to recognize the existence of a weaving section or to predetermine its effect on traffic movement has resulted in unsatisfactory operating conditions at numerous locations on freeways opened to traffic during the past several years. At most of the locations, reconstruction has already corrected the unsatisfactory condition, or plans are being made to correct the condition. In each case, the cost of correcting the condition has been high compared to what the added cost would have been to eliminate the unsatisfactory condition during the original design and construction.

Accurate traffic counts by vehicle types for each of the movements through several of these problem locations have been recorded for each 10- or 15-minute time interval, together with the operating conditions, congestion, and vehicle speeds during the peak and nearpeak periods of flow. This report is based on the results of an analysis of these data.

A weaving section is defined in the "Highway Capacity Manual" (1) as: "A length of one-way roadway serving as an elongated intersection of two one-way roads crossing each other at an acute angle in such a manner that the interference between cross traffic is minimized through substitution of weaving for direct crossing of vehicle pathways." Highway sections that specifically meet this definition are generally easily recognized.

In its broader sense, however, the definition also includes a large variety of highway sections not so easily recognized, such as the roadway between two inner loops of a cloverleaf, where the vehicles entering a freeway from the one inside loop must cross the path of the vehicles leaving the freeway on the other inside loop. Likewise, any section of a freeway between an "on ramp" which precedes an "off ramp" is in effect a weaving section, although it is generally not recognized as such unless the two ramps are close together. Such a condition does, however, affect both the possible and practical capacities of the section whenever the percentage of vehicles that must merge and shift lanes per unit length of highway exceeds the percentage of vehicles that normally shift lanes on sections far removed from any entrances or exits.

Studies conducted during high volume conditions on freeways show that about 10 percent of the vehicles shift lanes within each 1,000 ft for reasons other than those connected with entrance and exit requirements. To this extent, the effect of vehicles shifting lanes is therefore included in normal capacity determinations of multilane facilities. Whenever the required amount of lane shifting between an entrance and an exit exceeds this normal rate, the section of highway may be considered as a weaving section in a capacity analysis. For example, if 10 percent of the traffic on a section of highway entered from a ramp at one end and another 10 percent left the section at the other end, the section should be checked as a weaving area in any capacity determinations unless the two ramps are more than 2,000 ft apart. For most such conditions the analysis will show that the problem is simply one of merging two traffic streams; but under certain conditions, depending on the distribution of traffic between lanes, which varies with the total traffic, the percentage of trucks, and the design of the ramps, the problem is the same as for a weaving area.

Figure 1, showing the results of capacity studies conducted to determine operating characteristics of weaving sections, is similar to Figure 43 of the "Highway Capacity Manual" (1), the difference being that the curves entitled "Maximum possible capacity" and "30-mph operating speed" are somewhat higher than the corresponding curves in the original publication.

The results of recent studies conducted at weaving sections, including several of the sections on which the original curves were based, show that the maximum possible capacities of weaving sections are now somewhat higher than they were about 10 years ago when the original figure was prepared. The reason for this increase cannot be determined, but it may be due in a large measure to improved driver performance as a result of increased experience or practice in driving through weaving areas.

Other considerations are, however, more important than the difference between the values in the original publication and those of Figure 1 that are based on a larger volume of data and more current information. These more important considerations include:

1. The correction of improper methods which have been used in some instances when applying the data for weaving sections.
2. Refinements that have been developed which permit a better agreement between values estimated by the use of Figure 1 and the actual field conditions.
3. New techniques which have been developed for the analysis of weaving sections with more than two entrances or exits.

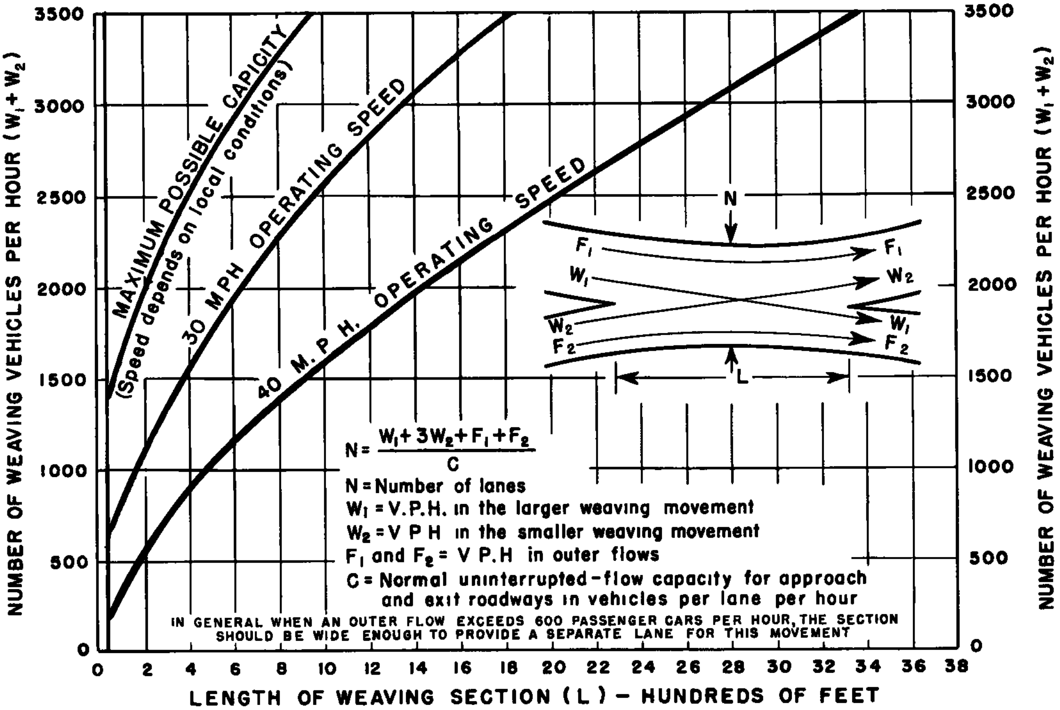

Figure 1. Operating characteristics of weaving sections.

The following are a number of items to clarify the use of Figure 1:

1. Weaving sections that satisfy both the length and width requirements as indicated by the chart will accommodate at least the corresponding traffic volumes. Because it was believed that the information would be used principally for design purposes, it was necessary to be sure that the resulting actual capacity would be at least as high as calculated. The instances during the past ten years in which accurate studies have revealed errors of a significant magnitude have been few, and in all such cases the actual volumes have been greater than calculated, an expected result.
2. The curves for the 30- and 40-mph operating speeds are applicable to the speeds of the vehicles that must perform the weaving maneuvers. The speeds of the other vehicles would depend on the value of C used. When weaving vehicles negotiate the section at a higher average speed during the corresponding traffic volumes, it is generally at the expense of the non-weaving traffic.
3. The 40-mph curve was intended principally for use in rural areas where practical lane capacities of 1,000 vehicles per hour (C) on the normal sections will assure

an operating speed of 45 to 50 mph; the 30-mph curve was intended for urban areas where practical lane capacities of 1,500 vehicles per hour (C) on the normal sections will assure operating speeds of 35 to 40 mph. The resulting slowdown at the weaving section for the vehicles involved in the weaving maneuvers was considered reasonable for these conditions.

Where higher or lower speeds than these occur on the approach roadways for the corresponding traffic volumes, the speeds of the weaving vehicles may also be expected to be correspondingly higher or lower. For example, when the operating speeds are 40 to 45 mph on the normal sections of highway when the volume is 1,500 vehicles per lane, the speeds of the weaving vehicles as selected from the 30-mph curve can be expected to be 35 rather than 30 mph and if 1,500 is used as the value of C, vehicles not involved in the weaving can be expected to negotiate the section at an average speed of 40 to 45 mph. This would, however, be an unusual condition, because at most locations speeds on the normal sections are 35 to 40 mph at volumes of 1,500 vehicles per lane.

4. It should be noted that no speed value has been placed on the curve for maximum possible capacity. This is because some sections attain their maximum capacity with the faster weaving vehicles averaging close to 30 mph, whereas at others the maximum capacity is attained with stop-and-go operation by nearly all the weaving vehicles. The same location may in fact accommodate the same maximum volume under several different operating conditions, but in each case the average speed of the weaving vehicles is below 30 mph. It is not correct, therefore, to assume that the higher volume curve is for 20 mph and that values for intermediate speeds can be obtained by interpolation.

5. In applying the equation for the number of lanes, the value of C must be adjusted for lane width and other factors (such as trucks) in the same manner as for other free-flowing facilities in determining both practical and possible capacities.

6. The note at the bottom of Figure 1 which reads: "In general when an outer flow exceeds 600 passenger cars per hour, the section should be wide enough to provide a separate lane for this movement," is not intended to imply that one lane should be added for each such movement in addition to the number, N, calculated by the formula. It was the intent that when separate lanes are provided for outer flows in excess of 600 vph, the appropriate symbol (F_1, or F_2, or both) would be omitted from the equation for determining the number of lanes. The lanes provided separately for outer flows would then be added to the number required for the weaving vehicles in order to obtain the total number of lanes in the section. It is only when N is less than 3 for a total flow with one outer movement exceeding 600 vph, or N is less than 4 for a total flow with both outer movements exceeding 600 vph, that one additional lane is recommended for each outer flow above 600 vph.

7. The relationship between the length and width of the weaving section as shown by Figure 1 will result in the minimum number of traffic lane miles within the weaving section to effect the crossing of the two traffic streams with an assurance of attaining the desired operating conditions. In many instances it is possible or more feasible to provide weaving sections longer than the needed lengths as shown by Figure 1. An adjustment may then be made in the width of the weaving section, because the necessary weaving maneuvers may be made over a longer distance. The adjustment is made in the term $3W_2$ and is based on the criterion that the added gaps needed for the weaving maneuvers vary inversely as the ratio between the actual length and the minimum required length as shown by Figure 1. For example, if Figure 1 shows that a weaving section 500 ft long is required, but a 1,000-ft section is provided, the term $3W_2$ becomes $\left[\frac{2\ (\text{Length as shown by Fig. 1})}{\text{Actual length}} + 1\right] W_2$ or $2W_2$. Likewise, if the section were actually three times as long as indicated by Figure 1, the term $3W_2$ would become $1.7W_2$.

Comprehensive studies are now under way to determine the effect of ramp design and the spacing between interchange ramps on freeway traffic operations. Until the results of these studies become available, it will not be possible to establish definite criteria governing the effect that weaving maneuvers between "on" and "off" ramps widely spaced have on the capacities of the intervening roadways. Lane usage or the distribution of traffic by vehicle type in the various lanes, the normal shifting between lanes because of speed differentials, and the lengths of the acceleration and deceleration lanes are but a few of the factors involved.

Oftentimes, on expressways, a weaving section may have more than two entrances or exits adjacent to one another or so closely spaced as to form a compound weaving section, or two weaving sections that overlap. When there are two entrances and three exits, or three entrances and two exits, there may be six different movements rather than four as in a weaving section with two entrances and two exits. Although traffic operation studies have been conducted at few such locations, the results indicate that Figure 1 can be applied by employing a somewhat modified treatment.

The required length of a section with three entrances or exits adjacent to one another may be determined by using the total number of weaving maneuvers that must be performed. In calculating the total number of lanes required the number of vehicles involved in the minor movements, wherever two movements cross, are tripled and added to the major crossing movements. For example, if the two entrances from left to right are A and B and the exits from left to right are X, Y, and Z, the two outer movements not involved in weaving would be AX and BZ. The maneuvers involved in weaving would be AY, AZ, BX, and BY. AY would cross BX, and AZ would cross both BX and BY. The number of weaving maneuvers in calculating the required length of the weaving section would become AY + BX + 2AZ + BX + BY, or AY + 2BX + 2AZ + BY. In calculating the number of lanes required, N, when AY > AZ > BX > BY, the numerator of the equation becomes AX + BZ + AY + 3BX + AZ + 3BX + 3BY + AZ, or AX + BZ + AY + 2AZ + 6BX + 3BY.

When the three entrances or the three exits are not adjacent to one another, the same principles may be applied by separating the overlapping weaving sections and making separate calculations for each. There is, in effect, a long weaving section which overlaps a shorter weaving section. The capacity analysis may be performed by separting the overlapping sections into two separate weaving areas and applying the principles previously discussed.

The weaving maneuvers must, however, be separated into two groups: (a) those that must be performed in the shorter section and (b) those that may be performed at any point over the entire section.

To check a fixed design, as many as possible of the weaving maneuvers in the second group are assigned to the area of the longer section which does not overlap the shorter section. Then those in the first group, and the balance of the second group, must be accommodated in the shorter section. Such a procedure could be followed to check the capacity of the example previously used to illustrate a weaving section with three exits, if exit X or exit Z occurred in advance of the other two exits and the distances between entrances and exits were fixed. When these distances are not fixed, several repeat calculations must be made to obtain a reasonable design, because there would be a large variety of lengths that could be employed in combination with different widths.

REFERENCE

1. "Highway Capacity Manual," U.S. Govt. Printing Office, Washington, D.C. (1950).