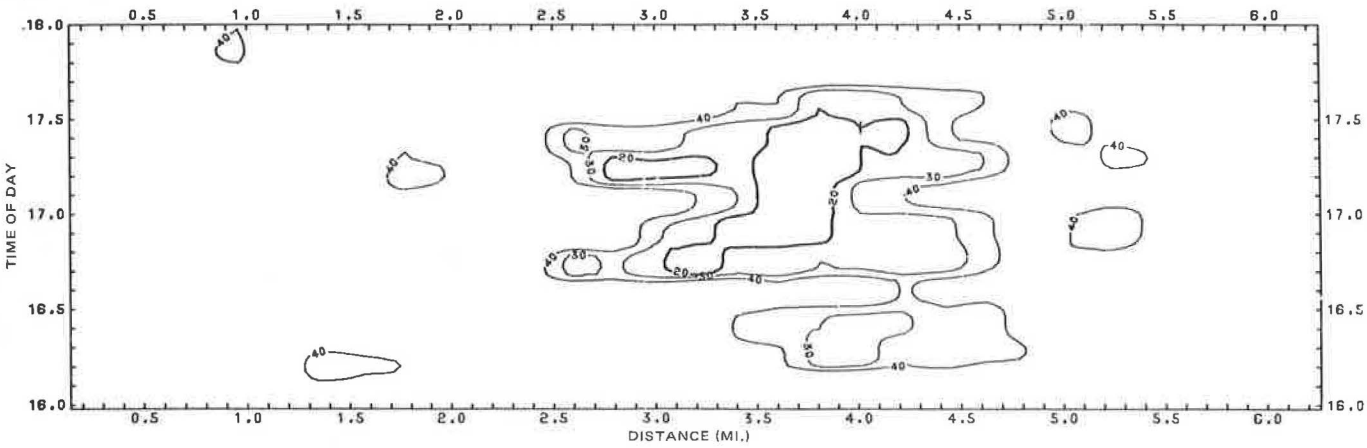
Figure 6. Speed contour map.



related plot is the speed profile (see Figure 5), which shows as many as 10 runs on the same plot, for ease of comparison. A different plot is the speed contour map (see Figure 6), which shows speed isopleths (contours) versus distance and time of day. Because it pictorially portrays magnitude, location, and duration of congestion, this is probably the most powerful output. It is meaningful to both the traffic engineer and the layperson.

Any of these outputs are available for any desired combination of runs.

CONCLUSIONS

TRANS uses advanced computer and traffic engineering techniques to achieve dramatic improvements in both the cost and the effectiveness of traffic-flow data collection. Costs are reduced because TRANS automates all three of the steps required for traffic-flow studies: data collection, analysis, and presentation. Effectiveness is greatly improved because TRANS measures all of the traffic-flow parameters that are currently of concern: distance, travel time, speed, number of stops, stop time, flow smoothness, fuel consumption, air pollutant emissions, and user costs. Several valuable digital plots, including the well-recognized speed profiles and the more striking speed contour maps, are also available.

TRANS can be a powerful analysis and evaluation tool for traffic-signal-system projects, freeway ramp-metering projects, roadway channelization and geometric improvement projects, inventories of travel time and operating speed, and energy and air pollution studies.

REFERENCE

1. P.S. Parsonson. Cost-Effectiveness of RUNCOST Evaluation Procedure. TRB, Transportation Research Record 630, 1977, pp. 21-24.

Publication of this paper sponsored by Committee on Traffic Flow Theory and Characteristics.

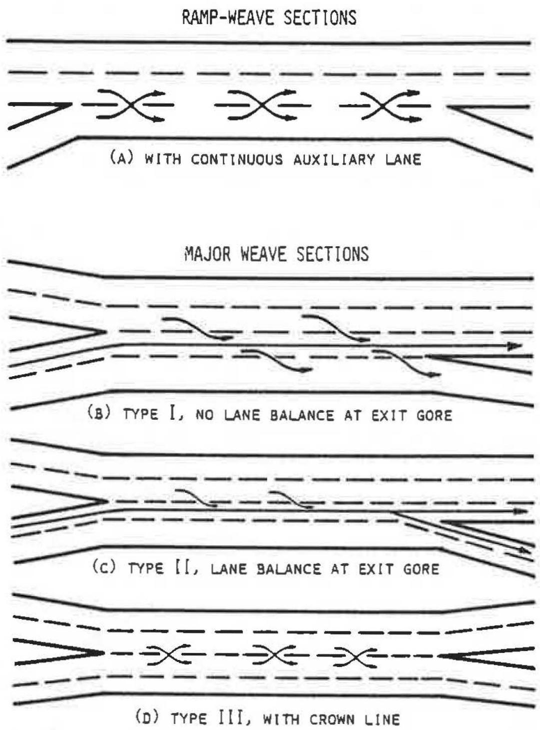
Revision of NCHRP Methodology for Analysis of Weaving-Area Capacity

ROGER P. ROESS, WILLIAM R. McSHANE, AND LOUIS J. PIGNATARO

As part of an effort sponsored by the Federal Highway Administration (FHWA) to revise and update procedures for freeway capacity analysis, the weaving-area methodology developed as a result of National Cooperative Highway Research Program (NCHRP) Project 3-15 was revised with two objectives in mind: (a) to recalibrate the procedure to reflect modified service-volume concepts developed in other parts of the FHWA effort and (b) to simplify the structure of the NCHRP procedure to make it easier to apply and understand while retaining its demonstrated accuracy and sensitivity to lane configuration, a major factor in highway operations. The revised method was developed by using standard multiple regression techniques and a data base consisting of results of the 1963 U.S. Bureau of Public Roads study of weaving-area capacity and the results of extensive data collection on NCHRP Project 3-15. The procedure consists of calibrated relations governing (a) the operation of nonweaving vehicles in weaving areas; (b) the maximum number of lanes that can be occupied by weaving vehicles for various configurations; (c) the "share", or percentage, of weaving-area lanes occupied by weaving vehicles under "balanced" operation; and (d) the relation between the average speed of weaving vehicles and that of nonweaving vehicles. To simplify the application of these relations in design and operational analysis, a series of nomographs has been developed.

In 1973, a major study of weaving-area operations was completed at the Polytechnic Institute of New York for the National Cooperative Highway Research Program (NCHRP) (1,2). The study resulted in the formulation of new procedures and relations for analysis of weaving-area capacity. These were (a) substantially more accurate than the procedures of the 1965 Highway Capacity Manual (HCM) in their representation of field conditions, (b) based on

Figure 1. Lane configurations for weaving areas.



consideration of lane configuration as a principal design and analysis parameter, and (c) able to predict cases in which weaving and nonweaving vehicles were operating "in balance," as well as cases in which they were not.

As part of a recent effort sponsored by the Federal Highway Administration (FHWA) to update and revise freeway capacity-analysis procedures, the 1963 and 1972 data bases were reexamined to determine whether or not the NCHRP procedure could be further improved. This reexamination was motivated by two factors:

1. The NCHRP relations were based on the acceptance of service-volume criteria given in Table 9.1 of the HCM (3). As a result of other findings of the FHWA study, it has been recommended that those service volumes be substantially revised (4).
2. The form of the NCHRP relations was found to be difficult for many people to use, a problem that has reduced the usefulness of the procedure to practitioners.

In the attempt to recalibrate the NCHRP procedure, there were three goals: (a) to improve its accuracy by considering the recalibration of HCM Table 9.1 standards, (b) to simplify the format and use of the procedure, and (c) to retain the advantages of greatly improved accuracy that the NCHRP procedure has over the 1965 HCM procedure.

LANE CONFIGURATION

The NCHRP study found that lane configuration was the principal parameter affecting the operation of weaving areas. Three types of lane configuration were identified as a result of the study; a fourth was added for the purposes of the FHWA effort.

Figure 1 shows the four types of weaving sections. These can be grouped into two broad categories: ramp weaves and major weaves. Ramp-weave sections are formed when an on ramp is followed by an off ramp and the two are joined by a continuous auxiliary lane. Major-weave areas are characterized by at least three of the input and output "legs" having two or more lanes.

The impact of configuration on weaving-area operations is highlighted in the three major-weave sections shown in Figure 1. These weaving areas have the same number of lanes and the same length and yet are substantially different operationally:

1. In the type 1 section, one weaving movement can be made without a lane change. The other weaving movement, however, requires two lane changes. This characteristic hampers the operation of weaving vehicles and limits the total number of lanes that weaving vehicles may occupy.
2. In the type 2 section, one weaving movement can also be made without a lane change. The reverse weaving movement, however, only requires one lane change. Thus, the type 2 section will provide for smoother operation of weaving vehicles and will allow them to occupy a larger number of lanes than a type 1 section. The difference between type 1 and type 2 sections is that the type 2 section provides for lane balance; that is, one lane divides to two at the exit gore so that a vehicle in that lane can travel down either exit leg without making a lane change.
3. The type 3 major-weave section has a weaving crown line--that is, a lane line that divides the section into distinct parts as it starts at the entrance gore point and connects directly to the exit gore point. In such sections, all weaving vehicles must execute one lane change. This somewhat restricts the operations of weaving vehicles; more importantly, it effectively restricts these vehicles to the two lanes adjacent to the crown line.

Ramp-weave sections are similar to type 3 major-weave sections in that they have a crown line. They differ, however, in that one input and one output leg are ramps, often with restrictive geometric features. Major weaves generally involve input and output legs that are high-speed collector-distributor roadways.

The importance of lane configuration in the development of a new or recalibrated procedure on weaving was recognized in the NCHRP study in the following ways:

1. It is not sufficient to define the total number of lanes (N) and the length (L) of a weaving section because operations may differ according to configuration features.
2. Consideration of a total N value is not sufficient to ensure proper design or analysis. The proportion of N used by weaving and nonweaving vehicles must be considered, and this factor is influenced by configuration.
3. Configuration of a given segment of width N (lanes) and length L (feet) is determined by the design and relative placement of entry and exit legs.

These factors were principal considerations in the development of the NCHRP procedure and were considered in the same light in the development of the recalibrated procedure. Configuration is discussed more fully elsewhere (5).

RECALIBRATION OF THE NCHRP PROCEDURE

Data Base

The data base used in the recalibration of the weaving procedure was the same as that used in the NCHRP study. This included data for 38 sites from

the 1963 Urban Area Weaving Capacity Study conducted by the then U.S. Bureau of Public Roads (BPR) and data for 14 sites collected specifically for the NCHRP study. The 1963 BPR data actually included 48 sites, but 10 were arterial cases that were deleted for this recalibration.

The 14 sites for which data were collected for the NCHRP study each contained about 4 h of data, broken into 6-min periods. The BPR data, which generally included fewer data for each site, were also broken into 6-min periods. The 6-min periods were aggregated into 12- and 18-min periods for comparative analysis. The NCHRP study based its calibrations on the 18-min aggregations because it concluded that 6- and 12-min data periods were "statistically unstable" and obscured any inherent relations. The same policy was adopted in this recalibration effort for similar reasons.

In general, the data base contains information on (a) segment geometry (width, length, configuration, and number of lanes), (b) segment volumes (6-min counts by flow components), and (c) segment speeds (6-min average speeds for each flow component). The 14 sites studied for NCHRP also contained additional information on lane changing and lane distribution of weaving and nonweaving vehicles.

Calibration Structure

Critical to any calibration effort that is to explicitly treat configuration as a key parameter is the ability to establish values in the data base for the number of lanes used by weaving vehicles (N_W) and the number of lanes used by nonweaving vehicles (N_{NW}) and to segregate the data base by configuration. Since N_W and N_{NW} were not directly observed, they must be computed or estimated. There are three alternatives:

1. Assume that nonweaving vehicles in a weaving section behave in essentially the same manner as vehicles in a basic freeway section. N_{NW} may then be computed by using the criteria for basic freeway segments, as recalibrated in the FHWA study, and N_W as $N - N_{NW}$. This was the technique used in calibrating the original NCHRP method, which used HCM criteria for basic freeway segments.
2. Assume an arbitrary relation for the behavior of nonweaving vehicles in a weaving section based on general observation of data trends. N_{NW} is then computed by using the assumed relation and N_W as $N - N_{NW}$.
3. Assume that there is a maximum value of N_W that can be achieved for each type of configuration and that cases in which the average speeds of weaving vehicles and nonweaving vehicles differ markedly [by more than 5 miles/h (8 km/h)] have reached this maximum value. Then, for these cases, N_W is set based on assumed values, and N_{NW} is computed as $N - N_W$. A regression relation is developed between N_{NW} and known variables for these cases and applied to compute N_{NW} for all other cases, for which N_W becomes $N - N_{NW}$.

The third alternative involves the concept of "constrained" versus "unconstrained" operation of weaving areas and the identification of such cases in the data base. If there is indeed a maximum practical value of N_W for any given configuration, then weaving vehicles, no matter what their volume, cannot occupy more than that number of lanes. In the normal case, weaving and nonweaving traffic compete for space on the roadway and reach some equilibrium so that both traffic streams experience relatively uniform operating conditions. However, if the configuration and the conditions are such that this equilibrium would occur with a value of N_W that is greater than the maximum value for the configuration, weaving vehicles will be constrained to occupy the maximum value of N_W, which is less than the equilibrium value, and nonweaving vehicles will occupy a value of N_{NW} lanes proportionally larger than the equilibrium value. The result will be that nonweaving vehicles will experience markedly better service than weaving vehicles, as indicated by higher average speeds.

All three techniques outlined above were investigated during this recalibration. Alternative 1 resulted in statistically poor fits to data during later analysis. Alternative 3, which appeared fruitful at first, led to internal inconsistencies in the maximum values of N_W for each configuration. Alternative 2 proved the most successful. Because it requires the postulation of a relation for nonweaving vehicles in weaving sections, numerous trials were required. Each was evaluated for the reasonableness and internal consistency of the results produced and the statistical accuracy of the regression relations generated.

The final output of the recalibration was a series of equations of the following form:

1. Nonweaving vehicles--an equation relating nonweaving volume to the number of nonweaving lanes (N_{NW}) and the average speed of nonweaving vehicles (S_{NW}) (this relation was postulated for each trial calibration);
2. Maximum values of N_W--for each type of configuration, a relation governing the maximum value of N_W, calibrated by using data from cases in which constrained operation was evident;
3. Speeds--for each type of configuration, a relation between the speed of weaving vehicles (S_W) and the speed of nonweaving vehicles (S_{NW}) (this relation was calibrated); and
4. Share of the roadway--for each type of configuration, a relation governing the proportion of total lanes occupied by weaving vehicles (N_W/N) (this relation was calibrated).

Some of the calibrated relations are primary--that is, they are valid for all cases of a particular configuration. Others are secondary, or valid only for unconstrained cases in which the equilibrium value of N_W is less than the maximum value of N_W for the configuration.

A set of equations was calibrated for ramp-weave sections and for type 1 and type 2 major-weave sections. The data base available did not include any cases of type 3 major-weave sections.

Recalibrated Relations

The recalibrated relations are given, in the form previously described, in Table 1, where

V_{NW} = volume of nonweaving vehicles (passenger cars/h),
V_W = volume of weaving vehicles (passenger cars/h),
S_{NW} = average speed of nonweaving vehicles (miles/h),
S_W = average speed of weaving vehicles (miles/h),
N_{NW} = number of lanes occupied by nonweaving vehicles,
N_W = number of lanes occupied by weaving vehicles,
N = total number of lanes in the weaving section = $N_W + N_{NW}$,
N_W(max) = maximum number of lanes that may be occupied by weaving vehicles,

Table 1. Calibrated relations for weaving areas.

Category	Equation No.	Equation	Type of Equation	Regression Coefficient	No. of Samples	F-Test Results
Nonweaving vehicles	1	$V_{NW} = 1500N_{NW} - 50S_{NW} + 1900$	Primary	–	–	–
Maximum value of N_W						
Ramp weaves	2	$N_W(max) = 2.0$	Primary	–	–	–
Type 1 weaves[a]	3	$\log N_W(max) = 0.714 + 0.480 \log R$	Primary	0.788	5	R not significant
Type 2 weaves	4	$\log N_W(max) = 0.896 + 0.186 \log R - 0.402 \log L_H$	Primary	0.655	19	R, L_H significant
Speed						
Ramp weaves	5	$\log S_W = 0.142 + 0.694 \log S_{NW} + 0.315 \log L_H$	Primary	0.883	142	S_{NW}, L_H significant
Type 1 weaves	6	$S_W = 15.031 + 0.819S_{NW} - 24.527\ VR$	Secondary	0.982	36	S_{NW}, VR significant
Type 2 weaves	7	$S_W = 2.309 + 0.871S_{NW} + 4.579\ VR$	Secondary	0.931	43	S_{NW}, significant VR not significant
Share of the roadway						
Ramp weaves	8	$\log N_W/N = 0.340 + 0.571 \log VR - 0.438 \log S_W + 0.234 \log L_H$	Secondary	0.764	109	VR, S_W, L_H significant
Type 1 weaves	9	$N_W/N = 0.761 - 0.011L_H - 0.005\Delta S + 0.047\ VR$	Primary	0.719	41	L_H, significant VR, S not significant
Type 2 weaves	10	$N_W/N = 0.085 + 0.703VR + (234.763/L) - 0.018\ \Delta S$	Primary	0.834	62	VR, L, ΔS significant

[a]Equation valid only for lengths in the range between 400 and 700 ft (122-213 m); outside this range use 85 percent of the value given by Equation 4.

L = length of the weaving section (ft),
L_H = length of the weaving section (ft 00s),
VR = ratio of weaving volume to total volume,
R = ratio of the smaller weaving volume to total weaving volume, and
$\Delta S = S_{NW} - S_W$.

Some key characteristics of these results are discussed below.

Nonweaving Vehicles

Through some of the earlier calibration attempts, two characteristics of nonweaving vehicles in weaving sections had become clear: (a) that nonweaving vehicles behave quite differently in weaving sections than they do on basic freeway sections and (b) that the relation between V_{NW} and S_{NW} appeared to be linear throughout the range of stable flow. Because of the increased level of lane changing and turbulence in the weaving area, speed is sensitive to volume levels not only as volume approaches capacity but throughout the stable flow region, as was found to be the case in basic sections. In general, a nonweaving vehicle traveling at a given speed will occupy more space in a weaving area than on a basic section--a reasonable result considering the additional turbulence caused by weaving.

Ramp Weaves Versus Major Weaves

There is a basic difference between the operational characteristics of a ramp-weave section and a major-weave section. In a ramp weave, ramp vehicles generally enter and exit at significantly reduced speeds, mainly because of restrictive ramp geometry and well-established driving habits. Thus, ramp vehicles are virtually always accelerating or decelerating through the ramp-weave section, and the average speed depends not on the competition for space between weaving and nonweaving vehicles but on the length of the section.

This creates two major difficulties. Since speed depends on length and not the results of the competition for space, it is not valid to identify operating conditions as constrained based on observations of large values of ΔS [>5 miles/h (>8 km/h)]. In shorter sections, large ΔS values will occur whether or not the section is operating in the constrained or unconstrained state.

Values of $N_W(max)$, therefore, could not be calibrated by using constrained-section data. Rather, a relation for $N_W(max)$ was needed to determine whether the segment was constrained or unconstrained. Logically, weaving vehicles in a ramp weave were substantially restricted to the use of the two lanes adjacent to the crown line. A review of the data substantiated this theory; an N_W of 2.0 appeared to be the maximum value achieved. Thus, an $N_W(max)$ of 2.0 was established for ramp-weave cases, and any case in which N_W approached or slightly exceeded this value in the data was categorized as constrained.

Thus, for ramp weaves, S_W is a function of S_{NW} and L_H, where L_H--the length of the section in hundreds of feet--does not depend on the relative presence of nonweaving flows. Furthermore, the relation is primary--that is, it does not depend on whether the section is operating in the constrained or unconstrained state.

In the case of major weaves, all vehicles usually enter and leave the section at normal freeway speeds, and little acceleration or deceleration takes place within the confines of the weaving area. Thus, unless they are prevented from doing so by a configurational constraint, weaving and nonweaving vehicles will compete for space and reach an equilibrium in which the speeds of both are reasonably similar [$\Delta S \leq 5$ miles/h (8 km/h)]. In such cases, large values of ΔS can be used to identify constrained cases.

For major weaves, then, S_W is a function of S_{NW} and VR, where VR is a measure of relative weaving and nonweaving flows. The relation is secondary, however, and holds only for unconstrained cases. Where constraints prevent the balance from being reached, the primary relation is the share-of-the-roadway equation, in which N_W/N is a function of VR, L_H, and ΔS.

$N_W(max)$ Regressions

The regression relations for $N_W(max)$ are the weakest of the set because of the small number of constrained cases available for their calibration. It might reasonably be expected that as length increases $N_W(max)$ does too, since more vehicles have the opportunity to weave via multiple lane changes. L, however, does not even enter the relation for type 1 segments and, for type 2 segments, the opposite trend is exhibited: As length increases, $N_W(max)$ decreases. A review of the data, however, confirms the latter trend. In shorter sections, the weaving turbulence is greater and nonweaving vehicles are more strongly inclined to segregate into outer lanes than they are in

longer sections. In effect, nonweaving vehicles give weaving vehicles "wider berth" in shorter sections to avoid higher turbulence levels.

Significance Levels

The F-test is used to determine whether the coefficient of a particular independent variable is significantly different from zero, in the strict statistical sense. In the development of the recalibrated procedure, four coefficients among the equations developed failed this test. Nevertheless, they are used because (a) their inclusion is necessary in order to produce a procedure capable of considering relevant demand and design variables and (b) the trends displayed in each case are physically meaningful and reasonable.

In each case, the inclusion of the variable did result in a higher multiple correlation coefficient. It is judged that a larger data base would have eliminated these F-test failures and that inclusion of the affected variables as indicated here does not pose a problem.

PROCEDURE FOR USING THE RECALIBRATED EQUATIONS

The methodology adopted for use of these equations is relatively straightforward even though it involves trial-and-error solutions. It is used only in the analysis mode; i.e., given a known situation, compute the expected speeds of weaving and nonweaving vehicles. Design is by trial and error. This is reasonable in that, for a given design, the practical value of N will be limited to two or three feasible integer values and L will be restricted to a range of about ±500 ft (±152 m). Thus, a maximum design within these limits is easily formulated and analyzed.

Before one begins the computations, two preliminary steps must be taken:

1. Convert all flows to passenger cars per hour and peak flow rates:

$$\text{Peak flow rate} = V/(PHF \times Q) \quad (11)$$

where

peak flow rate = passenger cars per hour,
V = volume (vehicles/h),
PHF = peak-hour factor, and
Q = correction factor for the combined effect of trucks, buses, and recreational vehicles on the traffic stream (6).

2. Construct a weaving diagram by using the converted peak flow rates. Compute the required parameters VR and R (as defined earlier).

Steps 1-7 below are iterative. A value of S_{NW} is assumed and then checked through successive computations. When the values agree closely [within ±2 miles/h (±3.2 km/h)], the computations are complete. It is imperative, however, that trials be conducted, starting with the high speeds. For unfamiliar users, computations may start with an assumed value of S_{NW} between 50 and 60 miles/h (80 and 96 km/h).

The steps are as follows:

1. Assume a value of S_{NW}.
2. Compute S_W by using the speed equation in Table 1 for the configuration under consideration.
3. Compute $N_W(max)$ by using the maximum-value-of-N_W equation in Table 1 for the configuration under consideration.
4. Compute N_W/N by using the share-of-the-roadway equation in Table 1 for the configuration under consideration.
5. Compute $N_W = (N_W/N) \times N$. If $N_W > N_W(max)$, the segment is constrained; go to step 6. If $N_W \leq N_W(max)$, the segment is unconstrained; go to step 7.
6. Set $N_W = N_W(max)$ and compute the resulting values of N_{NW} and N_W/N. Compute S_{NW} from Equation 1 in Table 1. Compute S_W from the primary relation for the configuration under consideration. The constrained problem is now complete.
7. Compute $N_{NW} = N - N_W$. Compute S_{NW} from Equation 1 in Table 1. If this S_{NW} is within ±2 miles/h (±3.2 km/h) of the assumed S_{NW}, the problem is complete. If it is not, assume another speed somewhat slower than the computed S_{NW} and repeat the computations.

Nomographs developed for each equation to aid in the computational procedure are shown in Figures 2-5.

SAMPLE PROBLEM

To illustrate the use of the recalibrated methodology, a sample problem is presented. Figure 6 shows a ramp-weave configuration in which the volumes shown on the weaving diagram have already been converted to peak flow rates in passenger cars per hour. The problem is to analyze the operating conditions that are expected to prevail. The procedure includes the following numbered steps:

1. Assume a value of S_{NW} = 60 miles/h (96 km/h).
2. Compute S_W by using Equation 5 in Table 1 (shown in Figure 4a): S_W = 49 miles/h (78.4 km/h).
3. Compute $N_W(max)$ by using Equation 5 in Table 1 (shown in Figure 3): $N_W(max)$ = 2.0 lanes.
4. Compute N_W/N by using Equation 8 in Table 1 (shown in Figure 5a): N_W/N = 0.26.
5. Compute N_W = 0.26 x 4 = 1.04 lanes. Is $N_W \leq N_W(max)$? If yes, the section is unconstrained; go to step 6.
6. Compute N_{NW} = 4 - 1.04 = 2.96 lanes. Compute S_{NW} from Equation 1 in Table 1 (shown in Figure 2): S_{NW} = 45 miles/h (72 km/h).

Since the computed value of S_{NW} (45 miles/h) does not closely agree with the assumed value of 60 miles/h, a second trial is obviously necessary. As indicated in the instructions for step 6, a second iteration will begin with an assumed value of S_{NW} that is somewhat lower than 45 miles/h:

1. Assume a value of S_{NW} = 42 miles/h (67.2 km/h).
2. Compute S_W by using Equation 5 in Table 1 (shown in Figure 4a): S_W = 38 miles/h (60.8 km/h).
3. Compute $N_W(max)$ = 2.0 lanes (as before).
4. Compute N_W/N by using Equation 8 in Table 1 (shown in Figure 5a): N_W/N = 0.29.
5. Compute N_W = 0.29 x 4 = 1.16 lanes. Is $N_W \leq N_W(max)$? If yes, the section is unconstrained; go to step 6.
6. Compute N_{NW} = 4 - 1.16 = 2.04 lanes. Compute S_{NW} from Equation 1 in Table 1 (shown in Figure 2): S_{NW} = 42 miles/h (67.2 km/h).

Since the agreement between the computed and assumed values of S_{NW} is within 2 miles/h (3.2 km/h) (exact in this case), the problem is complete. Operations with an average speed for nonweaving vehicles of 42 miles/h (67.2 km/h) and an average speed for

weaving vehicles of 38 miles/h (60.8 km/h) would be expected.

LEVELS OF SERVICE

Because the procedure developed includes S_W and S_{NW} as explicit parameters in equations and nomographs, the defining of criteria for levels of service becomes primarily an issue of policy. In the FHWA effort, of which the work reported here is a part, levels of service for weaving areas were defined based on the following criteria:

1. As in other parts of the FHWA work, average running speed (also called space mean speed) was used as the defining parameter.
2. Since situations can and do arise in which weaving and nonweaving vehicles experience markedly different operating conditions, levels of service should be separately assigned to describe the operation of weaving and nonweaving flows.
3. It is assumed that for a given level of service weaving drivers will tolerate average running speeds up to 5 miles/h (8 km/h) slower than the speed of nonweaving drivers because of the complexity of the required weaving maneuver. Data analysis bears out the assumption of this maximum 5-mile/h speed differential as the limit of normal unconstrained operation.

Figure 2. Speed-flow relation for nonweaving vehicles in a weaving section.

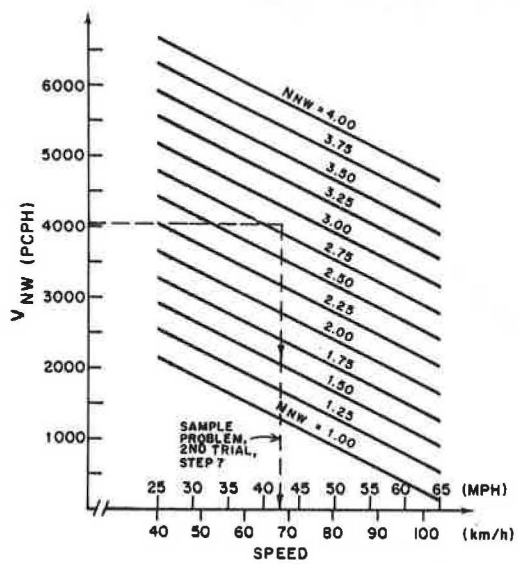


Figure 3. Maximum values of N_W in major-weave sections.

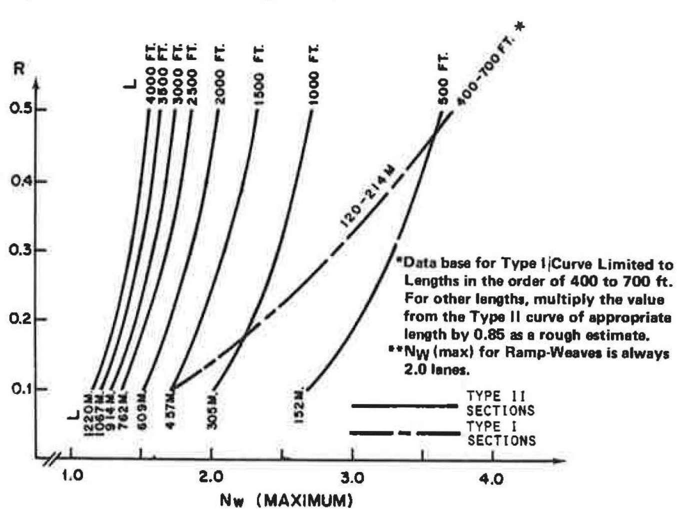
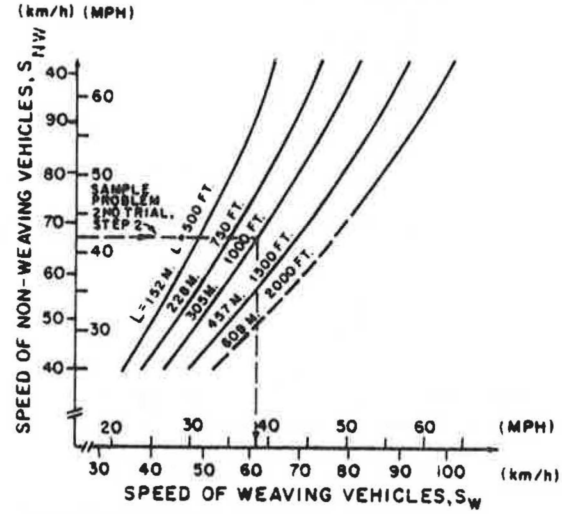
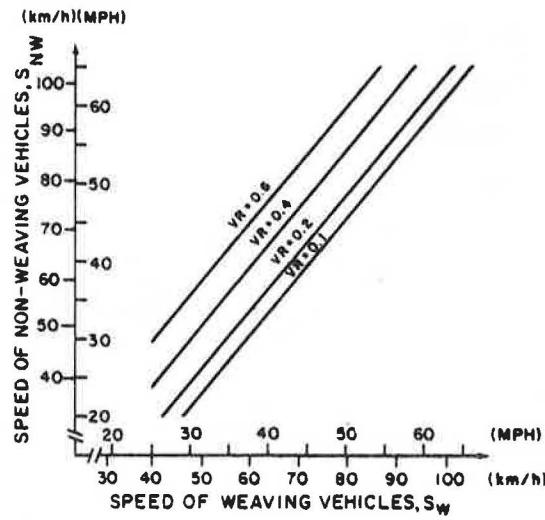


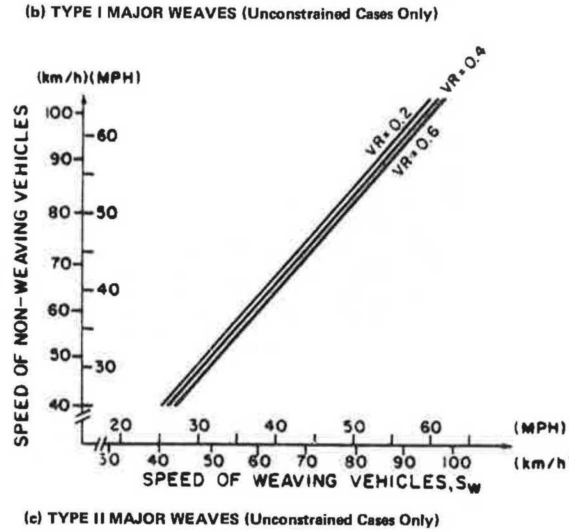
Figure 4. Speed relations for weaving configurations.



(a) RAMP-WEAVES (all Cases)

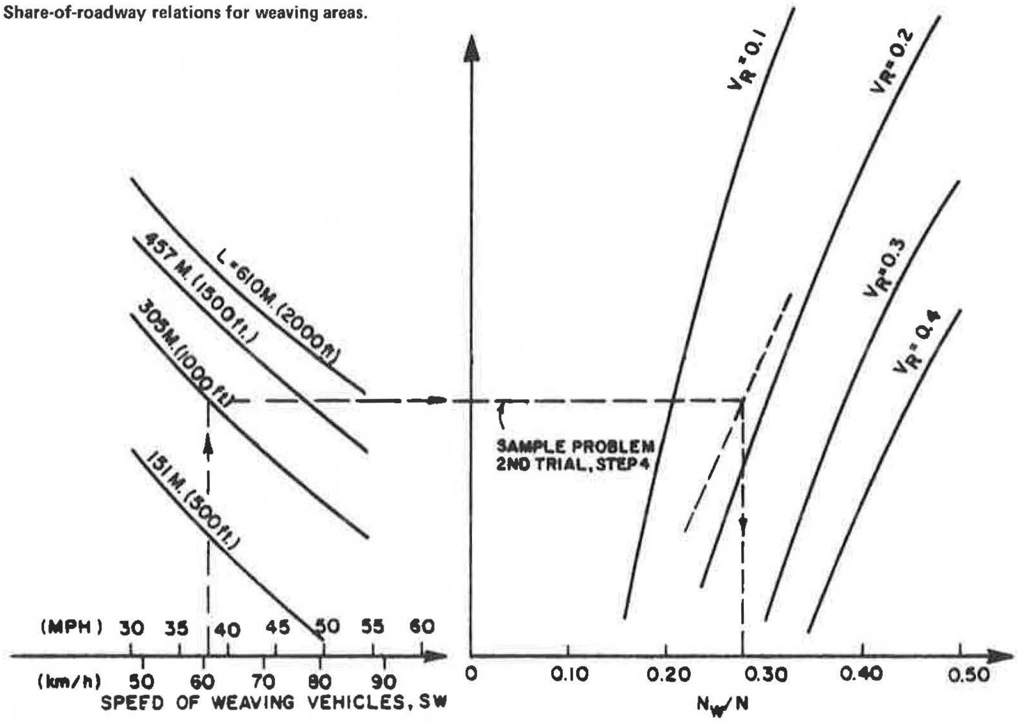


(b) TYPE I MAJOR WEAVES (Unconstrained Cases Only)

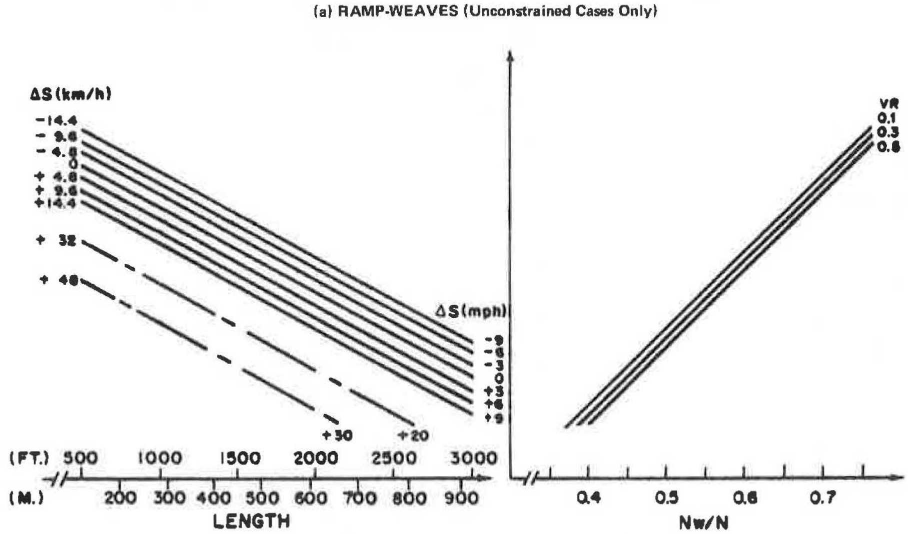


(c) TYPE II MAJOR WEAVES (Unconstrained Cases Only)

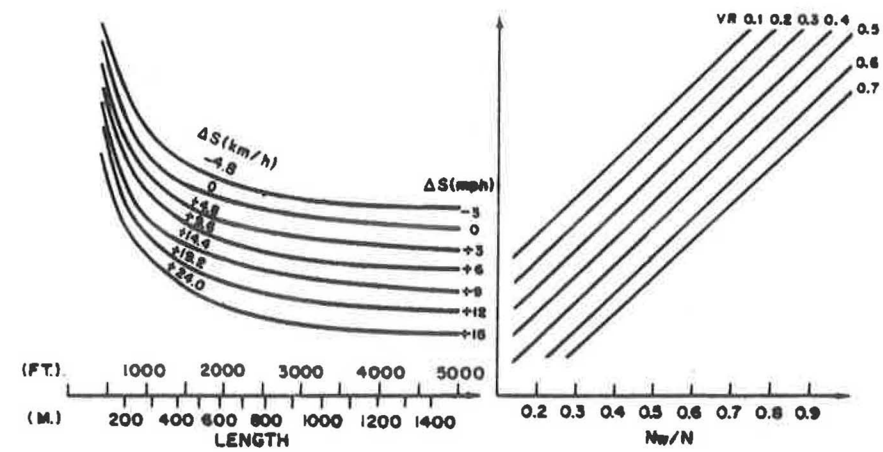
Figure 5. Share-of-roadway relations for weaving areas.



(a) RAMP-WEAVES (Unconstrained Cases Only)

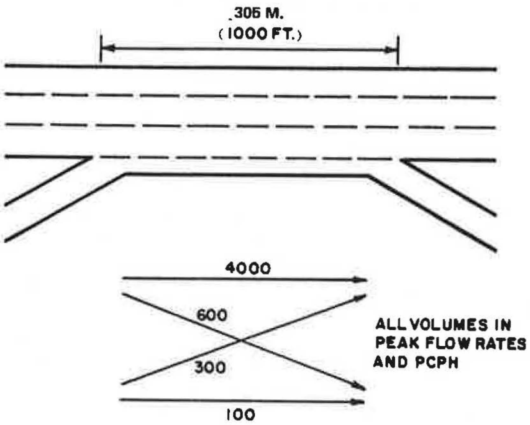


(b) TYPE I MAJOR WEAVES (All Cases)



(c) TYPE II MAJOR WEAVES (All Cases)

Figure 6. Sample problem.



$$R = \frac{300}{900} = 0.333$$

$$VR = \frac{900}{5000} = 0.180$$

4. It is further assumed that nonweaving drivers would expect primarily speeds equal to those experienced on basic freeway segments for a given level of service.

The resulting criteria for levels of service in weaving areas are given below (1 mile/h = 1.6 km/h):

Level of Service	Avg S_{NW} (miles/h)
A	≥ 50
B	≥ 45
C	≥ 40
D	≥ 35
E	≥ 30
F	<30

Level of Service for Weaving Vehicles Versus That for Nonweaving Vehicles	ΔS (miles/h)
Same	≤ 5
One level poorer	≤ 10
Two levels poorer	≤ 15
Three levels poorer	≤ 20
Four levels poorer	≤ 25

For the sample problem described earlier, the level of service for weaving as well as nonweaving vehicles is C. Had the problem been solved by using the methodology in Chapter 7 of the HCM, the results would be quality of flow III, which predicts operating speeds of about 40 miles/h (64 km/h) for weaving vehicles, and level of service C, which predicts operating speeds for all vehicles of more than 50 miles/h (80 km/h). The solution given here indicates significantly lower speeds, particularly for nonweaving traffic. Furthermore, whereas the HCM speed predictions seem to indicate substantial imbalance between weaving and nonweaving speeds, the solution given here clearly indicates a balanced operation.

VALIDATION

Because of the number of cells into which the data base was divided, there were not sufficient data to withhold cases for validation. The results were, however, checked with those given by the original NCHRP procedure, which had been validated. The results compare favorably: The new procedure is more sensitive to configurational variables than the NCHRP procedure.

An opportunity to apply the procedure to an external case has presented itself through work currently being done by the firm of Howard, Needles, Tammen, and Bergendoff under an FHWA contract to redesign a weaving area on the Shirley Highway (I-95) between the Capital Beltway (I-495) and the Springfield Interchange. The recalibration procedure was applied, and it accurately predicted the existing breakdown conditions in the area (the HCM method indicated level of service D). It was also used to evaluate a series of alternatives that were under consideration and highlighted the importance of configuration to the case.

The complete procedures for basic freeway segments, weaving areas, and ramp junctions developed as a result of the FHWA contract on freeway capacity-analysis procedures have been published elsewhere (7).

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The views and opinions expressed here are ours. The procedures described do not represent standards or methods endorsed by the Federal Highway Administration or any other agency.

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