RECOMMENDED PROCEDURE FOR WEAVE-AREA OPERATIONS AND DESIGN

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ABRIDGMENT

•TWENTY-FIVE years have passed since the original Highway Capacity Manual (1) first appeared in print. Since then, the procedures developed in the first manual as well as the modifications, extensions, and new methodologies presented in the 1965 edition of the Highway Capacity Manual (HCM) (2) have become national guides in the design and analysis of highway sections. As such, they have been exposed, through constant application, to detailed scrutiny by traffic planning, design, and operation specialists. Such exhaustive on-the-job evaluation has exposed problem areas, instructions that may be subject to misinterpretation, procedures that are complex and difficult to apply, and results that sometimes appear unreasonable.

In 1969, the National Cooperative Highway Research Program (NCHRP) authorized Project 3-15. The project statement stated: "Design criteria for weaving sections on multilane controlled-access highways require revision and updating, taking into account such variables as roadway geometrics, composition of traffic, volumes of mainline vehicles, and volumes of weaving vehicles."

As a result of an extensive evaluation of the accuracy and consistency of existing weave-area design and analysis procedures, it was recommended that a new procedure be developed. This paper reports on that procedure.

The end result of research under NCHRP auspices should be of direct use to the practicing engineer. The final recommended procedure is written as a self-contained document within the final report (3) in which a computer program implementing the procedure is also described.

The program handles both design and analysis problems, ramp weave, and major weave. It includes a feature by which consecutive analysis problems may be done without intermediate headings, so that comparison is simplified. Another feature allows one to step through a range of weave volumes and design an appropriate length for each. In this way, one may plot required length as a function of weave volume when all other parameters are fixed.

As part of the research, 1 multiple weave site was filmed. On the basis of this and other data, guidelines for application of the recommended procedure to multiple weaves were generated.

DEVELOPMENT OF WEAVE PROCEDURE

The following are some of the general concepts or ideas integral to the weave procedure:

1. Mean space speeds rather than operating speeds are used to define levels of operation.
2. Service volume concepts of the HCM are adapted and used for nonweaving traffic.
3. Volumes are considered in passenger car equivalents in units of passenger cars per hour. Adjustments of vehicles per hour to passenger cars per hour are made according to the HCM.
4. Levels of service are defined separately for weaving and nonweaving flows.

5. Although balanced design (comparable levels of service) is sought, configuration may prevent it from being realized.

6. As far as basic relations are concerned, there are 2 sets of equations: 1 for major-weave sections and 1 for ramp-weave sections.

Consideration and awareness of configuration (section lane arrangement, including number of lanes on each leg) are important and essential elements of the recommended weaving procedure and should be kept in mind while all research is done.

It is of prime importance in design that the configuration be such that

1. The computed weaving width can be delivered,
2. Lanes required for each outer flow (nonweaving flow) can be delivered, and
3. Lanes on each input-output leg can handle volumes at the level of service desired.

One of the prime results of the research leading to the recommended procedure was the determination of the maximum width that can be used by weaving traffic. It was found that this depended on configuration.

DEVELOPMENT OF BASIC RELATIONS

Extensive analysis of both the macroscopic data (6-min or greater flows and speeds) and the microscopic data and models developed within this research project led to development of the regression-based relations that form the core of the recommended procedure.

Some of the characteristics of the calibration, beyond those already noted, are as follows:

1. During calibration, one should distinguish between ramp weaves and major weaves.

2. The proper range of the calibration was found to be 30 mph (48 km/h) or greater for nonweave speeds (S_{nw}s). This limit, the common limit for level of service, was found as a result of investigation; it was not an a priori assumption.

3. For major weaves, weave speed (S_w) can go as low as 20 mph (32 km/h) for $S_{nw}s \geq 30$ mph (48 km/h). This can be, and is, used to define a lower limit for weave level of service.

4. The resulting relations include S_{nw}s and S_ws (sometimes by $\Delta S = S_{nw} - S_w$) such that a continuum results rather than subcases for each of a set of levels of service. As a result, levels of service can be, and are, specified exogenously. Definitions that considered existing uses were selected.

5. Data aggregated in 18-min periods yielded better regularity than did 6- or 12-min periods. Longer periods did not improve regularity but did reduce the number of data points available. Calibration was based on 18-min time periods.

The best relationships describing weaving traffic were developed from the assumption that the ratio of weaving to total lanes is proportional (functionally related) to the ratio of weaving to total volume. That is to say, the percentage of width required by weaving vehicles is directly related to the percentage of total traffic that the vehicles constitute. Note that this relation involves both weaving and nonweaving types of flow in the determination of weaving. This is reasonable because, although flows are significantly segregated as vehicles enter the section, a physical overlap and interaction exist in the space the vehicles occupy.

MECHANISMS OF WEAVING: RESULTS

The project data base was used for a wide range of microscopic studies, and a number of microscopic models for various purposes were formulated. These investigations served 2 purposes: (a) they were a guide and a control in the macroscopic investigations, and (b) they provided a better understanding of the basic mechanisms of weave section operation.

These studies affirm that

1. There is a substantial presegration of weaving and nonweaving traffic as it enters the weave section. The degree of presegregation lessens as section length increases, but the sensitivity is significant [under 2,000 ft (610 m)] for ramp weaves.
2. Configuration is important.
3. The benefit of increasing length dissipates rapidly.
4. Weave sections often are controlled by specific concentrations of vehicles or "hot spots" within the weave section. Conversely, some areas within the weave section are underused.
5. As far as can be discerned, lane-change probabilities are not dependent on volume, longitudinal position within the weave section, or section length. They do vary according to essential or nonessential lane changing and, for nonessential changes, according to direction of movement.
6. A weave section may be, and frequently is, subjected to a wide range of conditions regarding flow levels. This range can cover a typical day, a few hours, or seasons.
7. In addition to substantial presegregation, the multiple weave site in the project data base also gave evidence that the allocation of weaving according to subsection lengths recommended in the HCM does not hold.
8. The difference in speed between the 2 weaving movements is such that heavier volume is almost always faster. This pattern is more pronounced for ramp weaves than for major weaves.
9. Although the accident rate is greater in weave sections than on open freeway sections, attributing this rate specifically to length, weave volume, or any other factor is not possible according to available data. In addition to the limited quantity of data, other factors such as signing may be predominant, and an investigation should take all factors into account.

SUMMARY

A new procedure for weave section design and analysis has been developed, and is recommended for use. A complete methodology and sample problems, which are given in the project report (3), explicitly recognizes the importance of configuration because configuration controls the maximum weaving width that can be delivered.

Although the formulation allows for an analytic solution, the nomographic approach or the computer program should be used. For analysis problems, nomographic approval requires an iterative solution with which a user can rapidly become facile. In design, such iterations are not required. The NCHRP report (3) contains results of the evaluation of previously existing procedures that are both accurate and consistent. It also presents a validation of the recommended procedure. Guidelines are presented for multiple weaves, but they are based on limited data. Although the data are limited, the practicing engineer must cope with the design and analysis of multiple weave sections. Therefore, the best possible guidelines should be developed from existing knowledge, and the engineer should be advised to use them with caution.

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