a. Do not use in a moving vehicle unless two men are in the car; it is not practical or safe to attempt to drive and use the chart simultaneously.
b. Care should be exercised in noting the distance that the observation is made and other variables which may affect the accuracy of the reading.
c. The readings should only be taken in daylight hours, and during periods of good visibility.
d. Concentrate upon the serious violators first. As experience is gained and as conditions on the road improve the less serious cases can be investigated.
e. On any notice of arrest or warning issued note under "violation" the density number appearing on the Ringelmann Chart. Example: Excessive Smoke—Reading No. 3 on Ringelmann Chart.

**New Material E. RAYMOND CATO, *Chief*
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APPROVED:
EDGAR E. LAMPTON
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WEAVING TRAFFIC

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SYNOPSIS

Cross weaving may occur on any type of highway or its connections and is a result of the convergence and relatively nearby divergence of traffic streams.

The section of the roadway in which cross weaving takes place is commonly known as a weaving area.

A weaving area can be constructed for but a fraction of the cost of an equivalent grade separated facility.

For successful operation of a weaving area, the speeds of the several traffic streams must be nearly equal. Uniformity of operating speeds can be achieved only when the three main elements of a weaving section are properly proportioned for the volume of traffic to be handled. A change in any one of these elements would alter the speed of the traffic streams, reduce the capacity, and affect the overall operation.

The three main elements of a weaving section are: (1) the angle of approach, (2) the width, and (3) the length.

The angle of approach affects the speed of the entering traffic, the angle of weaving, and the place of weaving.

The width of the weaving section must be sufficient to allow the traffic that is to weave to spread out laterally, thus creating the necessary gaps between vehicles and allowing weaving to take place throughout the length and width of the weaving section. This width must also be sufficient to carry the through traffic at each side without interference to the weaving vehicles.

More data are needed before determination can be made for the proper combination of length, width, and angle of approach for various volumes and speeds of traffic. The data available seem to indicate that if the maximum length is more than 900 ft. traffic streams tend to travel side by side, resulting in a forced weaving near the end of the weaving section.

Weaving has been defined as "The act performed by a vehicle in moving obliquely from one lane to an adjacent lane, thus crossing the path of other vehicles moving in the same direction."

Cross weaving is the converging at an oblique angle of separate traffic streams moving in the same general direction so that the streams cross each other in the weaving area and then diverge in separate traffic streams.

Cross weaving occurs whenever traffic streams come together and then separate. This may occur on all types of highways. For example, as shown in Figure 1, a divided highway may have an outer connection at one interchange and an inner connection at the next interchange. Traffic entering at the first interchange and desiring to use the outer connection would have to cross weave with the through traffic. Weaving areas may also occur at intersections at grade or at interchange areas.

Figure 2 shows weaving areas on the main roadways of an interchange area now under construction.

Another type occurs at the main connections of an interchange where it is necessary to provide for several turning movements. An example of the type is shown in Figure 3.

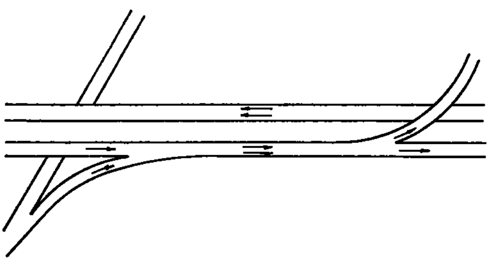

Figure 1. Weaving Area Between Interchanges

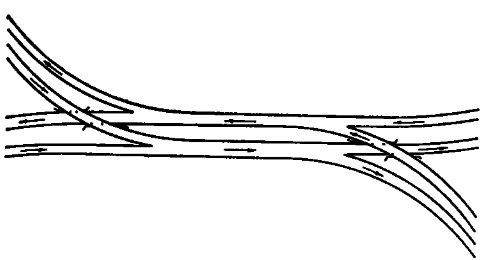

Figure 2. Weaving Area on Main Roadway

At the top of Figure 4 is shown a weaving area and below is shown a line diagram of a grade separated facility to handle the same traffic movements. The cost of the weaving area would in general be only a fraction of that of the grade separated facility. If the latter facility is constructed to adequate alignment and grades, considerable area would be required. As the intersecting roadways for a weaving area are at the same level, less grading is required and better grades and sight distance can be obtained.

For these reasons weaving areas have a definite place in modern highway design. Very little material has been published on this subject and designers have been handicapped by lack of satisfactory data. Particularly needed is more information on operating conditions for different types of design.

Field studies have been made of operating conditions on two weaving areas in New Jersey.

WEAVING AREA 1 AT INTERSECTION OF ROUTES 21, 25, AND 29

Figure 5 shows a weaving area at the intersection of Routes 21, 25, and 29. This 50-ft. wide and 395-ft. long weaving area is on tangent alignment but the curved entrance and exit roadways have center line radii of 140-ft. This facility was constructed in 1931 and in 1936 the weaving area was widened from 40-ft. to 50-ft.

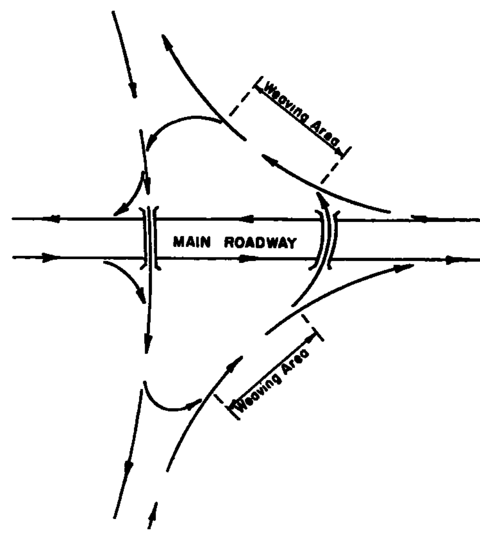

Figure 3. Weaving Area on Ramps

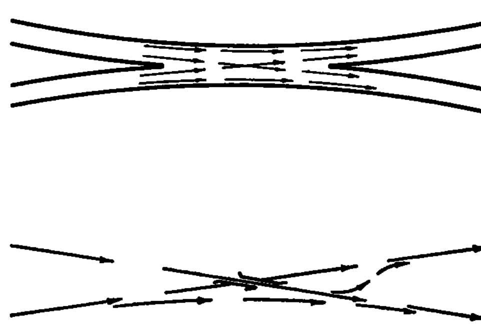

Figure 4

The percentage of the weaving traffic originating from each of the four entering lanes varied slightly for different volumes. At lower volumes a higher percentage of the weaving traffic originated from center lanes 2 and 3. The table on Figure 5 shows these percentages for weaving volumes of 2526 and 1968.

Figure 6 shows the place of weaving for traffic from each of the four entering lanes for a weaving volume of 2200 vehicles per hour. Due to the fact that traffic from inside lanes 2 and 3 is in a position to weave first, traffic

LANE	VOLUME 1968	VOLUME 2526
1	18%	24%
2	35%	39%
3	34%	21%
4	13%	16%

% of total weaving traffic originating from each lane

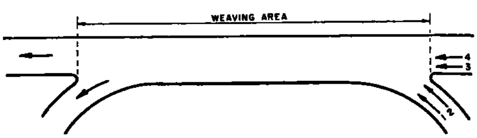

Figure 5. Weaving Area Intersection of Routes 21, 25, 829

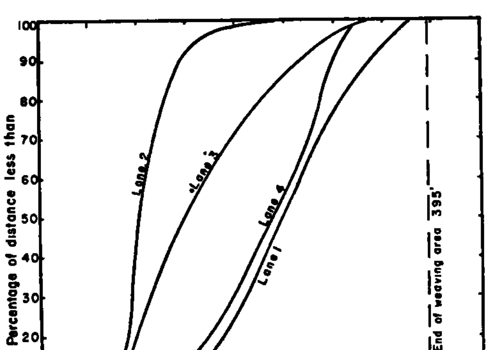

Figure 6

from outside lanes 1 and 4 weaves nearer the end of the weaving area. The place of weaving of lane 2 is nearer the beginning of the weaving area than lane 3. This is due to the angle of approach of the curved entering ramp. Traffic from lane 2 tends to follow the angle of approach and weave as soon as possible. A few drivers from lane 2 would stop and wait for a gap in order to weave near the entrance rather than continue and weave further down.

From observations at several weaving areas it is concluded that traffic approaching another stream at a large angle or from a sharp radius is given the impression of entering an intersection. As a result, some drivers tend to slow down or stop before weaving. Drivers also appeared to be hesitant to do any maneuvering when approaching from a sharp radius until straightened out sufficiently to reduce the side friction very nearly to zero.

At this location the percentage of traffic that stopped ranged from 1.8 percent for a weaving volume of 1000 vehicles per hour to 4.4 percent for a weaving volume of 2500.

For weaving volumes ranging from 1000 to 2500 vehicles per hour no relationship could be found between volumes and the place of

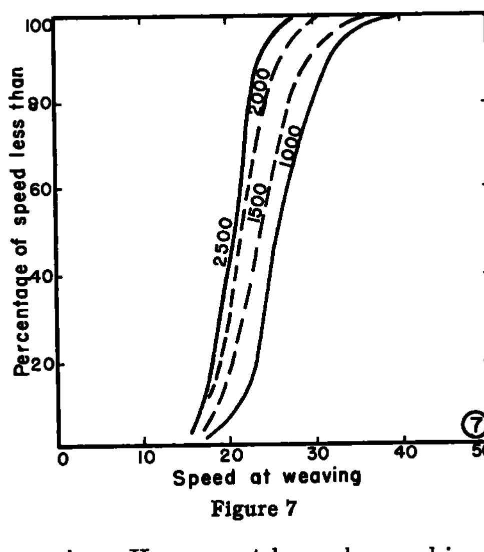

Figure 7

weaving. However, at low volumes, drivers had more freedom of movement and there was a tendency for some drivers to weave as soon as possible. This was especially noticeable for traffic from the curved entering ramp.

Figure 7 shows the relationship between weaving volumes and speeds of the weaving vehicles. These weaving speeds are from 3 to 5 miles slower than the average speed of the same vehicles for the full length of the weaving area. This is because some vehicles would have to make adjustments in speed before weaving.

In order to obtain the speeds of the vehicles, the time required for a vehicle to cross a certain number of joint lines was noted with a stop watch. Over 2000 speed checks were made at this location for various volumes of traffic.

The speed of the through traffic on the inside lane was practically the same as that of the weaving area. Through traffic on the outside land had nearly complete freedom of movement. As a result, the average speed for this lane remained nearly constant at 33 m.p.h. for all observed traffic volumes.

The maximum weaving volume during the period observed was at a rate of 2856 vehicles per hour—14.5 percent of this volume consisted of trucks. If one truck is considered equal to two passenger vehicles for purposes of capacity, on a passenger car basis the maximum weaving volume observed would be at a rate of 3276 vehicles per hour.

The total traffic through the weaving area at that time was 4770 vehicles per hour. On a passenger car basis this would be 5190 vehicles per hour. This maximum rate was observed for a period of 10 min.

Accident Record—In the last 5 years there have been 36 accidents at this location, 25 involving property damage only. The other 11 accidents caused 24 injuries. There were no fatalities. Some of these accidents had no connection with weaving but were due to faults of the vehicle or driver. For the 395-ft. long weaving section this gives a rate of 920 accidents per 100,000,000 vehicle miles and an injury rate of 612.

WEAVING AREA 2 AT FOUNDRY STREET RAMP ON ROUTE 25

Figure 8 shows the weaving area at Foundry Street Ramp on Route 25. This weaving area is 580-ft. long and 68-ft. wide at its narrowest point.

The maximum weaving volumes during the period observed was 1353. For a 10-min. period the maximum rate was 1878. About 25 percent of this volume consisted of trucks. On a passenger car basis the maximun weaving volume observed would be 2343 vehicles per hour and the total traffic through the area about 4000 vehicles per hour.

The speeds of over 3500 vehicles were determined at various volumes of traffic. Average speed of the traffic streams are shown on Figure 8. These speed are average speeds for the full length of the weaving area. No relationship could be found between speed and volume of traffic.

The place of weaving at different volumes was also observed and was found to be independent of the volume.

The reason for the lack of relationship between volume, speed and place of weaving is because none of the volumes of weaving traffic observed were at, or near, the maximum capacity.

Speed differentials between the weaving streams were in general quite small. Drivers did not hesitate to weave immediately in back of a vehicle in the other stream. This resulted in weaving streams that were free flowing and there was a minimum of traffic friction.

This smoothness of operation is reflected in the accident data. In the last five years there have been six accidents at this location, five of which involved property damage only. The other accident, involving one injury, was due to a southbound vehicle that somehow or other managed to get into the northbound roadway. Of the five property damage accidents two involved parked vehicles. One was caused by a driver making a U turn and two were caused by sudden stops by vehicles entering from the ramp. Only the last two accidents can be connected with the weaving area and even these two were mainly due to poor driving habits. During the five year period 50 million vehicles have passed through the 580-ft. long weaving area. If all of the above accidents are included, this results in an accident rate of 109 per 100 million vehicle miles and an injury rate of 18. The fatality rate is zero. If only the last two accidents are included, the accident rate would be 36.

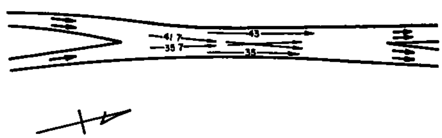

Figure 8. Weaving Area at Foundry Street Ramp

The accident rate during the last 5 years for all State Highways in New Jersey is 246, the injury rate 156 and the fatality rate 7. For four lane divided highways, the accident rate is 221, the injury rate 146 and the fatality rate 6 per 100 million vehicle miles.

Including all accidents for the 5-year period, the accident rate at this weaving area has been less than ½ and the injury rate ⅓ of the rate for 4-lane divided highways.

COMPARISON OF OPERATING CONDITIONS

Traffic through weaving area 1 (and to a lesser extent at weaving area 2) gave the impression of moving laterally as well as forward. If one place in the weaving area tended to become congested, traffic immediately following would bypass the congested area and weave at another location.

Traffic speeds through a weaving section are generally lower than on the approach roadways. As a result, traffic will tend to "bunch up" and there will not be the gaps that are necessary for satisfactory or safe operation unless the weaving section is wide enough so that traffic can spread out laterally. This spreading of the traffic streams creates the necessary gaps between vehicles and allows weaving to take place throughout the length and width of the weaving section.

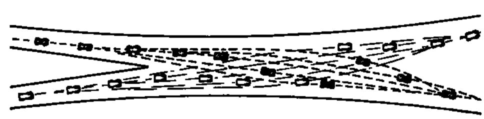

Figure 9. Note: Spacing of Vehicles on Approach Roadways Based on Speed of 20 MPH With Time Gap Between Vehicles of 1.1 Seconds

This freedom of movement is essential for successful operation, particularly for high volumes of traffic. If this freedom of movement is not permitted, traffic tends to cross at one point and the capacity approaches that of an oblique intersection.

At weaving area 1, traffic (particularly at higher volumes) tended to travel in parallel streams. Weaving from this position is more difficult and creates considerable traffic friction. Under these conditions it is generally necessary for a vehicle to weave at a gap between vehicles travelling in the adjacent parallel line of traffic. At higher volumes, some vehicles would have to weave through two or three lines of traffic.

During peak volumes at weaving area 2, traffic on the main approach roadway was closely bunched with very few gaps. On entering the weaving area, this traffic spread out laterally and there was but little evidence of parallel streams of weaving traffic. Weaving took place throughout much of the length and width of the weaving area and as a result few vehicles had to weave between two other vehicles travelling in an adjacent parallel line of traffic.

A study was started of the time gaps that would be accepted or rejected by drivers. This study had to be dropped at location 2 due to the small percentage of vehicles that weaved between two other nearby vehicles in the adjacent lane.

Figure 9 shows diagrammatically the spreading of two streams of weaving traffic.

As drivers approach the weaving area they evidently make up their minds as to the general area they propose to weave at and adjust their lateral position and speed accordingly. It is believed Figure 9 shows that the problem cannot be resolved in terms of a time gap in weaving traffic as each driver in turn modified the movement of the other and affects the place of weaving.

CONCLUSION

For successful operation of a weaving area, the speeds of the several traffic streams must be nearly equal. Uniformity of operating speeds can be achieved only when the three main elements of a weaving section are properly proportioned for the volume of traffic to be handled. A change in any one of these elements can alter the speed of the traffic streams, reduce the capacity, and affect the overall operation.

The three main elements of a weaving section are (1) the angle of approach, (2) the width, and (3) the length.

The angle of approach affects the speed of the entering traffic, the angle of weaving, and the place of weaving.

The physical angle of approach at Foundry Street is 16 deg. The operational angle of approach is about 20 deg. This angle works very well. Drivers were able to observe the other stream and by slight adjustments in speed and lateral position were able to meet gaps in the traffic streams. This resulted in weaving at the proper time and speed and with a minimum of conflict between vehicles.

The width of the weaving section must be sufficient to allow the traffic that is to weave to spread out laterally, thus creating the necessary gaps between vehicles and allowing weaving to take place throughout the length and width of the weaving area. The weaving section should have a width at least of one more lane than would be normally required by the total entering traffic that is to weave plus a sufficient number of lanes at each side to carry the through traffic without interference to the weaving vehicles.

Adequate sight distance ahead of the weaving area is also important in order that drivers may size up the situation in advance and make any necessary adjustments in order to arrive at the weaving area at the proper time and place.

More data are needed before determination can be made for the proper combination of length, width and angle of approach for various volumes and speeds of traffic. The data available seem to indicate that if the maximum length is more than 900 ft., traffic streams tend to travel side by side, resulting in a forced weaving near the end of the weaving section.

Accident records show that weaving areas are not necessarily places of hazard and traffic friction but can be constructed so that they are at least as safe as any other section of a modern highway.

APPRAISAL OF RURAL ROUTES

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SYNOPSIS

Straight line diagrams have provided a means of recording in one place the pertinent details and features of a non-uniform length of highway. Such diagrams have been developed by many States for each of the routes constituting their highway systems. The Public Roads Administration used similar record diagrams in development and portrayal of the features of the routes on the strategic system. Currently the states are preparing such diagrams for the routes on the Interstate System of highways.

The principal feature of these diagrams is the highway map, straightened out across the top of the sheet. Arranged on separate horizontal lines beneath and appropriately spaced along the length of the road were numerical, word, or symbol notations indicating type and width of roadbed and shoulders, traffic volumes, curves, grades, sight restrictions, accident locations and similar pertinent data. Because of the number of items to be recorded, the space allowed for each was limited vertically, and the information was often shown by abbreviated words to keep the length of the diagram within limits.

A major advantage of the straight line portrayal is the fact that all the data pertaining to a point on the road is shown directly beneath it on the other lines of the chart. However, many of the details were not easily recognized because they were expressed in numbers or words. It was thought that if these details could be graphed or plotted, their significance would be more apparent.

In developing a straight line diagram for a 38-mile route between Glastonbury and New London, Connecticut, various graphic methods were used. A map was used across the top of the sheet with all intersecting roads and villages shown in true position along the route being studied. Traffic was shown in profile. Desirable maximum operating speeds were established after consideration of topography and adjacent land use. They were shown alongside the actual average operating speeds. Widths of travelled path and shoulders were graphed to show their variations. Curves and grades were plotted to show length, degree or percent, and direction. Those in excess of the maximums desirable for each operating speed were accented. Sight distances insufficient for passing or stopping at the desirable speeds were plotted to show length of restriction in each direction. The accidents were located and classified by the direction the driver at fault was travelling.

With the diagram thus plotted, and the deficiencies in each feature accented, it was a comparatively simple matter to establish the limits of the sections most in need of reconstruction.