Minimum Speed Limits on Freeways

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This study was made to determine the feasibility of establishing minimum speed limits by lane on multiple-lane highways. This was done by erecting signs and observing traffic at four different sites throughout the state. The factors under particular consideration included mean speeds, speed distributions, headways, headway distribution, volume distribution by lane, lane changing, passing on the right and enforcement problems. Before-and-after observations revealed few if any beneficial results of the minimum speed limits and showed some results definitely unfavorable to operation and safety.

•THE 1965 Regular Session of the California State Legislature requested the Department of Public Works to make a study of the feasibility of establishing minimum speed limits on multiple-lane highways on a lane-to-lane basis.

Based on historical evolution of driving habits and road development, it is customary to think that on a 4-lane road the right lane in either direction is the driving lane and the left lane is the "passing" lane. However, when traffic flow reaches a certain level, many drivers stay in the left lane instead of returning to the right lane between each vehicle overtaken, because otherwise they would be weaving back and forth continually. This annoys drivers who desire to go even faster than the passing vehicles that stay in the left lane.

Another less frequently observed problem is that some drivers drive in the left lane at speeds less than the speed limit even when there is very little traffic in the right lane. This again requires fast drivers to change lanes and pass on the right, which, although legal, is thought undesirable.

If signing or other traffic control measures are to have a beneficial effect, we would expect some of the following changes to occur:

1. The speed distribution for a given lane should fall into a more uniform grouping. This would be indicated by a smaller variation of speeds. Yet, this should be accomplished without reducing the average speed because a reduction in average speed would automatically result in greater impedance to the faster group of drivers.
2. The distribution of headways is also a significant indicator. We would expect to find fewer platoons of vehicles, and smaller numbers of vehicles in them. A beneficial effect would evidence itself by a decrease in the number or percentage of short headways (less tailgating).
3. The number of lane-changing maneuvers would be expected to decrease.
4. We would hope to find fewer vehicles passing on the right.
5. If slower vehicles were moved to the right, we would expect volumes to redistribute throughout the lanes, and generally increase in the right lanes while decreasing in the left lanes.

STUDY PROCEDURE

Four study sites (Fig. 1) were selected throughout the state freeway system: one 4-lane, one 6-lane, one 8-lane, and one where an 8-lane freeway narrows to 6 lanes. The

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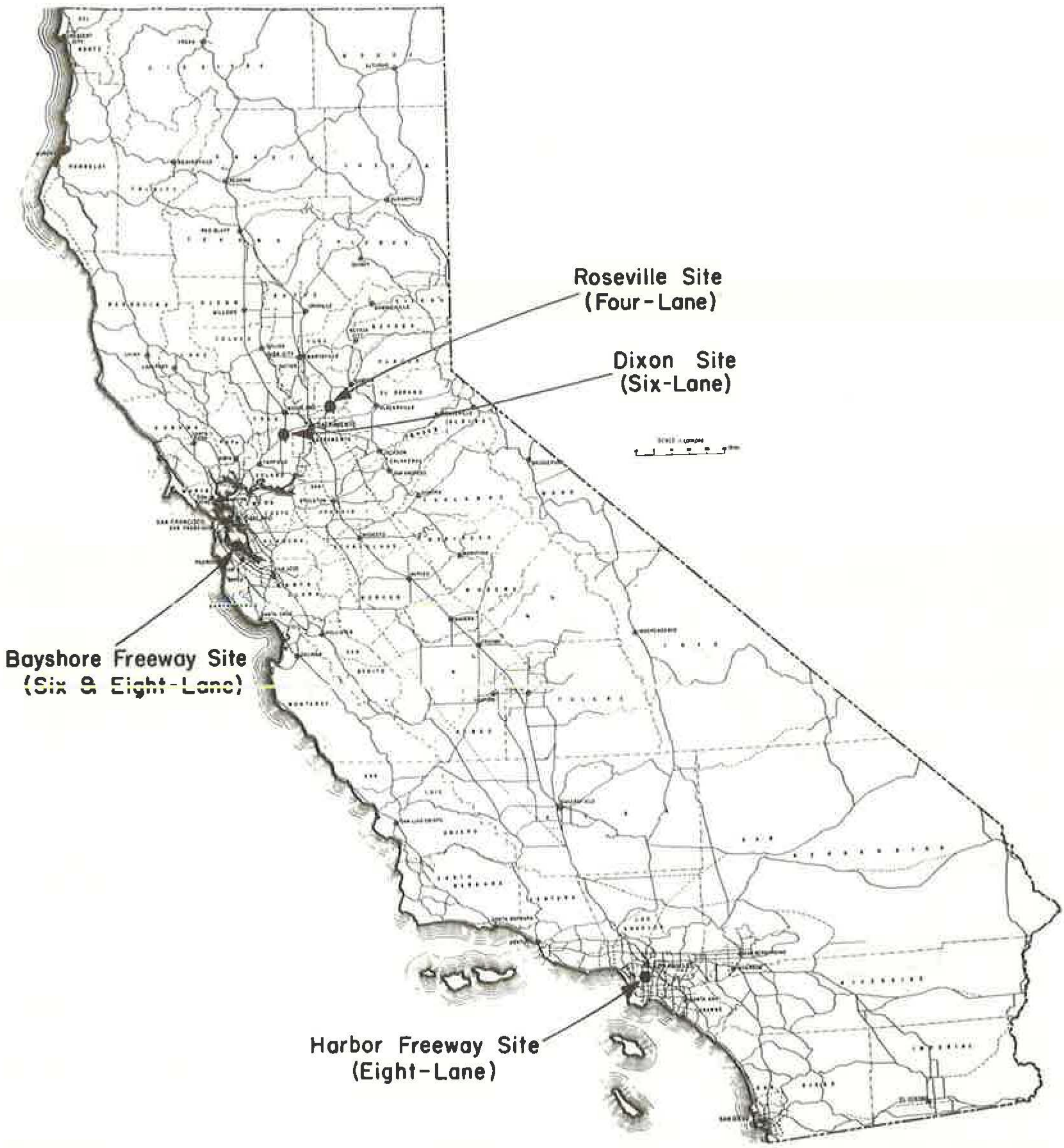

Figure 1. Location of minimum lane speed study sites.

latter actually served as two study sites. The 4-lane section was on Interstate 80 (Roseville Freeway) near Roseville between South Roseville Road and Foothill Farms pedestrian overcrossing. The 6-lane section was on Interstate 80 near Dixon between Pedrick Road and Dixon-Grant Road. The 8-lane section was on Route 11 (Harbor Freeway), between 111th Place and 149th Street in Los Angeles. The combined section was on US 101 (Bayshore Freeway) in San Mateo County between Peninsular Avenue and Ralston Avenue. These sites were selected primarily because (a) they have nearly straight alignment, (b) they have no sustained grades that would significantly affect truck speeds, (c) they have no high-volume on- or off-ramps that would induce an excessive amount of lane changing, passing on the right, and below-normal speeds, and (d) they all have overcrossings on which signs could be mounted. It is noted that the first three considerations create an atmosphere for high speeds. It was not thought

desirable to impose restrictive minimum speeds where there are slower design speed features.

At each of the study sites, signs were erected over the lanes of traffic imposing minimum speeds by lane (Fig. 2). Each study site had a minimum of three sets of signs at approximately 1-mile spacing over a 3- to 4-mile length of roadway. The signs were white letters on a black background and each sign was 7 by 9 ft in dimension, which is almost as large as possible for a sign that is identified with one 12-ft lane.

"Before" and "after" data were gathered at each of the study sites. The "after" data were taken after the signs had been in place a minimum of 2 weeks. Speed, volume, and headway information was obtained with the Bureau of Public Roads Traffic Analyzer (1), a recording device that prints numbers on a paper tape showing the speed of each vehicle across a 36-ft speed trap, as well as its time of day to the nearest ⅓ second. The Traffic Analyzer data were taken near the downstream signs at each study site. Observations of more than 85,000 vehicles were made with this equipment for the purpose of this study. The timing device of the Analyzer was frequently checked and calibrated by numerous comparisons with the calibrated speedometers of Highway Patrol cars through the trap. Stopwatch observations over a longer trap length were also used for comparison.

The lane-changing incidence and the incidence of passing on the right was obtained by a visual count and also from an analysis of time-lapse photography using 16-mm movie film taken at 1 frame per second.

To gain some knowledge of the enforcement problems involved, a sampling of information was taken from the violators of the minimum speed, i.e., drivers who were stopped for driving slower than the posted speed for the lane involved. This information was gathered with the cooperation of the California Highway Patrol and the Los Angeles Police Department.

Figure 2. Placement of minimum speed signs on 8-lane freeway.

SPEEDS

The maximum speed limit in California is 65 mph for 2-axle vehicles and buses (except for a few sections of freeway where the maximum speed is 70 mph) and 50 mph for vehicles and combinations with 3 or more axles. Sections of highway which have a 65-mph speed limit may be zoned for a maximum limit less than 65 on the basis of an engineering and traffic survey. These lower limits are "prima facie" and may be exceeded if the driver can establish by competent evidence that speed in excess of the prima facie limit does not violate the basic speed law. To comply with the basic speed law, a driver shall not drive at a speed greater than is reasonable or prudent having due regard for weather, visibility, traffic, and surface and width of the highway, and in no event at a speed which endangers the safety of persons or property.

In addition to these maximum speed limits, California has a minimum speed law which states that no person shall drive at such a slow speed as to impede or block the normal and reasonable movement of traffic except when reduced speed is necessary for safe operation, or because upon a grade, or in compliance with law. Whenever the Department of Public Works determines on the basis of an engineering and traffic survey that slow speeds consistently impede the normal and reasonable movement of traffic, the Department may determine and declare a minimum speed limit. The vehicle code further provides that official signs may be erected directing slow-moving traffic to use a designated lane. It is the policy of the Division of Highways to install "Slower Traffic Keep Right" signs at approximately 5-mile intervals on divided highways.

In 1965 the California Highway Patrol maintained an aggressive enforcement program toward those vehicles that failed to drive in the right-hand lanes and/or impeded the normal flow of traffic. During this period the Patrol issued 21,783 arrests for these violations.

At very high traffic volumes, such as those found during peak hours on many urban freeways, the maximum attainable speed is controlled by the presence of the other vehicles that "got there sooner," and any minimum speed limit would have no meaning because it would be so much greater than the maximum attainable speed. At lower volumes, cars that catch up to a slow car in the left lane (or lanes) will pass on the left or right if possible. If they are unable to pass because cars in the adjacent lanes are traveling approximately the same speed, they will queue up behind the slow car and maintain approximately the same average headway as before queueing up. Even though the rate of flow of a lane is not severely reduced by a slow car, the speeds of all the cars in the queue are reduced and thus all travel times are increased. Drivers are very conscious of increased travel times and this can be quite a source of irritation to them.

The problem of slow drivers in the left lane(s) is most severe when there are only 2 lanes in one direction, since a slow driver can "block" the highway if he drives about the same speed as a vehicle in the right lane. On a 6- or 8-lane facility the chances of 3 or 4 drivers driving side by side at the same speed are very small.

It is conceivable that slow-moving vehicles can create an accident problem both by driving slow in the left-hand or fast lanes and by causing faster vehicles to use the right-hand or slow lane. The only problem of this nature that has come to our attention is caused by slow trucks on long grades where fast vehicles in the right lane occasionally run into the rear of a slow truck. In this case, the trucks are traveling very slow, sometimes only 10 mph. It would require additional very specific legislation to make it illegal to go slower than a speed that cannot be attained by large numbers of vehicles on grades.

It was initially thought that the posted minimum speeds should be at least 15 mph below the posted maximum speed limits. This would mean that left lanes of traffic would be posted at a minimum speed of 50 mph or less, and the right lanes, used by trucks, would be posted at 35 mph or less. However, after a consideration of existing spot speeds, it was realized that the posted minimum speeds would have to be much higher than this to have any effect. For the purpose of this study, the posted minimum speeds used for a 2-lane section were 60 and 45 mph for the median and shoulder lanes respectively. For the 3-lane sections, 60, 55, and 45 mph minimums were used from

left to right lane respectively. At the 4-lane sites, 60, 60, 55, and 45 mph minimums were used, proceeding from left to right lane. Lane designations throughout this report are by number, increasing from left to right.

In the left lane (lane No. 1) of traffic a driver was faced with a 5-mph driving range, i.e., a minimum speed of 60 mph and a maximum speed of 65 mph. A truck driver in the right lane of traffic was faced with a minimum speed of 45 mph and a maximum speed of 50 mph. By posting the second lane from the right at a speed greater than 50 mph, trucks were legally prohibited from using any lane other than the extreme right one. If minimum speeds by lane were posted on a widespread basis, the minimum speed in the lane adjacent to the right lane would have to be lowered to accommodate trucks passing slower vehicles, and therefore the signs would be of little significance to other vehicles. Or provisions could be provided in the vehicle code to exempt trucks from the minimum speed restriction when in the process of passing slower vehicles.

To our knowledge no minimum speed limits have been established previously for each lane of multiple-lane highways. Several states have statewide minimum speed limits, or minimum speed limits on certain stretches of highway, but these apply to the entire roadway uniformly, rather than individually by lane. Very little research has been published, and it is of a qualitative nature rather than quantitative.

Mean Speed and Deviation

Since a reduction of delay is a major objective of minimum speeds, the comparison of "before" and "after" mean speeds and deviations is important. The "before" and "after" observations were of the same period of the day, the same character of traffic and almost identical rates of flow. The minimum number of speed observations at any one site was greater than 2000 vehicles and included all vehicles. Neither the "before" nor the "after" data were used for any periods when abnormal conditions (parked vehicles on shoulder, etc.) existed. To insure valid speed comparisons, all data were collected when volumes were well below capacity, the maximum being approximately 1300 vehicles per hour for any one lane. These comparisons at all of the study sites are given in Tables 1, 2, 3, 4 and 5. Speed distribution curves are shown in the Appendix (Figs. 11 through 25). The mean speeds are calculated as the numerical average of the spot speed of each vehicle.

Vehicles travel at variable rates of speed past a given point. There is a spread, or dispersion, of speeds about the mean. A statistical measure of this dispersion is called the standard deviation: 68 percent of the vehicles will travel within one standard deviation (plus and minus) of the mean, and 95 percent of the vehicles will travel within two standard deviations.

Positive reactions to the minimum speed signing would reveal themselves in one or both of two ways relative to speed: (a) the mean speed would increase; (b) the standard deviation would decrease. The reverse of these results would be considered to accomplish the reverse of what minimum speed limits are intended to do; i.e., there would be more interference by slow vehicles with the desired speed of the faster vehicles.

Table 1 would indicate that at the suburban site where there were only 2 lanes in each direction, the mean speed did increase in both lanes. The standard deviation, however, showed an increase in the left lane while it showed a decrease in the right lane. This was the only study site that showed a significant positive change in speeds. This positive change, however, does not necessarily reflect an improvement in traffic operations. A look at the speed distribution curves for lane 1 (shown in Fig. 11) reveals that there was little change in speeds of vehicles traveling less than 68 mph. The vehicles in the median lane traveling faster than 68 mph

TABLE 1

EFFECT OF MINIMUM SPEED SIGNING ON SPEEDS—I-80 AT FOOTHILL FARMS PEDESTRIAN OVERCROSSING

Lane No.	Mean Speed (mph)		Standard Deviation (mph)		Significance of Diff. in Speed at 95% Level*
	Before	After	Before	After	
1	67.2	68.2	5.30	5.64	S
2	59.0	59.6	7.11	6.92	S

* S indicates significant; NS indicates not significant in all Tables.

TABLE 2

EFFECT OF MINIMUM SPEED SIGNING ON SPEEDS—I-80 AT DIXON

Lane No.	Mean Speed (mph)		Standard Deviation (mph)		Significance of Diff. in Speed at 95% Level
	Before	After	Before	After	
1 (Weekday)	70.5	68.6	5.27	5.34	S
2 (Weekday)	65.7	63.7	5.75	5.84	S
3 (Weekday)	57.8	54.2	7.92	7.30	S
1 (Sunday)	69.6	67.6	5.11	4.37	S
2 (Sunday)	64.7	63.0	5.20	5.16	S
3 (Sunday)	57.8	57.6	7.01	6.69	NS

TABLE 3

EFFECT OF MINIMUM SPEED SIGNING ON SPEEDS—BAYSHORE FREEWAY AT SUNNYBRAE AVENUE

Lane No.	Mean Speed (mph)		Standard Deviation (mph)		Significance of Diff. in Speed at 95% Level
	Before	After	Before	After	
1	67.7	67.9	5.21	4.72	NS
2	63.1	64.0	5.07	4.63	S
3	59.7	*	6.00	*	*
4	51.6	51.5	7.15	6.67	NS

* Insufficient data.

TABLE 4

EFFECT OF MINIMUM SPEED SIGNING ON SPEEDS—BAYSHORE FREEWAY AT RALSTON AVENUE

Lane No.	Mean Speed (mph)		Standard Deviation (mph)		Significance of Diff. in Speed at 95% Level
	Before	After	Before	After	
1	67.5	67.5	4.36	4.74	NS
2	61.7	61.2	5.29	5.35	NS
3	52.6	52.8	6.98	6.97	NS

TABLE 5

EFFECT OF MINIMUM SPEED SIGNING ON SPEEDS—HARBOR FREEWAY AT 149th STREET

Lane No.	Mean Speed (mph)		Standard Deviation (mph)		Significance of Diff. in Speed at 95% Level
	Before	After	Before	After	
1	67.6	67.2	4.45	4.13	S
2	67.8	67.5	5.12	4.43	S
3	60.6	60.8	5.86	5.70	NS
4	54.5	54.3	7.19	6.85	NS

speeded up, and thereby increased the mean speed as well as deviation. Minimum speed signs were not intended to increase speeds of the vehicles that are already exceeding the speed limit.

At the I-80 site near Dixon, which was 3 lanes in each direction at comparatively low traffic volume and density, a significant decrease occurred in mean speeds in almost all lanes. This happened during weekday study and Sunday study as well. Since there was no concomitant reduction in variability of speeds among cars in a lane, it may be said that the minimum speed signing accomplished the opposite of what was intended. Overall travel time was increased, and presumably the fast drivers who most desire minimum speeds were forced to go slower. It will be noted later that at this high-speed 3-lane rural study site there was a definite redistribution of traffic among lanes. This redistribution is considered to contribute to the slowdown in mean speeds; i.e., some of the slow drivers moved into the fast lanes and thereby caused a reduction in speed of all drivers. In other words, they interfered.

Another 3-lane site used for study was on the Bayshore Freeway near Ralston Avenue. Table 4 shows that there was no significant difference in speeds after minimum lane speed signs were imposed. The slight increase in standard deviation would be considered of negative value, if it were large enough to be significant.

At the 4-lane study site on the Bayshore Freeway, Table 3 shows little significance to any changes in mean speeds. The standard deviation was reduced slightly. However, there was a second external factor that probably affected the "after" data at this site. Some necessary construction had the shoulder lane closed for several days during the week prior to the collection of "after" data, and some downstream ramps were permanently closed. A reduction

of volume in the right lane is evidence of this fact.

The Harbor Freeway site, with speed results given in Table 5, is considered to be more representative of a four-lane metropolitan site. The Harbor Freeway site showed some mean speed change in lanes 1 and 2 (the left lanes of 4 in one direction). Due to the large samples of the traffic observed at this site, even the small change is considered statistically significant at the 95 percent level. This change was a reduction in mean speed of about 0.4 mph, not enough to say that safety was increased, and in the opposite direction to the intent of minimum limits. Mean speeds in lanes 2 and 3 showed a small change, but they are not considered significant. All lanes showed some improvement by reducing the standard deviation. The overall effect of minimum speed signing at this site would not reduce travel times.

TABLE 6

MINIMUM SPEED VIOLATION RATE—I-80 AT FOOTHILL FARMS PEDESTRIAN OVERCROSSING

Condition	Lane 1: Percent of Vehicles Traveling Less Than 60 mph	Lane 2: Percent of Vehicles Traveling Less Than 45 mph	All Lanes
Before	7.0	2.8	4.19
After	6.0	1.6	3.56

Observation of more than 8,000 vehicles.

Minimum Speed Violation

Tables 6, 7, 8, and 9 show the effect of minimum speed signing on the "violation rate." This rate is defined as the number of minimum speed violations per 100 vehicles passing the study site. Even though there was no actual violation in the "before" condition, it is referred to as such in this report.

Table 6 (the 1-directional 2-lane study site near Roseville) shows a slight decrease in the violation rate for both lanes of travel.

All of the 3-lane study sites, as shown in Tables 7 and 8, indicate an increase in the violation rate.

The violation rate of the Bayshore Freeway at Sunnybrae Avenue is not shown because construction operations near the site made observations abnormal.

Table 9, which gives the minimum speed violation rate at the Harbor Freeway site, shows that there was a slight increase in the violation rate for lanes 1 and 2 together with a decrease in violation for the 2 right lanes.

When comparing the minimum speed violation rates (Tables 6, 7, 8, and 9) with the volume distribution (Figs. 7, 8, 9, and 10) it may be noted that where the total volume was light, the minimum speed signs resulted in a shift to the left; i.e., the percentage of vehicles traveling in the left lanes increased. This in turn increased the incidence of violation in all lanes, because a slow vehicle staying in the right lane may not have been a violator at all. All of the 3-lane sites showed this to be the case.

HEADWAYS

A headway is defined as the time interval between passage of consecutive vehicles moving in the same direction past a given point. In this report, as in most uses, it

TABLE 7

MINIMUM SPEED VIOLATION RATE—I-80 AT DIXON

Condition	Lane 1: Percent of Vehicles Traveling Less Than 60 mph	Lane 2: Percent of Vehicles Traveling Less Than 55 mph	Lane 3: Percent of Vehicles Traveling Less Than 45 mph	All Lanes
Weekday, Before	0.5	3.2	4.0	2.84
Weekday, After	3.8	6.3	11.0	7.03
Sunday, Before	2.0	2.5	3.2	2.49
Sunday, After	3.0	5.0	3.0	3.67

Observation of more than 16,000 vehicles.

TABLE 8

MINIMUM SPEED VIOLATION RATE—BAYSHORE FREEWAY AT RALSTON AVENUE

Condition	Lane 1: Percent of Vehicles Traveling Less Than 60 mph	Lane 2: Percent of Vehicles Traveling Less Than 55 mph	Lane 3: Percent of Vehicles Traveling Less Than 45 mph	All Lanes
Before	3.6	7.9	10.0	6.68
After	4.7	14.3	10.8	8.53

Observation of more than 16,000 vehicles.

TABLE 9

MINIMUM SPEED VIOLATION RATE—HARBOR FREEWAY AT 149th STREET

Condition	Lane 1: Percent of Vehicles Traveling Less Than 60 mph	Lane 2: Percent of Vehicles Traveling Less Than 60 mph	Lane 3: Percent of Vehicles Traveling Less Than 55 mph	Lane 4: Percent of Vehicles Traveling Less Than 45 mph	All Lanes
Before	2.3	3.0	16.0	8.0	7.69
After	2.7	4.4	13.0	6.3	5.13

Observation of more than 25,000 vehicles.

refers to a single lane of travel. An analysis of headways is important because short headways (tailgating) are of great concern from the standpoint of highway safety.

A certain proportion of all vehicles on the road travel in platoons, often with short headways, even when traffic volume is very low. There are several reasons why this occurs. One reason is that when there is a reasonable variability in speeds (by definition, this is one condition of free flow) the headway in front of a given vehicle is continually changing, and often approaches a minimum just before a passing maneuver takes place. Thus, sheer chance (probability) will account for many short headways as well as some very long ones. Another reason is that when one vehicle is traveling considerably below the average speed (for example, a car with a house trailer required by law to travel slowly), all the other vehicles on the road must pass it. These other vehicles are normally scattered among all the available lanes, but when they pass the slow vehicle they are compressed into a roadway of one less lane. In the case of a 4-lane freeway, this means that all the vehicles except the slow one have to use 1 lane instead of 2 while passing the slow vehicle. This causes the headways in the "passing lane" to become very short. A third reason for short headways, and probably not very important, is that some drivers just like to drive with short headways.

Finally, platoons can be formed because the lead car is going slow and other cars catch up with it when there is no opportunity to pass on the right. (This is closely related to the second reason given above.) It is this type of platoon that minimum speed limits are designed to alleviate.

Headways between vehicles are tied to traffic volume by mathematical laws. Specifically, headway (unit time/vehicle) is the inverse of volume (vehicles/unit time). If the road has plenty of capacity, the traffic volume represents the demand. When the demand is 720 vehicles per hour per lane, the average headway is 5 seconds; i.e., there are 3600 seconds in one hour and if there are 720 headways, the average is 3600 divided by 720, or 5. If these 720 cars all came along in one continuous platoon, at an average headway of 2 seconds, there would be 719 headways of 2 seconds apiece and one headway of 2162 seconds to take up the rest of the hour. This would be very undesirable operation. It would be more desirable to reduce the number of very short headways and increase the number of longer headways (the total number has to remain 720), but of course this would shorten each "long" headway. Generally, the more platooning there

is, the more very short headways will occur, and the less desirable traffic operations will be.

Figures 3, 4, 5, and 6 show the percentage of very short headways before and after erecting minimum speed limit signs at the four locations studied. At the Roseville site (Fig. 3), it will be seen that at 1000 vph, headways of less than 1.5 seconds were increased from 9 percent before to 11 percent after the signs were erected. This is an increase of about 20 percent. The headways less than 2 seconds also increased at this site.

At the Dixon site (Fig. 4), the percentage of very short headways also increased at most rates of flow. At the Bayshore and Harbor sites, total flow was much heavier, and the percentage of very short headways was not affected significantly because they were more a result of sheer mathematical chance than anything else.

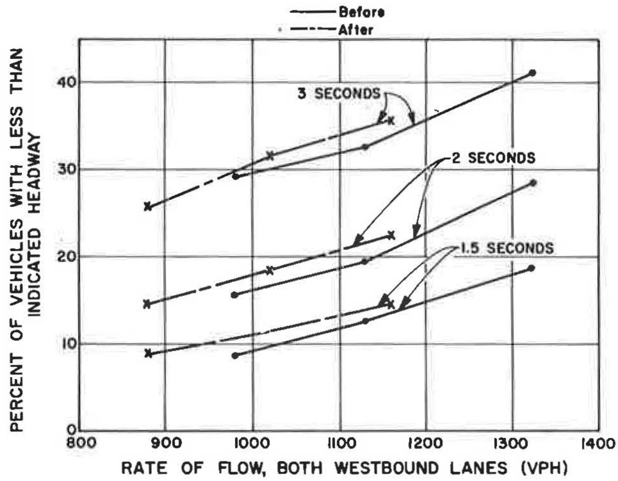

Figure 3. Effect of minimum lane speed signs on short headways—I-80 near Roseville.

Although the increase in very short headways caused by the minimum speed signs was not great, there was an increase, especially at low volumes, and it must be concluded that the signs did not accomplish the purpose of reducing platooning behind slower vehicles. This finding is consistent with the finding previously described, of a shift to the left by slower vehicles.

VOLUME DISTRIBUTION BY LANE

Figures 7, 8, 9, and 10 show the effect of the signing on the traffic distribution by lane. The percent of total volume both "before" and "after" is shown.

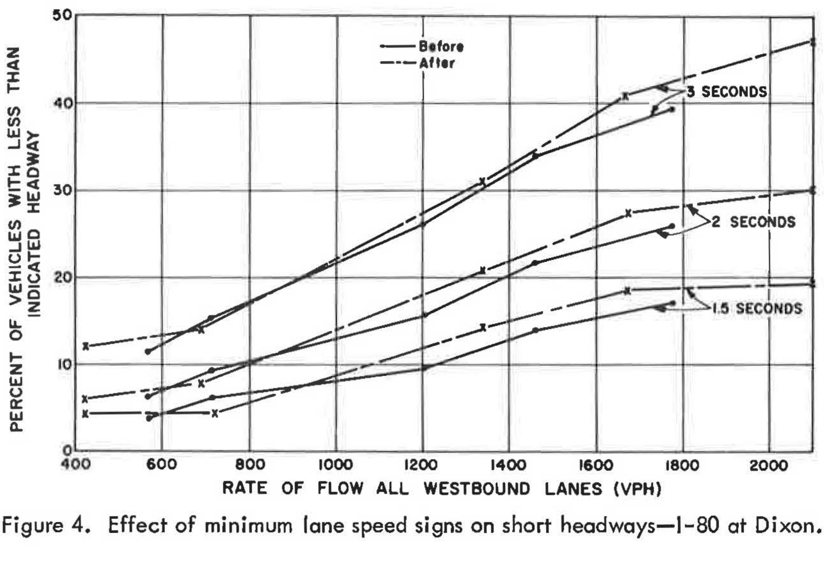

Figure 4. Effect of minimum lane speed signs on short headways—I-80 at Dixon.

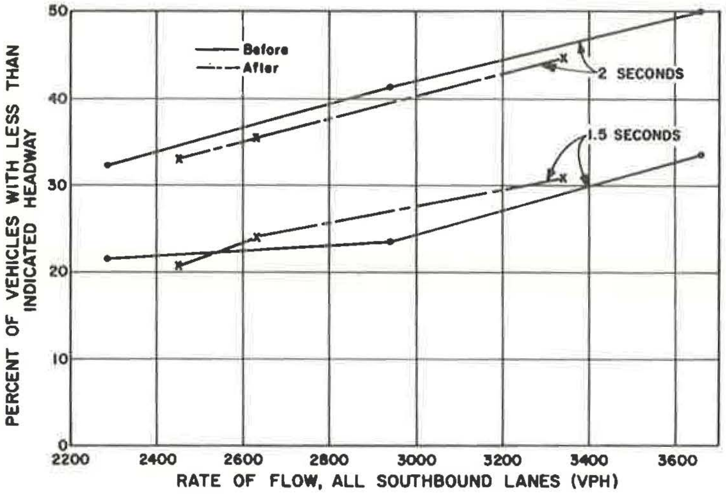

Figure 5. Effect of minimum lane speed signs on short headways—Bayshore Freeway at Ralston Avenue.

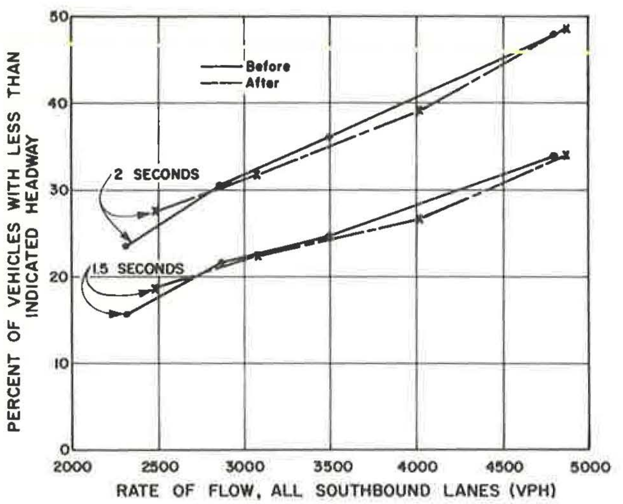

Figure 6. Effect of minimum lane speed signs on short headways—Harbor Freeway at 149th Street.

At the 1-directional 2-lane study site, the range in observed volumes varied through the study period from approximately 800 vph to 1300 vph (total for both lanes). Figure 7 shows that the minimum speed signing did redistribute the vehicles throughout this flow rate. This redistribution did not move slow vehicles to the right, as was originally anticipated, but instead, moved approximately 3 percent more of the total vehicles into the left lane.

The 1-directional 3-lane study site at Dixon also showed a definite redistribution of vehicles in the "after" period. The volume range during the study period was approximately 400 to 700 vph (all lanes) on weekdays, and from 1200 to 2100 vph (all lanes) on Sunday. Figure 8 shows the relationship of "before" and "after" lane distribution at this site. Approximately 6 percent more of the total volume was moved into the left lane at a volume of 500 vph, decreasing to approximately 3 percent more at 1700 vph. The larger share of these vehicles came from the center lane. At less than 1300 vph flow rate, many drivers even moved left from the right shoulder lane. The point of equal lane distribution in lanes 1 and 2 was moved from the rate of 1850 vph back to approximately 1600 vph. As was mentioned earlier, this changed lane distribution moved the drivers left at this site, but they did so without increasing their speed. It resulted in a reduced mean speed for all lanes.

As normally found at a 3-lane site of low volume, the center lane carries a larger portion of traffic than the left lane. In this case, at a volume of 600 vph, there were approximately 20 percent of the vehicles in lane 1 and 50 percent of the vehicles in lane 2 in the "before" condition. This is evidence of the fact that many drivers do consider the left lane for passing only when volume is low. But, with a shift to approxi-

mately 25 percent and 45 percent respectively in lanes 1 and 2 at the same volume, we would be discouraging the attitude of keep right and pass left.

For the 3-lane site on the Bayshore Freeway, Figure 9 again shows results of a traffic shift to the left lane, although of a lesser magnitude. Even at these higher flow rates, the signs did affect the lane distribution. These flow rates, however, are still well below capacity.

The Harbor Freeway site, with volume distribution results shown in Figure 10, exhibits little significant change. The "after" condition does, however, tend to group all lane distributions a little closer about the 25 percent per lane range. As the number of lanes increases, and as volume increases, the driver has less tendency to consider the left lanes as passing lanes, and also has less of an opportunity to use them for this purpose.

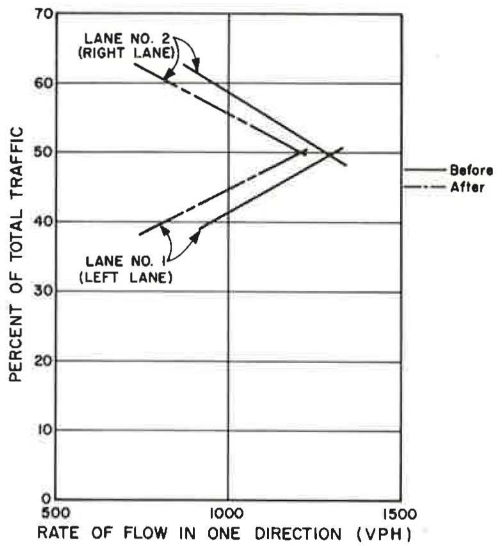

Figure 7. Effect of minimum speed signs on volume distribution by lane at 4-lane site—I-80 near Roseville.

MANEUVERS

Lane-changing and passing maneuvers were observed by two different methods and at two locations within each study site. At the leading set of signs at several sites, these maneuvers were visually observed and recorded between limits of ¼ mile upstream of the sign and ¼ mile downstream of the sign. The purpose was to determine whether or not the signing had any effect on driver behavior when he first observes the signs. Another observation was then made downstream, near the end of each study site. This observation was made within limits of approximately ¼ mile, using time-lapse photography, and its purpose was to determine what effect continuous minimum speeds by lane would have on lane-changing and passing maneuvers.

Lane Changing

The observation of lane-changing maneuvers at the leading set of signs was conclusive. There was a 38 percent increase in this maneuver in the "after" condition. The

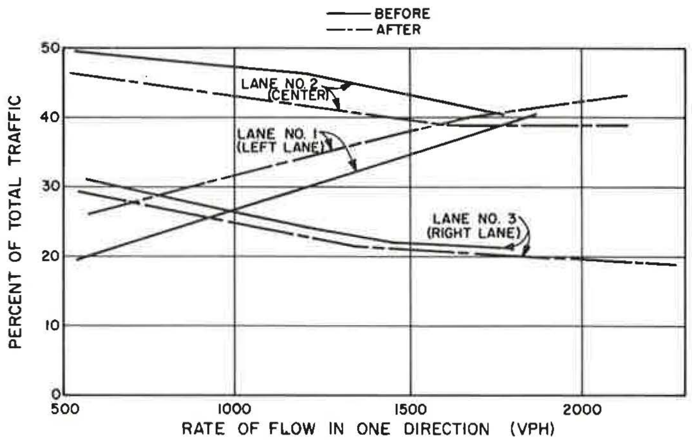

Figure 8. Effect of minimum speed signs on volume distribution by lane at 6-lane rural site—I-80 at Dixon.

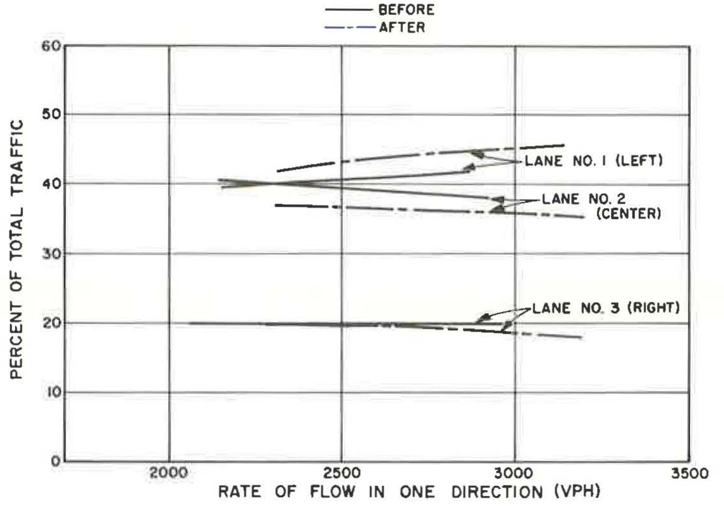

Figure 9. Effect of minimum speed signs on volume distribution by lane at 6-lane metropolitan site—Bayshore Freeway at Ralston Avenue.

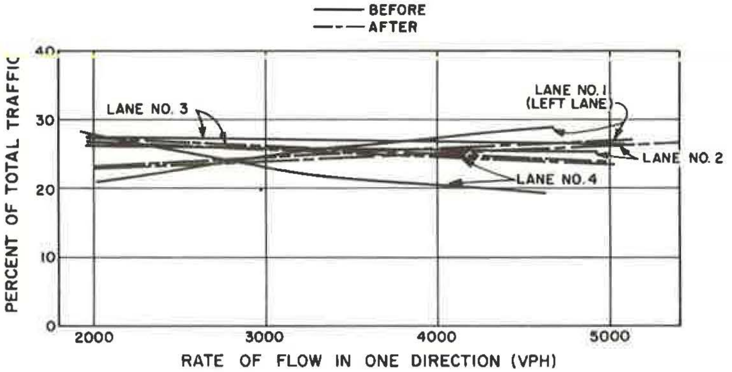

Figure 10. Effect of minimum speed signs on volume distribution by lane at 8-lane site—Harbor Freeway at 149th Street.

increase was realized in all lanes. This would indicate that some drivers felt a need for changing lanes when observing the signs. From the results of the volume distribution, as discussed earlier, it is now realized that the signs urged drivers to move to the left lanes. Where traffic was very light, they stayed in the left lane and did not discourage others from using that lane because of little or no conflict. However, when traffic volumes were moderate to heavy, there is an indication that some of the drivers who had moved left, returned to the right or caused other drivers to move right before reaching the data collection location, approximately 4 miles downstream.

Table 10 shows the results of the downstream lane-changing observation. The "before" and "after" observation periods and time of day were identical and included not less than 3 hours each. Any reduction of lane-changing in the "after" condition is considered a positive factor in the interest of safety. It may be observed that at the Roseville and Dixon locations there is evidence of more lane-changing in most lanes. There is no significant reduction. At the 3-lane Bayshore Freeway study site (higher volume), lane-changing decreased in all lanes. At the Harbor Freeway (also high volume), lane-changing decreased for vehicles moving to the right and showed some increase for vehicles moving to the left lanes.

TABLE 10

OBSERVED LANE CHANGES PER ¼ MILE NEAR DOWNSTREAM SIGNS

Location	Before						After					
	1-2*	2-3	3-4	4-3	3-2	2-1	1-2	2-3	3-4	4-3	3-2	2-1
I-80 at Spruce Avenue	169	–	–	–	–	201	225	–	–	–	–	201
I-80 at Dixon Road (Weekday)	16	11	–	–	7	13	13	12	–	–	9	12
I-80 at Dixon Road (Sunday)	94	49	–	–	56	69	94	62	–	–	73	96
Bayshore Freeway at Ralston Avenue	160	160	–	–	77	104	110	135	–	–	67	64
Harbor Freeway at 149th Street	80	132	98	83	66	34	52	91	93	103	65	43

* Notation indicates lane numbers changed from and to; for instance, 1-2 indicates changes from lane 1 (adjacent to median) to lane 2.

Passing on the Right

The observation of passing at the leading set of signs showed increased passing on the right of all left lanes. There was 77 percent more passing on the right in the "after" observation. This would indicate that as some drivers changed lanes by generally moving to the left, they did not increase their speed. They were, therefore, passed on the right.

The results of the passing on the right observation at the downstream location of each study site are given in Table 11. While Table 11 shows that passing on the right increased, the numbers involved are relatively small; e.g., at the Dixon site, during a 5-hour Sunday period before signs were erected, 76 passings on the right occurred, and during the after period, 103 passings on the right occurred. Neither of these numbers is very important when it is remembered that thousands of vehicles went by during these periods.

TABLE 11

PASSES ON THE RIGHT OBSERVED PER ¼ MILE NEAR DOWNSTREAM SIGNS

Location	Before			After		
	2-1*	3-2	4-3	2-1	3-2	4-3
I-80 at Spruce Avenue	22	–	–	10	–	–
I-80 at Dixon Road (Weekday)	9	3	–	8	10	–
I-80 at Dixon Road (Sunday)	31	45	–	47	56	–
Bayshore Freeway at Ralston Avenue	25	25	–	23	25	–
Harbor Freeway at 149th Street	31	30	32	38	61	38

* Notation indicates vehicle in lane numbered passing vehicle in adjacent lane numbered; for instance, vehicle in lane 2 passed vehicle in lane 1, shown as 2-1.

ENFORCEMENT

Insight into enforcement problems was gained primarily from incident interviews with violators of the minimum posted speeds. Many comments were also obtained from discussions with law enforcement officers. All incident reports and comments pointed to one definite conclusion: Minimum speed limits are difficult to enforce.

Probably the primary reason for this difficulty of enforcement is speedometer error. Automobile speedometers generally read higher than actual speed. Even tire wear may make a difference of 3 or 4 percent. The error in some older car speedometers is extremely high, and many speedometers do not even function. From the incident reports, it was learned that 29 percent of the violators indicated they thought they were traveling at a speed greater than the posted minimum.

As posted, for purposes of this study, we were asking the motorist to drive at a minimum speed of only 5 mph less than the maximum allowable (most lanes). Yet, it was observed that the driver traveling 60 mph in the extreme left lane was often impeding traffic under the vehicle code. The posted minimum would make it difficult to cite these violators.

SIGNING

The signs used for this study were regulatory (white letters on a black background). The sign over each lane of traffic was 9 ft wide and 7 ft high. The sign messages were all similar to those shown in Figure 2.

A significant problem in minimum speed signing lies in the word "minimum" itself. The word "minimum" was frequently read as "maximum," if we may believe the claims of drivers stopped by patrolmen for violating the minimums—13 percent of the violation incident reports indicated this fact. It would, therefore, be necessary to devise a word message which excludes the word "minimum" if the signing is to be most effective. Another way to avoid this confusion might be to show maximum and minimum speeds on the same sign.

Another significant problem is one common to all signing. Many signs are not seen by the motoring public. Approximately 24 percent of the minimum speed violators indicated that they had not seen the signing. This rate was evidenced by the incident reports obtained. The problem of communication with the driver has been a matter of increasing concern to traffic engineers. Freeway driving, particularly in metropolitan areas, is quite demanding and signs are often missed. One reason, of course, is the existing profusion of signs. Adding still more signs with multiple messages (one for each lane) has obvious drawbacks in this respect, as well as aesthetically. Methods of communicating with drivers by means other than visual have been under consideration for several years, but no practical method has yet been developed.

For this study, the minimum speed signs were all placed on overcrossings. The availability of overcrossings, however, is quite limited. Many of the newer freeways in metropolitan areas have been built on embankment with undercrossings in lieu of overcrossings. Many of the existing overcrossings are already being used for other signing. It would, therefore, be necessary to construct sign bridges. If the minimum-speed sign spacing was set at 2 miles, the cost of the sign bridge installation would be approximately $7,000 per mile for a 4-lane facility, $8,200 per mile for a 6-lane facility and $10,000 per mile for an 8-lane facility. There are approximately 2,000 miles of existing freeway in California. The annual maintenance cost would be in addition to this installation.

The installation of sign bridges on a broad basis would significantly increase the exposure of the motorist to fixed objects. Fixed objects constitute 25 percent of all freeway accidents, and 31 percent of freeway fatal accidents (2). Fixed-object accidents have a much higher fatality incidence than other accidents.

A recent study (3) showed a high severity rate for fixed-object accidents, and recommended removal of any unnecessary signing. It is therefore realized that we would decrease the overall safety of freeways by increasing the number of signposts.

CONCLUSIONS

Minimum speeds by lane cannot be considered as a relief for traffic congestion. Congestion occurs when a portion of the roadway reaches capacity. As traffic volumes approach capacity, drivers are forced to reduce their speeds. The mean speed on a mainline roadway at capacity is approximately 35 to 45 mph. Minimum speed signing, therefore, would have no effect when a roadway is operating at capacity.

The desired results of minimum speeds by lane would be (a) decreased travel time for the fast driver, (b) less frustration to a driver being delayed, and (c) increased safety. All of these desired results could only hope to be achieved when traffic volumes are well below capacity. From the results of this study, none of the desires were realized at any volume.

Probably the most unanticipated result of this study was the fact that the minimum-speed signing generally moved more drivers into the left lanes instead of moving slow drivers to the right lane. This was contrary to the intent of the signs, i.e., that drivers should keep right and pass left. This shift generally caused (a) a reduction of mean speeds for vehicles traveling in the left lanes, (b) increased passing on the right, and (c) increased, rather than reduced, travel time.

From an operational point of view, it may be definitely concluded that imposing minimum speeds by lane showed little or no positive advantages and showed some definite disadvantages.

The study also pointed to the fact that speeds in the left lanes of traffic are very close to the legal maximum speed limit. A vehicle traveling at the minimum posted speed in the left lanes would often be impeding other traffic because usually more than 95 percent of the traffic in that lane is traveling faster than 60 mph. This would lead to the conclusion that, to be effective, minimum speed limits should be even higher than those used and perhaps the minimum speed limit should be even higher than the maximum speed limit. This is not feasible, however, with speedometer error, safety considerations, and the like.

The minimum speed signs were posted for only 2 to 4 weeks at each study site. This, of course, was too short a period to evaluate the accident picture with a before-and-after comparison. There are, however, several conclusions to be drawn regarding safety. This study has provided no evidence that a freeway posted with minimum speed signs would induce a safer operation. There was no decrease in short headways (tailgating). There is, however, evidence that the overall safety of the freeway would be less, due to the installation of fixed objects (sign bridges).

In summary, it should be concluded that minimum speed by lane signs would only add clutter to the highways, with definite operational and safety disadvantages.

ACKNOWLEDGMENTS

The work reported was done for the California Division of Highways by the Traffic Department. The study was under the general direction of Karl Moskowitz and E. F. Graham. The co-investigator and designer of the study was Roger T. Johnson.

The author wishes to acknowledge the assistance of the Traffic and Maintenance Departments of Districts 03 (Marysville), 04 (San Francisco), 07 (Los Angeles), and 10 (Stockton) for providing the help with sign erection and data collection for this study. Recognition is also given to the Materials and Research Department (Sacramento) for providing the time-lapse photography and other technical assistance. The cooperation and assistance of the California Highway Patrol and the Los Angeles Police Department is greatly appreciated.

This project was accomplished in cooperation with the U. S. Bureau of Public Roads. The opinions, findings, and conclusions expressed are those of the Division of Highways and not necessarily those of the Bureau of Public Roads.

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1. Taragin, A., and Hopkins, R. C. Traffic Analyzer: Its Development and Application. Proc. Inst. Traffic Engineers, p. 263, 1960.
2. Johnson, Roger. Freeway Fatal Accidents—1961 and 1962. California Division of Highways, p. 6-9, Nov. 1963.
3. Objective Criteria for Guardrail Installation. California Division of Highways, July 1966.

Appendix

SPEED DISTRIBUTION CURVES

(Figures 11 through 25 Shown on the Following Pages)

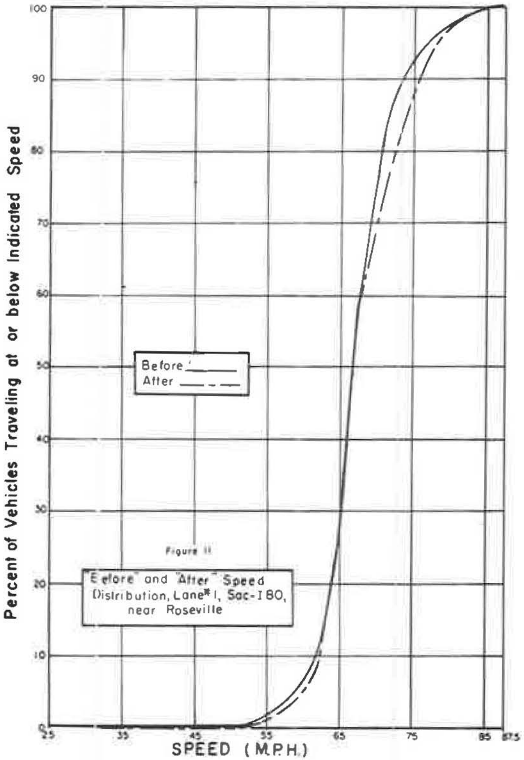


Figure 11

"Eefore" and "After" Speed Distribution, Lane#1, Sac-I 80, near Roseville

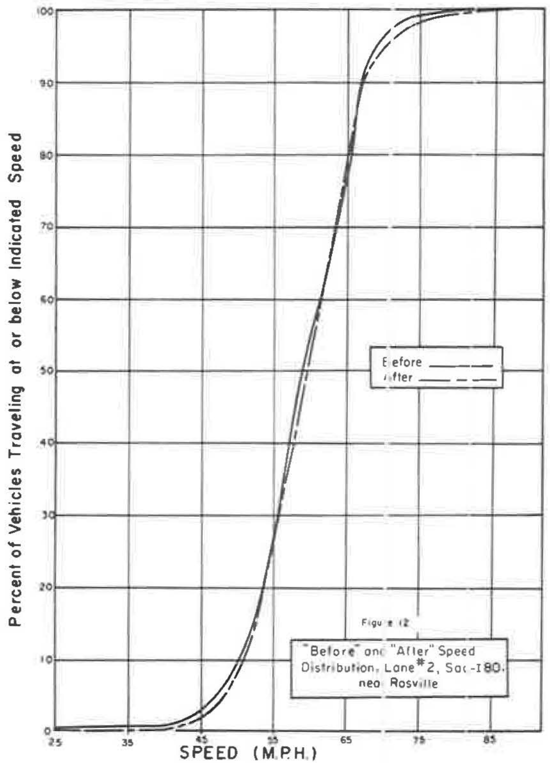


Figure 12

"Before" and "After" Speed Distribution, Lane #2, Sac-I 80, near Rosville

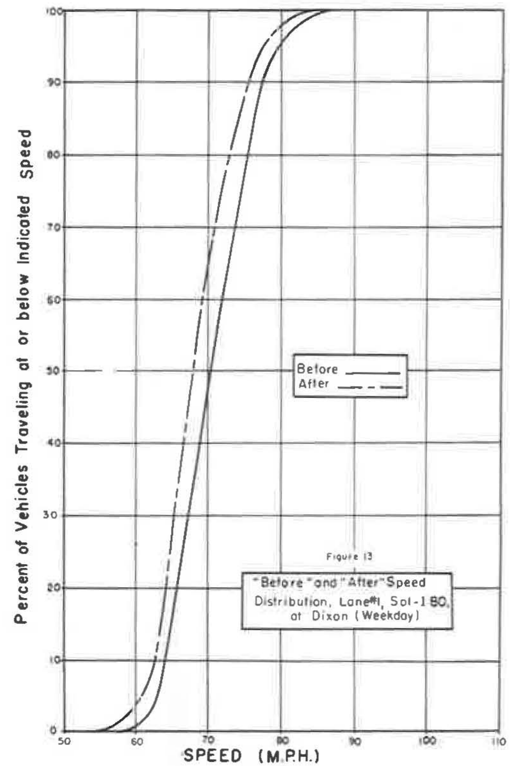
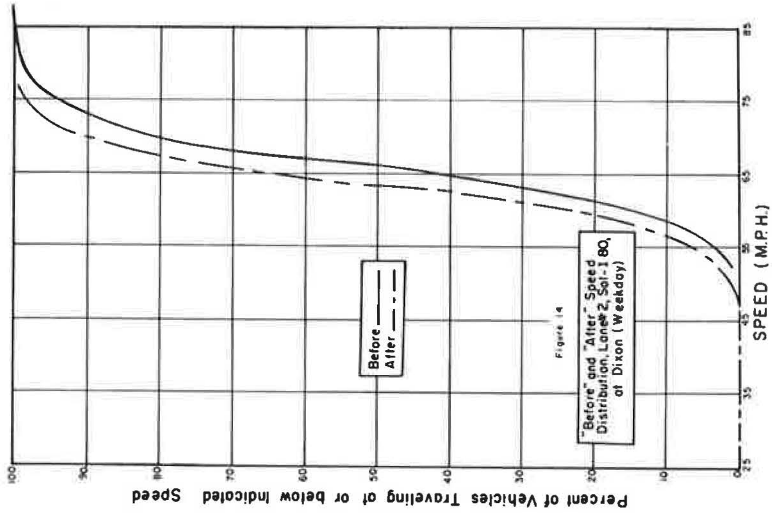
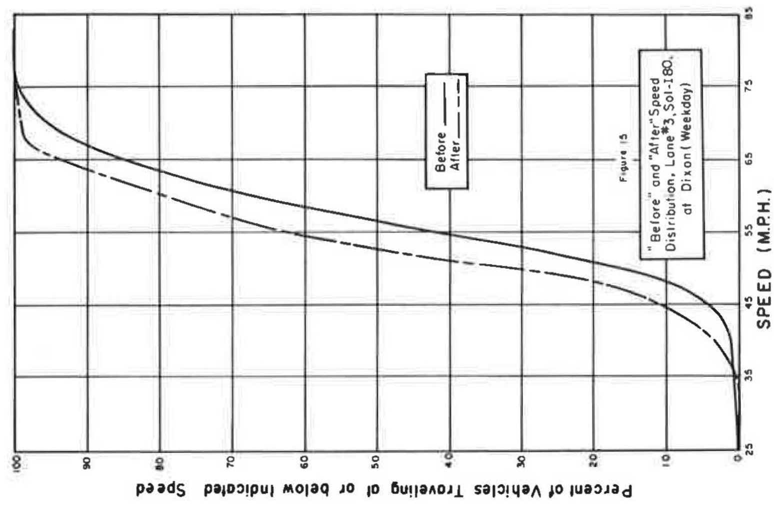
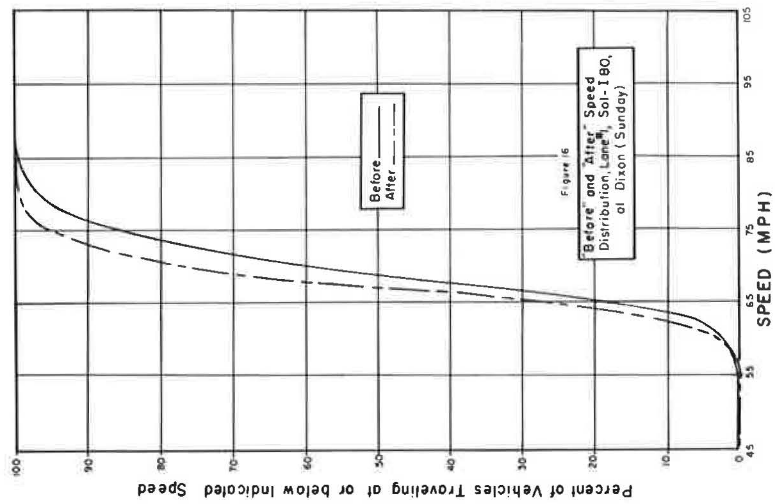


Figure 13

"Before" and "After" Speed Distribution, Lane#1, Sol-I 80, at Dixon (Weekday)


Percent of Vehicles Traveling at or below Indicated Speed
SPEED (M.P.H.)
Before
After
Figure 14
"Before" and "After" Speed Distribution, Lane #2, Sol-I 80, at Dixon (Weekday)


Percent of Vehicles Traveling at or below Indicated Speed
SPEED (M.P.H.)
Before
After
Figure 15
"Before" and "After" Speed Distribution, Lane #3, Sol-I80, at Dixon (Weekday)


Percent of Vehicles Traveling at or below Indicated Speed
SPEED (MPH)
Before
After
Figure 16
"Before" and "After" Speed Distribution, Lane #1, Sol-I 80, at Dixon (Sunday)

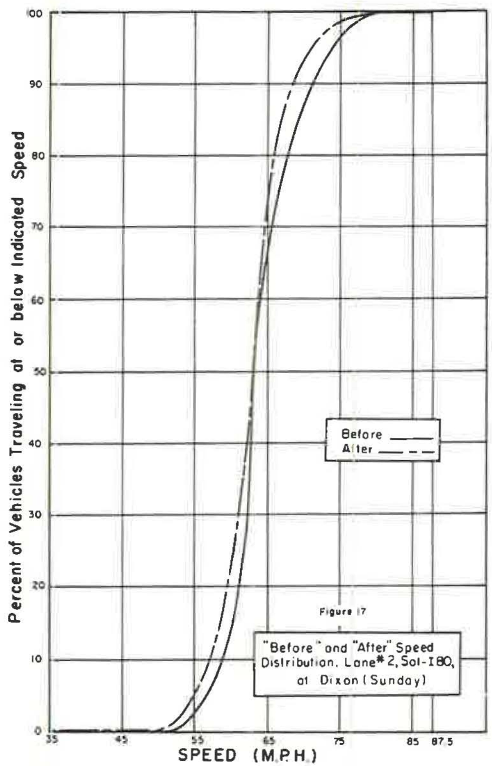


Figure 17

"Before" and "After" Speed Distribution, Lane# 2, Sol-I 80, at Dixon (Sunday)

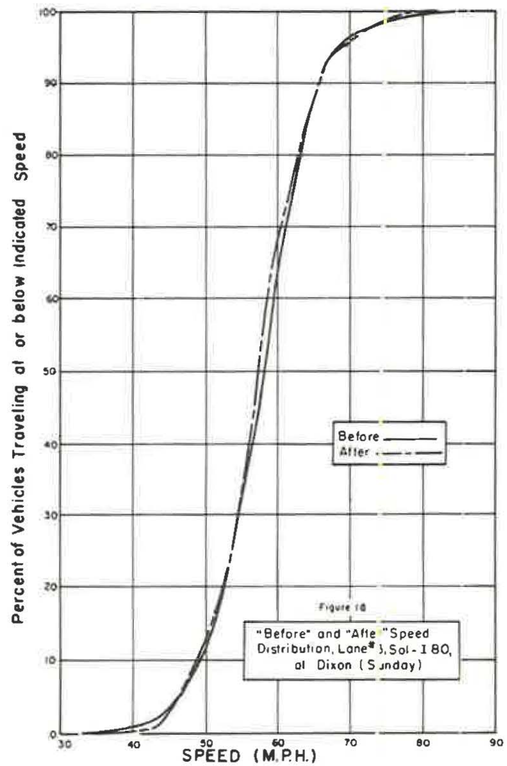


Figure 18

"Before" and "After" Speed Distribution, Lane# 1, Sol-I 80, at Dixon (Sunday)

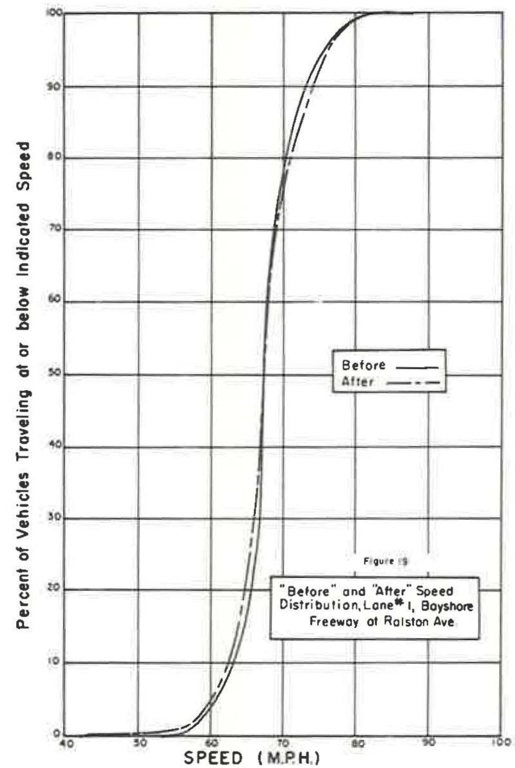
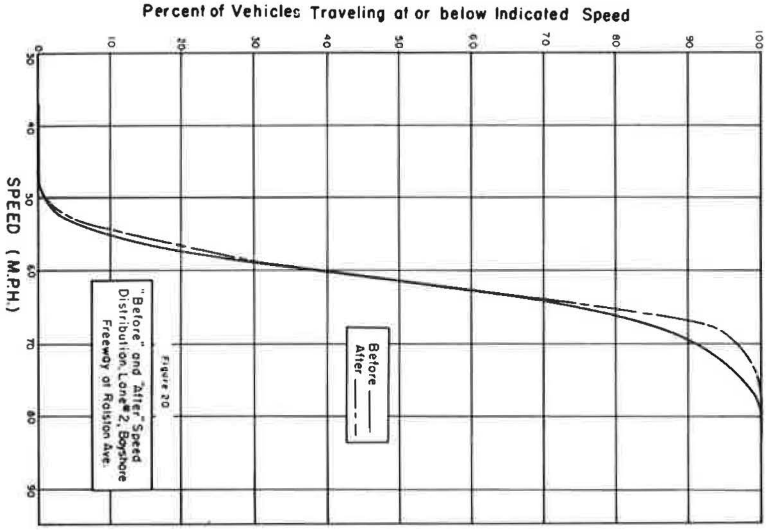
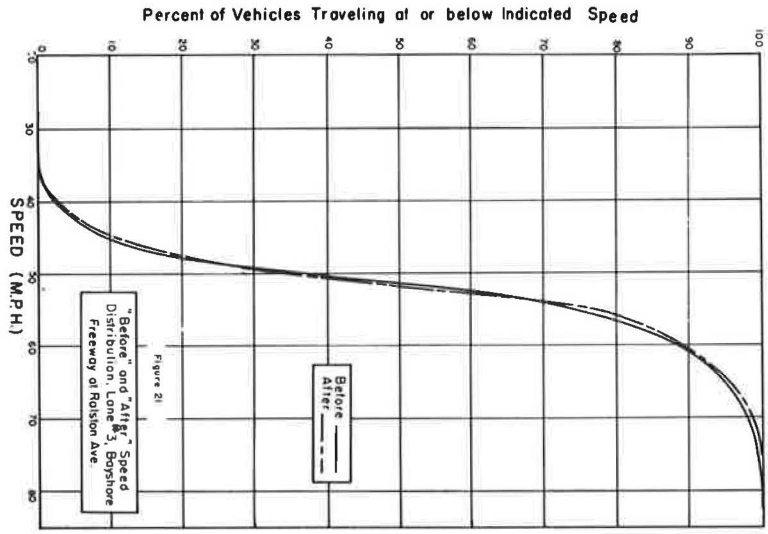
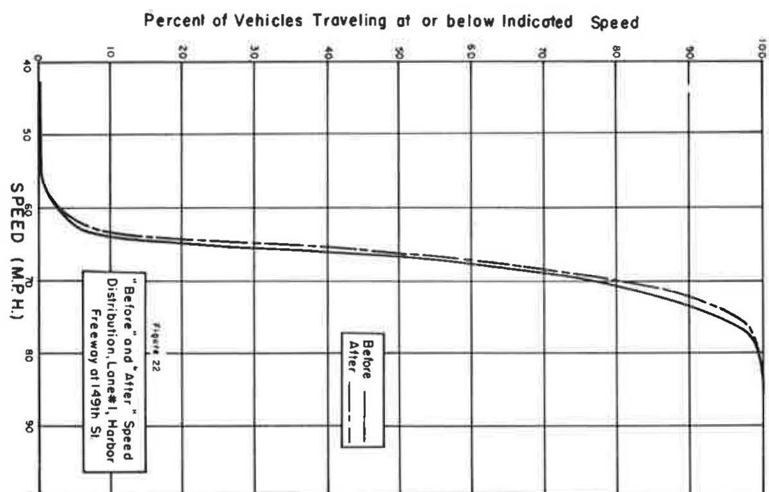


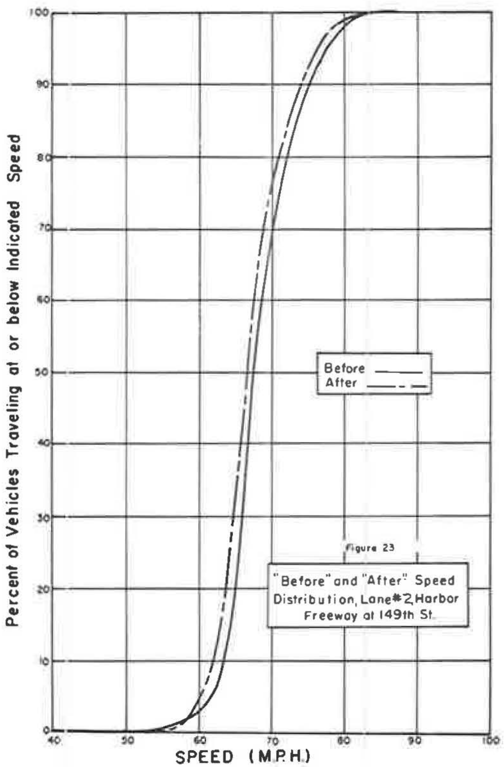
Figure 19

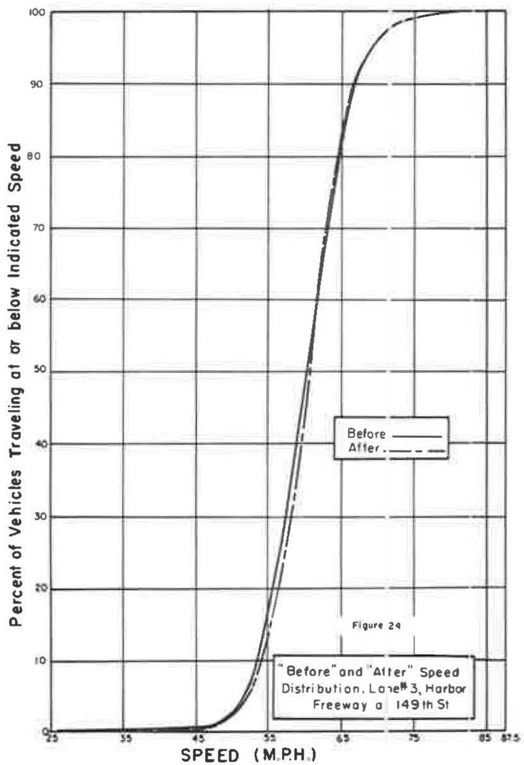
"Before" and "After" Speed Distribution, Lane# 1, Bayshore Freeway at Ralston Ave.

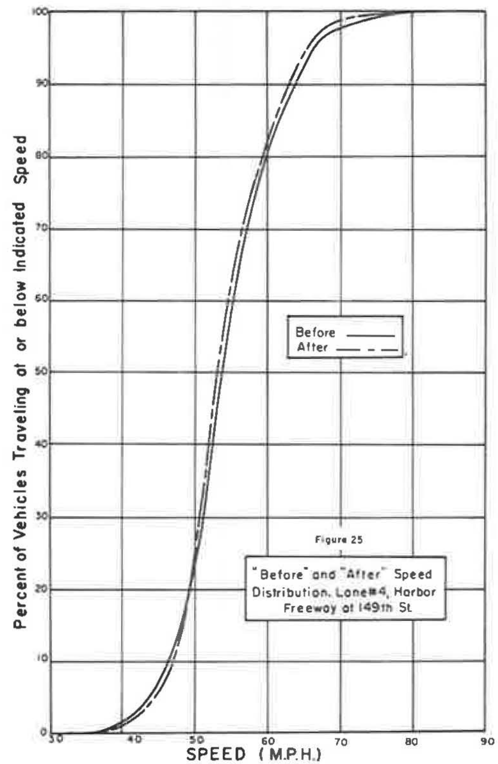

Percent of Vehicles Traveling at or below Indicated Speed
SPEED (M.P.H.)
Before
After
Figure 20
"Before" and "After" Speed Distribution, Lane #2, Bayshore Freeway at Ralston Ave.


Percent of Vehicles Traveling at or below Indicated Speed
SPEED (M.P.H.)
Before
After
Figure 21
"Before" and "After" Speed Distribution, Lane #3, Bayshore Freeway at Ralston Ave.


Percent of Vehicles Traveling at or below Indicated Speed
SPEED (M.P.H.)
Before
After
Figure 22
"Before" and "After" Speed Distribution, Lane #1, Harbor Freeway at 149th St.


Percent of Vehicles Traveling at or below Indicated Speed
Before
After
Figure 23
"Before" and "After" Speed Distribution, Lane #2, Harbor Freeway at 149th St.
SPEED (M.P.H.)


Percent of Vehicles Traveling at or below Indicated Speed
Before
After
Figure 24
"Before" and "After" Speed Distribution, Lane #3, Harbor Freeway a 149th St
SPEED (M.P.H.)


Percent of Vehicles Traveling at or below Indicated Speed
Before
After
Figure 25
"Before" and "After" Speed Distribution, Lane #4, Harbor Freeway at 149th St.
SPEED (M.P.H.)

Discussion

JOHN J. HAYNES, Professor and Head of Civil Engineering Department, University of Texas at Arlington—This interesting research project is important in contributing new knowledge concerning the operation of vehicles on freeways. The conclusions seem to be substantially valid. This study and its associated research have shed new light on a very real problem. The concept of directing the drivers in each lane, by means of proper signing, to travel within a certain small range of speeds would at first seem to be a proper approach to the operation of vehicles on freeways. It is, in fact, an extension or refinement of the old rule of traffic which asks that "slow drivers keep right." As the author indicated, this particular approach is aimed primarily at the operation of traffic on multilane facilities having low densities and high levels of service. It is not likely that this approach would be of any value except in levels of service A or B. A question raised early in this research project might be: "Since freeways with low volumes of traffic operating at low densities present few conflicts and only minor operational problems, why should an attempt be made to improve on a condition that is admittedly very satisfactory?"

This report indicates that a majority of vehicles traveling in the left lane of these freeway sections were speeding; that is, they were traveling in excess of 65 mph. Indeed, the data indicated that the average speed of this left lane was in excess of 67 mph. One of the stated objectives of the research was to determine whether the average speed in each of the lanes could be increased. Such an increase, it was stated, would be deemed an improvement. It would seem questionable that an increase in the number of speeders should be called a figure of merit. It rather might be called a detriment to the operation of the freeway.

It was reported that one of the unexpected results of this signing was more shifting to the left and less shifting to the right. A major reason many individuals moved left because of this signing is, undoubtedly, attributable to the inaccuracy of their speedometers. The authors have rightly pointed this out. Only a small percentage of speedometers are accurate to within 5 percent and many new automobiles are sold with speedometers in error over 15 percent. (I happen to own one.) Usually the error is on the safe side; that is, the speedometer reads higher than the true speed. The total range of speeds required in the left, or median lane, by the signing was only about 8 percent of the average lane speed. It is likely that inaccurate speedometers were the principal reason that this particular study showed no beneficial effects. Calibrated speedometers are available on automobiles at some extra cost. It might be well to recommend that all speedometers be made accurate to within some small percentage of error, say plus or minus 2 percent for the particular rear-end ratio and rear tire size of the vehicle. This seems a reasonable recommendation in the light of many other restrictions now being imposed upon the automobile manufacturers.

Since the study sites were comparatively short and had only a few sets of signs, the question arises whether the motorists really knew when this particular speed requirement had ended. Furthermore, since the signs had been in place at least 2 weeks prior to taking any data, it could further be questioned whether the people who regularly used the facility had a knowledge that it was required for only a few miles and thus were less responsive by the time the data were taken.

In the determination of mean speeds and deviations, it was stated that the volumes were well below capacity when the data were collected. The maximum volumes were approximately 1300 vph per lane and the minimum volumes were only about 200 vph per lane. The volumes on each particular study site varied from some minimum value to about double the minimum value. There is a considerable difference in the speeds to be expected at volumes of 1300 vph per lane and volumes of 700 vph per lane. The speed data were not related to volume data well enough to permit a detailed study of the speed-volume relationships. The minor differences in means and standard deviations that resulted from the analysis of the before-and-after data become less meaningful since the effects of volume on the speed data were not considered.

The overall travel times alluded to in the report were apparently determined by extrapolating spot speed information for the vehicles observed. It should be pointed

out again that the very small increases or decreases in travel time would be more a function of the volumes existing at the time the data were taken than indicative of the result of the signing alone. Another point to be made in connection with these small calculated increases in overall travel time is that the drivers might not have been able to have detected the increase. It could have been interesting if the motorists could have been polled to see if they thought they were traveling slower or if they thought they were traveling a little more quickly. They, in fact, might have indicated that they considered the signing better for them and that they believed their travel time was less. As a research project conducted in response to a legislative request, it could have been interesting to determine what the motorists thought of the signing.

In the study of short headways, the data points shown in Figures 3, 4, 5, and 6 indicate that there was a broad range or grouping of volumes for the purposes of relating short headways to volumes. Volume groups with ranges of about 15 percent seem to be too broad to yield sufficiently accurate headway distribution data. Headways, or the time interval between the passage of successive vehicles, actually form the basis of the rate of flow. Each headway, then, is indicative of a flow rate, and thus flow rates can be exactly as variable as headways are. Because of the close interrelationship between headways and flow rates, the analysis of short headways should be carefully done within small intervals of volume. By using the given lane distribution, this discussant calculated the expected percentage of small headways according to a Poisson, or random, distribution for several total volumes on a few of the study sites. The observed percentages of small headways were somewhat less than the expected percentages for both the "before" and "after" studies.

In their discussion of volume distribution by lane, the authors have included some figures (Figs. 7, 8, 9, and 10) without showing any data points. Such data points would have been instructive. Each lane distribution-volume relationship was represented essentially by one or two straight-line segments. This relationship can usually be represented more closely by a second-degree parabola.

Concerning the subject of lane changing, it was pointed out that there was a significant increase in this particular maneuver in the "after" condition, and that "it is now realized that the signs," in fact, "urged drivers to move to the left lanes." It was stated that when traffic was very light, drivers stayed in the left lane and that this did not discourage others from using that lane because little or no conflict existed. However, when traffic volumes were moderate to heavy there was an indication that some of the drivers who had moved left returned to the right or caused other drivers to move right before reaching the data collection location. A description of the volumes observed should not include the term "heavy," because only light to moderate volumes were observed in this research. It is also stated that the "before" and "after" periods of observation during the day were identical and included at least 3 hours each. Volume changes occurred within these 3-hour periods. It is unfortunate that the relationship of lane changing vs volumes was not included in the analysis; such data could be valuable.

The author indicates, in connection with the discussion of the signs themselves, that a significant problem was that the signs were apparently not seen by many motorists. This is a problem associated with all types of signing. It was stated that approximately 24 percent of the minimum speed violators indicated they had not seen the signing. It would have been of value to have determined how many times these persons had traveled the study site. It would not be too surprising to find that a driver had not noticed the signs if it was the first time he had traveled the study site. It would be quite discouraging, however, to find that an individual who had traveled the route regularly for over 2 weeks had never noticed the signs.

The cost of such signing was estimated at $7,000 to $10,000 per mile of freeway. Certainly, it would be agreed that the results of this research would not indicate such expenditures would be justified. Furthermore, as indicated, the required sign standard would present additional fixed objects within the right-of-way and thus create additional safety hazards. The study actually produced no evidence of operational advantage due to minimum speed signing by lane.

The author is to be commended for a very interesting report. This work will be of interest to many who are involved in the operation of freeways.

J. L. VARDON, Metropolitan Toronto Planning Board—There is little doubt that the author has presented a comprehensive and complete report of findings with respect to minimum speed limits by lane on freeways. It is a fine piece of work and should become a prime reference on the subject for some time to come.

It is surprising to realize that a major effort on this topic has been so long forthcoming in light of the many suggestions for minimum freeway speed limits in the past 10 years or so. The investigation is timely and worthwhile for many road authorities in North America.

The justification for minimum speed limits and the source of the suggestions would make an interesting study in itself. The source of the request in this case is typical, wherein the California Legislature asked for a study to determine if slow speeds on any part of a state highway consistently impede the normal and reasonable movement of traffic. No evidence was presented to indicate that there was a problem and that there was sufficient justification for increased control.

Isolated occurrences of problems and poor driver habits tend to create an undue impact on the observer. The study was designed to investigate the traffic characteristics of the total driving universe, by lane, for the specific locations. It was not designed to place any particular emphasis on the observation of "rare events". Hence the lack of spectacular effects of the proposed control device could be anticipated.

Fortunately, the author has been able to translate the mandate into five reasonable criteria. However, it is significant to note that the underlying premise has been one of free-flow or quasi-free-flow conditions. Hence the investigation becomes a study to determine the effect of minimum speed limits by lane on free-flow conditions. This makes infinitely more sense, as pointed out, than a determination of minimum speed limits under congested conditions. Nevertheless, there are some difficulties with the former case because of the relation between the existing maximum limit and the assumed minimum limit.

The maximum speed limit on the majority of California freeways is 65 mph. The average speed for the left lane of these freeways is "in the range of 67 mph". The minimum speed limit for the left lane was set at 60 mph. Hence the range of available legal speeds is very small and, possibly, not within the accuracy range of the average speedometer nor within the capability of the average driver to maintain his speed in this narrow range.

In light of the foregoing plus the relatively low minimum speed violation rate, one wonders about the regard that any driver in the left lane has for a speed limit—particularly a minimum. Since the average left lane speed is in excess of the maximum speed limit, it is suggested that the higher legal limit would be of more concern for a majority of the drivers in the left lane. The slight decrease in observed "after" speeds could be explained by a keener driver awareness of increased speed control, surveillance and/or enforcement.

If material benefits were to accrue from a minimum speed limit, it is suggested that they would manifest themselves most strongly in lane 2 of a 3-lane roadway and lane 3 of a 4-lane roadway. The higher maximum-minimum speed differential plus the lower absolute speeds gives the driver a better opportunity to comply and maneuver within the intent of the speed control device. The right-hand lane is likely not typical because of the presence of trucks. However, the data present little substantiation for such a subtle hypothesis. Certainly the speed and standard deviation data do not reinforce it.

The increased minimum speed violation rate for these lanes might be construed to mean that drivers were attempting to comply with the minimum limit but that the error

in their speedometers gave them false speed information and hence put them below the 55-mph limit. Here too there is little credence to the suggestion because there is no confirmation by the speed date, a reduced number of lane changes, nor a reduction in the right-hand passing.

The author has stated that "Headways between vehicles are tied to traffic volume by mathematical laws." He then presents an arithmetical example involving the relation between the gaps created by a hypothetical volume and the number of seconds in one hour. In this sense he is correct but the basic statement is misleading. Headways between vehicles are not governed by mathematical laws, unfortunately, but can be shown to approximate known theoretical mathematical distributions.

The results of this investigation have brought into focus the main considerations and problems of minimum speed limits by lane under free-flow conditions. In spite of the low differential between maximum and minimum limits, one would tend to conclude that materially improved vehicular control could not be achieved by this technique. The paper does imply some important questions with respect to the necessity for increased freeway controls, the conditions that should dictate their use, and the techniques to be employed that will give the desired result. One wonders whether a prima facie speed control or other legislative action would not be more appropriate for any problems associated with the infrequent slow driver.

T. DARCY SULLIVAN, Senior Traffic Field Engineer, Illinois Division of Highways—Regulation of vehicular speeds is one of the most controversial and important problems in traffic operations today. It is controversial because of the wide differences of opinion that exist among engineers, enforcement officers, motorists, legislators, and the general public concerning the solution of a speed problem. It is important because the severity of accidents that occur at high speeds is much greater than for those occurring at low speeds.

The need in speed regulation is for speed controls that are realistic, can be easily and impartially enforced, and enhance smooth traffic flow on the roadway. By realistic, I mean that the control should be readily accepted by the motorist and thus, to a great extent, be self-enforcing. Easily enforceable means that undue burden has not been placed on the arresting officer by making the conditions of the arrest so numerous that the case is difficult to substantiate in court. Traffic flow may be enhanced through modification of drivers' habits as measured by speed, volume, density, and other traffic flow characteristics. Although these needs are generally thought of as applying to maximum speed limits, there is no reason to think that they cannot be just as validly applied to minimum speed limits.

How does the concept of assignment of minimum speed limits by lane satisfy the needs of realism, enforceability, and smooth traffic flow? The concept seems to be a realistic one in terms of driver acceptance. The system evaluated in the project under discussion or a modification of it has been proposed in many different areas. In fact, it had sufficient popular support to be brought before the California Legislature in the form of a resolution. Another indication that it was accepted by the public was the fact that, according to the research results, generally less than 5 percent of the motorists violated the minimum speed restriction.

From an enforcement point of view, the system certainly presents problems. For the usual minimum speed violation summons, the arresting officer only has to prove that the offending motorist was traveling below a specified speed. The officer has only to make the necessary allowance for equipment and speedometer errors and he can prove his case beyond a reasonable doubt. Under the proposed system, the officer would have to prove that the motorist was driving in the specified lane and was not slowing down in an attempt to move into a lane farther to the right. Either of these items might be used as a defense by the motorist thereby casting doubt on the validity of the

summons. Discussions with several enforcement officials have indicated that these factors would make the proposed system extremely difficult if not possible to enforce.

The author has defined four measurable traffic flow characteristics that he believed might be indicators of reduced internal traffic stream conflicts. These included a more uniform speed distribution, fewer platoons of vehicles, longer headways, a decreased number of lane changes, and a reduced number of vehicles passing on the right. These criteria are well chosen and express most, if not all, of the desirable effects minimum speed regulation might have. Unfortunately, the posting of minimum speed limits by lane had little influence on some of the variables and negatively influenced the results on most of the others.

Based on the previous discussion, it appears that the posting of minimum speed limits by lane satisfies only one of the three basic needs in a good speed regulation program: the need of realism. If we then reject the concept of minimum speed limits by lane, what alternatives do we have to the solution of the basic problem of vehicles driving in the left lane or lanes and blocking other traffic that desires to travel at a higher rate of speed?

One of the most obvious alternatives is the "Keep Right Except to Pass" sign. This sign is used in many states where the state law requires vehicles to stay in the right lane at all times except when overtaking and passing. The regulation has been readily accepted by most motorists in the states where it has been used and is easily enforced. Unfortunately, while the sign may produce entirely satisfactory results on very light volume roadways, on more heavily traveled roads it results in an excessive number of lane changes. A vehicle traveling at a slightly higher than average rate of speed has a choice of staying in the left lane or returning to the right lane between each vehicle that is overtaken and passed. A driver, choosing the second alternative in compliance with the law, thus becomes involved in almost continuous lane-changing maneuvers. The larger number of lane changes thus generated not only produces a potentially hazardous situation, but it may also reduce the capacity of the highway and the level of service being provided. The use of this sign would meet two of the needs previously established: realism and enforceability.

Another sign that may be used is the "Slower Traffic Keep Right" sign. This sign is being used increasingly in many states and has been readily accepted by the motoring public. Discussions with enforcement officials indicate that this sign is just as easily enforced as the "Keep Right Except to Pass" sign under most conditions. With this sign posted, a motorist would be permitted to drive in any lane so long as he was not overtaken by another motorist who desired to pass. However, as soon as he was overtaken, he would be under an obligation to move to the right to make room for the faster vehicle. This sign would encourage motorists to drive in the right-hand lane but allow them to remain in the left lane so long as they did not impede other traffic. The number of lane change maneuvers would thereby be minimized. This sign appears to meet all three needs of realism, enforceability, and enhancement of smooth traffic flow.

An additional technique, which has been used on the Chicago Metropolitan Area expressways for several years, is the restriction of trucks to the two right lanes except in the vicinity of left-hand entrance or exit ramps. This regulation has been well accepted by truckers in the area. A law recently passed by the Connecticut General Assembly provides for similar restrictions on all freeways in that state, upon posting of signs by the State Highway Department. The City of Chicago Police Department and the Illinois State Police, both of whom patrol the freeway system in the Chicago Metropolitan Area, have encountered few problems in enforcing the "Trucks Use Two Right Lanes" restriction. This technique automatically restricts many of the slow-moving vehicles to the right-hand portion of the roadway on facilities with three or more lanes in each direction and insures that at least one lane is available for the exclusive use of generally faster moving passenger vehicles. While this regulation meets the needs of realism and enforceability, it does not entirely satisfy the traffic flow need. Thus, it could only be considered a partial answer to the problem.

In summary, it would seem that the use of "Slower Traffic Keep Right" signs, independently or in combination with the restriction of trucks to the two right lanes, would achieve most of the traffic flow results desired, be readily accepted by the public, and

not place an undue burden on the enforcement agencies. I am not implying that such regulations should be imposed on a system-wide basis. In fact, in areas where volumes are light and a level of service A or B is provided, probably no restrictions are needed. Any sign posted under these circumstances would simply be one more roadside obstacle and should not be erected unless a definite need has been established.

NORMAN C. WINGERD, Closure—The discussions presented by Messrs. Haynes, Vardon, and Sullivan have been of great value to the study of minimum speed limits. They have been stimulating and objective. Several suggestions for study of side issues have resulted.

Through this study I have been reminded of something basic to research. It is the fact that we must be realistic, ignore preconceived notions, and look for results that might not be anticipated. Prior to the collection of any data for this study, I presented the idea of minimum speed limits by lane to many of my friends and polled their opinions. Probably 80 percent of those questioned thought that implementation of the plan would yield very beneficial results. Such a plan has found favor among people in high office and even among some traffic engineers.

The basic misconception has been due to the failure to realize that where volumes are heavy, the speeds are controlled by traffic and not by speed limits.

The slow driver who impedes the flow of other vehicles is actually quite rare. We sometimes feel that their numbers are great, but it is only because each one makes us so aware of his presence.

I liked Mr. Sullivan's approach of weighing the proposed solutions relative to the problem. A solution to the impedance problem should be directed to the rare driver. With the signing of "Slower Traffic Keep Right" and a speed law that states that no person shall drive at such a slow speed as to impede or block the normal and reasonable movement of traffic, the State of California has the tools to cope with the problem through enforcement and education.

We will, however, remain vigilant for other solutions to the problem.