Evaluation of Minor Improvements

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This investigation evaluated the effectiveness of left-turn channelization in reducing reported accidents. The before-and-after study method was used to evaluate 53 left-turn channelized intersections. Warrants for this type of improvement were developed and accident predictive parameters investigated. The effectiveness of specific sign installations in reducing reported accidents was also investigated. The before-and-after study method was used to evaluate 34 sign installations. Accident predictive methods were investigated for curve warning, advisory speed, special combination advisory speed, and 4-way stop sign installations.

•ALTHOUGH new or improved freeway systems are decreasing the pressure on the presently overtaxed streets and roads, the fact remains that the motorist must drive on the conventional road system for at least part of his travel. The California Division of Highways, for many years, has channeled certain funds into a "minor improvement program" to increase safety to the conventional road user.

The Evaluation of Minor Improvements study was designed to develop objective criteria for the evaluation of minor improvements, and thereby permit maximum safety benefits per dollar spent in the minor improvement program. The objectives of the overall study are as follows:

1. To determine the effectiveness of minor improvements in reducing traffic accidents.
2. To determine what conditions are susceptible to improvement and how much improvement can be expected.
3. To determine methods and measures for predicting the magnitude of the accident reduction on proposed minor improvement projects.
4. To review present improvement warrants for validity and adequacy and to determine if new warrants are required.

METHODOLOGY

Before and after periods of equal length were compared. To avoid bias due to seasonal fluctuations in accidents, the same number of each calendar month was used in each pair of before and after periods when fractional parts of a year were used (e.g., May 1961 to December 1962-before, and May 1963 to December 1964-after).

The periods used were, insofar as possible, immediately before and after the improvement construction to reduce the influence of any general trend in accident rates. An investigation of a possible increasing or decreasing trend showed no such phenomenon.

The before and after accidents and accident rates were compared. The "accident rate" is simply the number of accidents related to vehicle exposure (the total entering volume when considering intersections). When accident breakdowns are shown in tables, fatal and injury accidents were combined since the number of fatal accidents were few.

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SIGNIFICANCE TESTING

The chi-square test was generally employed to establish whether the reductions in accidents were statistically significant (1). Generally a confidence level of 0.10 was used. In other words, any significant difference would not be expected to have occurred by chance more than ten times out of one hundred.

The statistical reliability of observed changes is often indicated by $P < 0.10$. This means that we can be 90 percent confident that the difference observed was a true difference and not one due to random sampling fluctuations.

Because of relatively few (generally less than 20) accidents occurring in the before period for any one location, a reduction even as high as 50 percent for the after period is rarely statistically significant. That is, for such a small sample, this amount of reduction could have occurred because of chance variation. Therefore, under these conditions, the hypothesis that the highway improvement caused the accident reduction cannot be accepted with confidence. However, a large sample which is the sum of several projects may show a significant reduction from before to after because of the added power due to the increased sample size.

LEFT-TURN CHANNELIZATION

The purposes of left-turn channelization are (a) to increase intersection capacity by removing stopped vehicles awaiting a left-turning opportunity; (b) to provide a refuge for the stopped vehicle from rear-end accidents; and (c) possibly to provide refuge at the islands for pedestrians crossing the highway. This channelization can be accomplished by painted stripes, raised bars with painted outline, and curbs.

The protection for the left-turning vehicle consists of a bulbing of the channelization upstream of the storage pocket.

The intersections with raised-bar channelization and those with curbed channelization were combined for analysis since, in both cases, a positive physical barrier was used to protect the left-turning vehicles. Also, the accident reductions noted were approximately the same. The two groups used are paint and physical protection (raised bars and curbs).

The relative effectiveness of the channelization was judged solely on an accident basis. This assumes that no appreciable difference in design policy existed between the respective types of channelization. The assumption appears to be valid since for many years California has used the same equation to determine the required length of the storage lane.

Fifty-three left-turn channelized intersections were evaluated. While only 10 intersections showed a statistically significant reduction, 42 of these intersections did experience some reduction in accident rates.

Left-turn channelization as a whole has been effective (34 percent reduction) with a 48 percent reduction at unsignalized and 17 percent reduction at signalized intersections.

TABLE 1

LEFT-TURN CHANNELIZATION PROJECT SUMMARY

Channelization	No. Projects	Accidents		Percent Change
		Before	After	
Unsignalized:				
Paint	27	157	106^{S}	32
Physically protected	13	156	56^{S}	64
Subtotal	40	313	162^{S}	48
Signalized:				
(No L. T. φ)	13	283	234^{S}	17
Total	53	596	396^{S}	34

^{S}Significant at 0.10 level using the chi-square test.

TABLE 2

LEFT-TURN CHANNELIZATION

Intersection	Sing. Veh.	Multi. Veh.	PDO	I+F	Day	Night	Total
13 Signalized (284 MV):							
Before	19	264	176	107	178	105	283
After	25	209	136	98	140	94	234
40 Unsignalized (275 MV):							
Before	29	284	182	131	203	110	313
After	28	134	104	58	94	68	162

Painted left-turn channelized projects experienced a 32 percent accident reduction, and physically protected intersections had a 64 percent reduction in accidents (Table 1).

Pedestrian accidents were few (dropping slightly from 20 to 14 for all 53 projects) and are not discussed further.

Accidents in lieu of accident rates are tabulated throughout the report (except as noted) since the exposure remained essentially the same—not having increased more than 10 percent in any comparison group in the after period. The chi-square calculations are, therefore, based on an assumption of equal volumes in both periods.

A summary of the accident breakdown for 13 signalized (with no left-turn phase) and 40 unsignalized intersections is given in Table 2. Generally, when left-turn channelization is provided at signalized intersections on state highways, a signal phase is also provided for the movement. The small sample size available of this unphased movement is an indication of this policy.

The signalized intersections are highly urbanized and have high entering volumes. Total accidents were reduced in both groups (signalized, $P < 0.05$; unsignalized, $P < 0.001$) with greater reductions at unsignalized intersections. Channelization did not appreciably reduce night accidents at signalized (lighted) intersections.

Single-vehicle accidents remained about the same. Multiple-vehicle accidents were reduced for both categories although multiple-vehicle accidents ($P < 0.001$) at unsignalized intersections were reduced more than at signalized intersections ($P < 0.02$). Even greater reductions would have been realized if crossing or broadside accidents in the unsignalized category had not increased. These broadside accident increases occurred at urban painted and physically protected intersections.

Left-turn and rear-end accidents are given in Table 3 with a signalized and unsignalized intersection breakdown.

At the signalized intersections, the left-turn accidents were reduced although rear-end accidents increased slightly. This reduction apparently occurred during the daytime with nighttime accidents remaining about the same. All of these signalized intersections had safety lighting although the level of illumination is not known. It is also interesting to note that the more severe accidents (injury and fatal) remained the same with a significant decrease in the PDO ($P < 0.05$) category.

TABLE 3

LEFT-TURN AND REAR-END ACCIDENTS

Intersection	Left Turn	Rear End	PDO	I+F	Day	Night	LT+RE
13 Signalized:							
Before	101	92	125	68	121	72	193
After	46	106	90	62	88	64	152
40 Unsignalized:							
Before	52	164	122	94	139	77	216
After	33	24	33	24	36	21	57

TABLE 4

PAINT VS PHYSICALLY PROTECTED LEFT-TURN CHANNELIZATION
(Unsignalized)

Intersection	Sing. Veh.	Multi. Veh.	PDO	I+F	Day	Night	Total
27 Ints.—Paint (134± MV):							
Before	15	142	84	73	98	59	157
After	18	88	64	42	58	48	106
13 Ints.—Physical Protection (140± MV):							
Before	14	142	98	58	105	51	156
After	10	47	40	16	36	20	56

At the 40 unsignalized intersections, both left-turn ($P < 0.10$) and rear-end ($P < 0.001$) accidents were reduced with greater reductions noted in rear-end accidents (85 percent). All severity classes were reduced, with similar reductions noted ($P < 0.001$) in injury and fatal accidents (-74 percent) and in PDO accidents (-73 percent). This is similar to the day-night breakdown.

NONSIGNALIZED INTERSECTIONS

Effect of Physical Protection

Data were available for 27 painted left-turn channelized intersections and 13 physically protected left-turn channelizations. Although the latter group was considerably smaller in number, the total number of accidents in both groups in the before period is approximately the same as is the total exposure (Table 4).

Both groups of intersections show statistically significant reductions in total accidents ($P < 0.01$). The group of intersections with the physically protected channelization had twice the accident reduction as did those with paint.

Effect of Urbanization

The unsignalized intersections were divided into urban and rural groups (Table 5). When the relative exposures are applied to the total accidents, the accident rates are almost identical.

Painted channelization accident experience was divided into urban and rural intersections as shown in Table 6.

One thing that stands out immediately is that despite equal exposure and accidents in the rural and urban groups, painted channelization yields much greater accident reductions (of all types) in rural areas than in urban areas. Total rural accidents were significantly reduced ($P < 0.02$) as were rural multiple vehicle, PDO, I + F, and daytime accidents, whereas no type of accidents (shown in this table) were significantly reduced in the painted urban channelization groups. The data indicate that much greater accident reductions can be expected from painted left-turn channelization in rural areas than in urban areas.

In urban painted channelization although the total number of accidents dropped only 15 percent (79 to 67), left-turn and rear-end accidents (susceptible to correction) were halved from 52 to 25 (Table 7), thus indicating success in protecting the left-turning vehicles.

Physically protected left-turn channelization is divided into rural and urban groups in Table 8. Both urban and rural intersections show significant reductions ($P < 0.01$) in total accidents when physically protected left-turn channelization is used. Both painted ($P < 0.10$) and physically protected ($P < 0.01$) urban intersec-

TABLE 5

ACCIDENT RATES OF URBAN-RURAL INTERSECTIONS

Time	Urban	Rural
Before	1.16	1.17
After	0.57	0.55

tions have significant broadside accident increases. These accident increases are given in Table 9 with a further breakdown of the type or location of crossing accidents by direction of travel of the crossroad vehicle.

TABLE 6

PAINTED CHANNELIZATION (URBAN—RURAL)

Location and Time	Sing. Veh.	Multi. Veh.	PDO	I+F	Day	Night	Total
12 Ints.—Urban (46 MV):							
Before	8	71	43	36	45	34	79
After	8	59	43	24	33	34	67
15 Ints.—Rural (67 MV):							
Before	7	71	41	37	53	25	78
After	10	29	21	18	25	14	39

TABLE 7

PAINTED CHANNELIZATION:
LEFT-TURN AND REAR-END ACCIDENTS

Location and Time	Left Turn	Rear End	PDO	I+F	Day	Night	LT+RE
Urban:							
Before	18	34	29	23	30	22	52
After	14	11	14	11	11	14	25
Rural:							
Before	19	34	26	27	35	18	53
After	10	6	8	8	14	2	16

TABLE 8

PHYSICALLY PROTECTED LEFT-TURN CHANNELIZATION

Location and Time	Sing. Veh.	Multi. Veh.	PDO	I+F	Day	Night	Total
9 Ints.—Urban (40± MV):							
Before	10	100	70	40	79	31	110
After	7	29	26	10	26	10	36
4 Ints.—Rural (40±MV):							
Before	4	40	28	18	26	20	46
After	3	17	14	6	10	10	20

TABLE 9

URBAN BROADSIDE ACCIDENTS

Channelization	Type A		Type B		Total	
	Before	After	Before	After	Before	After
Painted	5	11	9	15	14	26
Physically protected	1	8	0	4	1	12
Total	6	19	9	19	15	38

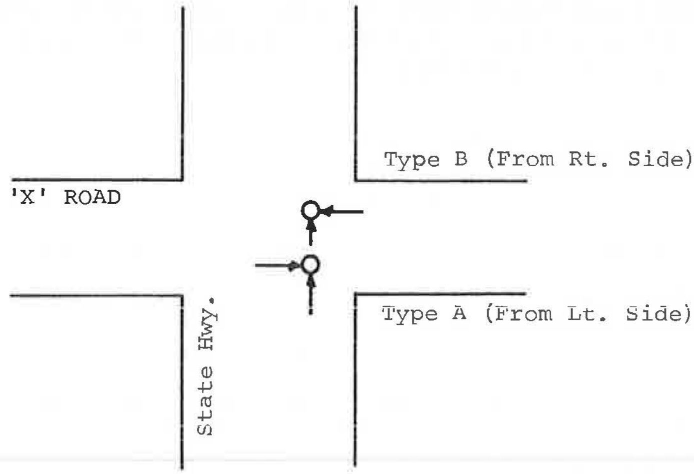

Figure 1.

It is interesting to note that both Type A broadside (Fig. 1) accidents (involving crossing street vehicles approaching from the left of the vehicle on the state highway) and Type B broadside accidents (involving crossing street vehicles approaching from the right of the vehicle on the state highway) were significantly increased (Type A, $P < 0.05$; Type B, $P < 0.10$).

It is possible that after the intersections were channelized, thus opening up through traffic to two lanes, that speeds on the state highway through the intersection increased. If this were the case, the cross road driver might not have adequate sight distance to judge the speed of vehicles on the state highway and thus broadside accidents could ensue.

Left-Turn Channelization Warrants

An investigation was made to determine the best criteria for establishing warrants for left-turn channelization of intersections. Various trial warrants were applied to the unsignalized intersection accident data (Table 10). These were compared to the results of all the intersections as constructed.

It is necessary to compare only accident frequency since the vehicular exposure is equal for all warrants. To compare the effects of different warrant criteria on all of the projects, it was necessary to estimate the accident experience in the after period for the unwarranted intersections. Since the before and after exposures were approximately the same, the number of before accidents was assumed to remain the same in the after period for projects not meeting a specific trial warrant. Therefore, the total accident experience in the after period was composed of the actual accidents of the warranted projects plus the before accident experience of the unwarranted intersections.

TABLE 10

EVALUATION OF WARRANTS—UNSIGNALIZED INTERSECTIONS

Warrant[a] Description	No. Warr. Projects	Estimated Reduction		
		L.T.	R.E.	Total
All Projects	40	20	140	151
3 LT+RE/Year[b]	22	24	119	141
4 LT+RE/Year[b]	13	9	96	98
5 LT+RE/Year[b]	10	6	93	93
4 LT+RE/Year or 6 LT+RE/2 Years	19	12	116	136

[a]Accidents involving channelized leg traffic.
[b]Average minimum number of accidents per year.

Note: The after accident experience for "Unwarranted" projects was estimated by assuming the number of before accidents would remain the same in the after period (before and after exposure approximately equal).

The accidents in Table 10 are total accidents. The projects declared unwarranted, however, were removed on the basis of the specific number and type of accidents of the warrant being considered. Since the before and after periods are equal for all projects, it is not necessary to compare accidents on a per year basis. In fact, by using the total periods, the changes are greater and more obvious.

When an average of three left-turn plus rear-end accidents was tried (Table 10), the total number of accidents reduced was only 10 less for these 22 projects than for all 40 projects. If the remaining 18 projects were constructed, a saving of less than 0.6 of an accident per project would be realized. This appears to be the best warrant evaluated. However, when a small separate study was made of 100 intersections with three accidents in the first year, only 40 of these had a two-year average of three accidents per year or greater; whereas, 66 of 100 intersections examined having four accidents in the first year had a two-year average of three or more accidents per year. For this reason, the last warrant which reduced 136 accidents while building 19 of the 40 projects is recommended.

The accident warrants as developed are intended as a guide to determine what corrective measure should be made relative to a specific accident pattern at a problem location. If a potential hazard is detected, improvements should be made without waiting for any specific number of accidents to occur.

The percents of accidents reduced were grouped relative to the zoned speeds on the state highway through the 19 warranted intersections. It was determined that at locations having zoned speeds of 55 mph or greater, painted left-turn channelization projects experienced slightly greater accident reductions than the physically protected intersections which were more effective at slower speeds (Table 11). These changes are all significant at $P < 0.001$ with the exception of painted channelization at the slower speeds which is significant at $P < 0.10$. It is felt that where physical protection is needed, the use of raised bars with a painted outline would in most instances do a good job in reducing accidents by economically providing an excellent delineator of the protective portion of the pocket in day or night. Also in night rainy weather, the bars provide reflective surfaces for headlights and make the channelization visible to drivers. One type of raised traffic bar used in California is only 1½ in. high and could be traversed in an emergency situation with little loss of vehicle control. These bars are an inexpensive and easily added-on device.

The number of projects are insufficient for warrant analysis at signalized intersections, especially since 9 of the 13 intersections were built as one painted channelization project and tend to bias the sample disproportionately.

Findings and Recommendations (Left-Turn Channelization)

1. Both painted and physically protected channelization were effective in reducing accidents (32 percent for paint and 64 percent for physically protected).

2. Painted left-turn channelization was more effective in reducing total accidents in rural areas than in urban areas. Paint and physical protection are equally effective in reducing total accidents in rural areas.

3. Significant total accident reductions were found in urban areas for physically protected intersections.

TABLE 11

MAIN LINE ZONED SPEEDS VERSUS TYPE OF CHANNELIZATION
(Warranted Projects Only)

Zoned Speed	Paint			Physically Protected		
	Acc.		Percent Change	Acc.		Percent Change
	B	A		B	A	
35-50	63	43	-32	46	11	-77
55-65	31	7	-77	87	31	-64

4. Painted intersections had a significant reduction in rear-end accidents under urban conditions. There were no indications that vehicles were driving over the paint and causing accidents.

5. Significant broadside accident increases were found at urban intersections at both painted and physically protected intersections.

6. The following warrants for left-turn channelization are recommended:

> The use of left-turn channelization as a traffic control device should be considered at unsignalized intersections having a total of 4 or more left-turn plus rear-end accidents in 12 months (involving vehicles from intersection legs to be channelized), or six or more left-turn plus rear-end accidents in a 24-month period. If the state highway is zoned for speeds 55 mph or greater, the use of painted channelization should be considered. If the zoned speeds are less than 55 mph, the use of physically protected form of channelization is suggested.
>
> Intersections with borderline warrants, where the improvement can be made at a reasonable cost, should also be considered on a cost-per-accident reduced basis.

7. It is recommended that for unsignalized intersections an average accident rate reduction of 60 percent or an average after base rate of 0.5 be used to estimate the numbers of future accidents. The preferred method is the use of the after base rate.

SIGNS

In California, signs are used only when justified by a factual review of field conditions. They are used where special regulations apply, where unusual conditions are not self-evident, and to furnish directional information.

Four general types of traffic signs are warning, regulatory, guide and construction. Specific warning and regulatory sign installations have been studied to determine their effect on safety.

Twenty-six of the 34 projects evaluated showed a reduction in accident rates with 8 of these projects having a significant accident reduction. There were no projects having significant accident increases.

The analysis of each type of sign installation is discussed separately. Before and after data have been reviewed at curve warning, curve warning plus advisory speed and at four-way stop signs. The total accident experience of these projects is given in Table 12.

Although there is an almost equal percent reduction in accidents when curve warning signs are used without advisory speed signs as with them, these reductions are not significant. This is an example of the unreliability of percent change of accidents as a criterion for comparing alternates.

Since the installation costs for these signs are generally minimal, no cost per accident reduced analysis was made.

TABLE 12

SIGN PROJECT SUMMARY

Sign	No. of Projects	Accidents		
		Before	After	Percent Change
Curve warning	4	22	18	-18
Advisory speed	24	209	162[s]	-22
4-Way stop	6	100	27[s]	-73
Total	34	331	207[s]	-37

[s]Significant at 0.10 level.

W3R (W1-1)　　W5R (W1-2)

Figure 2. Curve warning signs.

Figure 3. Standard advisory speed sign (special sign in background).

Curve Warning Signs

The use of curve warning signs has been standardized consistent with the degree of hazard at any particular location by considering speed of approach and the reading on a standard ballbank indicator when traversing the curve (2).

The W3R sign is placed 250 to 750 ft in advance of a curve that has a 10-deg ballbank indicator reading at 30 mph or less. The W5R is used when the ballbank indicator reading is 10 deg at speeds of between 30 and 60 mph. These signs are shown in Figure 2.

Accident statistics at four rural two-lane highway curve locations were reviewed having either W3R or W5R ground-mounted signs. (One location had reversing 1000-ft radius curves with four W5R signs.) Only slight insignificant reductions in total accidents were obtained at curves having these signs (Table 13).

Susceptible to correction accidents involving vehicles exceeding the safe speed into the curve were also reviewed. These accidents were not significantly reduced when only curve warning signs were present.

It is felt that there were too few projects in the curve warning category for meaningful analysis although slight accident reductions were noted. Curve warning signs alone may not convey enough information to enable the driver to make an intelligent estimate of the safe speed of the curve.

Advisory Speed Signs

W46R (W13-1) Signs Ground Mounted in Standard Position—When additional warning is required at curves to reduce approach speeds for safety, an advisory speed sign (W46R) is installed on the same post below the curve warning sign (Fig. 3).

The speed shown on the sign is the multiple of five nearest to the lowest safe speed found for the condition. Each direction of travel is considered separately (2).

No attempt was made to evaluate the advisory speed placed on the individual curves. As a portion of another study, the safe speed of a random sample of 200 curves throughout California was determined. Over 90 percent of these curves were found to have safe speeds equal to or within 5 mph of the advisory speed.

The effects of advisory speed signs on accidents have been studied at 15 curves having ground-mounted signs in the standard position. The accidents given in Table 14 are total accidents (regardless of type) occurring at the curve locations.

Total accidents ($P < 0.10$) were reduced as mentioned before. These were mainly single-vehicle ($P < 0.02$), and property damage only accidents ($P < 0.10$). There were no

TABLE 13

GROUND-MOUNTED W3R AND W5R CURVE WARNING SIGNS

Time[a]	Sing. Veh.	Multi. Veh.	PDO	I+F	Day	Night	Total
Before	15	7	12	10	11	11	22
After	11	7	11	7	12	6	18

[a]Before and after exposure approximately equal.

TABLE 14

TOTAL ACCIDENT EXPERIENCE AT CURVES WITH CURVE WARNING AND ADVISORY SPEED SIGNS[a]

Time	MV	Sing. Veh.	Multi. Veh.	PDO	I+F	Day	Night	Total
Before	62.7	95	47	76	66	68	74	142
After	67.6	68	55	58	65	61	62	123

[a]Ground mounted in standard position.

TABLE 15

ADD W46R TO EXISTING CURVE WARNING SIGN

Time	Accidents	Exposure (MV)	Rate (Acc/MV)
Before	52	14.6	3.56
After	43[a]	18.9	2.28
Percent rate change			-36

[a]$P < 0.05$.

significant changes in multiple-vehicle accidents or in daytime or night accidents. The more severe (I+ F) accidents also remained the same. Susceptible to correction accidents (exceeding the safe speed) were also examined. No appreciable difference from the total accident experience was found. These data were obtained from 13 locations where both curve warning and advisory speed signs were installed at the same time and two locations where advisory speed signs were added to existing curve warning signs.

To obtain a better evaluation of the advisory speed sign, data are given in Table 15 for 15 curves at which an advisory speed plate was added to an existing curve warning sign.

Where single-vehicle accidents were reviewed, the majority of accidents were of the run-off-the-road type, some hitting a fixed object. Fixed object and ran-off-the-road accidents occurring at night were significantly reduced.

Figure 4. Oversize special sign placed in head-on position.

Special Combination Signs

A large special sign having both a curve arrow and advisory speed has been used successfully in California. It is placed at the head-on position at curves where there is a severe ROR (ran-off-the-road) accident problem. It is generally placed where standard curve warning and advisory speed signs are already present. An example of this sign is shown in Figure 4.

A study of accident data at six special sign locations is given in Table 16.

Although available data are somewhat limited, total accidents (notably the single-vehicle type) were significantly reduced ($P < 0.01$). All other subgroups were significantly reduced with the exception of multiple-vehicle accidents. These signs apparently are doing a good job when additional emphasis of the safe speed beyond the standard W46R is needed by the motorist.

TABLE 16

ACCIDENT DATA FOR SPECIAL CURVE ARROW AND STATED SPEED SIGN

Time	MV	Sing. Veh.	Multi. Veh.	PDO	I+F	Day	Night	Total
Before	3.5	18	4	12	10	11	11	22
After	3.8	2	3	2	3	1	4	5

TABLE 17

TOTAL ACCIDENT EXPERIENCE ILLUMINATED OVERHEAD SIGNS

Time	MV	PDO	I+F	Day	Night	Total
Before	19.5	23	22	19	26	45
After	20.4	18	16	25	9	34

TABLE 18

FOUR-WAY STOP SIGNS (TOTAL ACCIDENTS)

Time	MV	Sing. Veh.	Multi. Veh.	PDO	I+F	Day	Night	Total
Before	50.8	4	96	53	47	66	34	100
After	59.3	0	27	18	9	11	16	27

Overhead Signs

Accident data from three projects having dual curve warning signs with an advisory speed sign mast arm mounted (Fig. 5) were examined. These signs were illuminated and placed on highways having four lanes.

Table 17 gives a breakdown of total accidents at these locations before and after the improvement. Although reductions were noted in total accidents, only night accidents were significantly changed ($P < 0.01$).

Four-Way Stop Signs

Four-way stop signs were installed at six intersections having stop signs facing minor road traffic in the before period. A four-way stop sign installation is a useful traffic control measure, and is most effective when the volume of traffic on the intersecting roads is about equal. The four-way stops were effective in reducing total accidents (Table 18).

Broadside accidents, a major problem at these intersections, were reduced from 78 to 12. The accident rate was reduced from 1.97 to 0.46 accidents per million vehicles, a 77 percent reduction.

Figure 5. Dual overhead curve warning and advisory speed signs.

Sign Warrants

Inasmuch as the cost of installing advisory speed and curve warning signs is

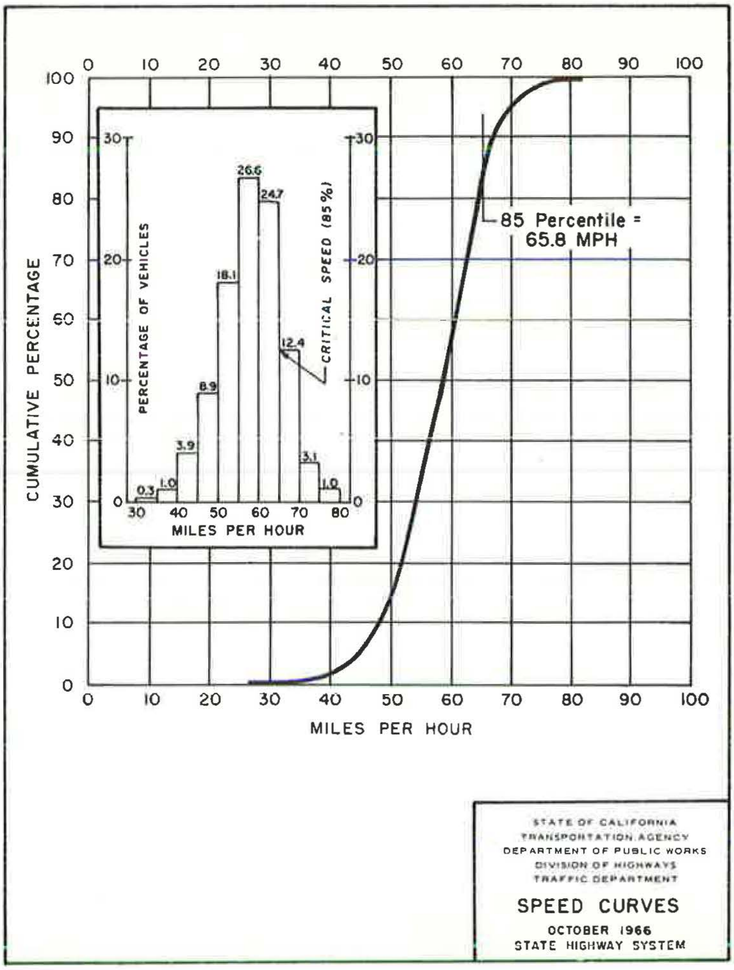

Figure 6.

very small (excepting the dual overhead signs), these signs could be quickly installed at a problem curve having a run-off-the-road accident problem.

Figure 6 is a speed curve for passenger cars from a statewide speed check in 1966. Some segments of traffic are exceeding the 85 percentile (critical) speed by approximately 17 mph. A portion of these fast vehicles would have difficulty negotiating a curve designed for the critical speed. If the safe speed on the curve is 5 mph slower than the critical speed on the curve approach, the upper segment of drivers are at least 20 mph over the safe speed.

Since the addition of an advisory speed sign to the standard curve warning sign resulted in greater accident reductions, consideration should be given to placing a W46R sign at locations with a 5-mph speed differential that requires a curve warning sign.

All of these six 4-way stop sign installations studied met the present warrants for the State of California. Because of the dearth of information, no warrant analyses for 4-way stop signs were made although it appears that present warrants are satisfactory.

Findings and Recommendations (Signs)

1. Curve Warning Signs (ground mounted in standard position)—Although the number of projects reviewed were few (four), present data indicate that no significant accident reductions occurred after placing either W3R or W5R (Curve Warning) signs.

2. Advisory Speed Signs (ground mounted in standard position)—When an advisory speed sign (W46R) was added to the curve warning sign, significant accident reductions were found. Specifically, ran-off-road accidents occurring at night were reduced at these ground-mounted signs. It is recommended that a W46R sign be placed at all locations requiring a curve warning sign. The placement of these signs should be considered when the safe speed is 5 mph less than the critical (85th percentile) speed of the approach.

3. Special Oversize—Combination curve warning and advisory speed signs placed in the head-on position at curves with a serious accident problem were quite effective in reducing single-vehicle accidents both in daytime and at night. When the standard curve warning and advisory speed signs are not totally effective and when approach speeds exceed 50 mph it is recommended that this special sign be used.

4. Illuminated dual overhead curve warning arrows with an advisory speed sign were effective in reducing night accidents on four-lane expressway curves.

5. Four-way stop signs were effective in reducing multiple-vehicle, namely right-angle or broadside, accidents. It appears that present warrants are satisfactory.

ACKNOWLEDGMENT

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