Effect of Raising Speed Limits on Urban Arterial Streets

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In 1956, 1957 and early 1958 speed limits on about 22 mi on portions of 11 arterial streets within the City of St. Paul were raised from 30 mph to 35 and in some cases to 40 mph. The streets affected carry from 4,000 to 26,000 veh per day, have no special access control, and are adjacent to a variety of land uses. Most of the spot speeds involved are from 25 to 40 mph. The new limits were set substantially in accordance with the "85 percentile" speed, a practice widely used on rural roads but not, it is believed, extensively used within municipalities on local arterial streets.

The purpose of the change was to establish a reasonable and enforceable speed limit on certain streets upon which it was obvious that the 30 mph limit was unreasonably low. Extensive "before" and "after" studies of the speed characteristics were conducted; the results are reported hereinafter. It is hoped that these findings will be of assistance to those contemplating a speed rezoning program on major streets within municipalities.

CONDUCT OF STUDY

Selection of Streets

● ON THE BASIS of spot speed sampling studies, 11 streets were selected upon which most drivers exceeded substantially the blanket 30 mph speed limit generally in effect throughout the city. On these streets, speeds of 5 to 10 mph higher than the limit were judged to be safe, this judgment being based on trial runs and such considerations as cross traffic characteristics, sight distance, pedestrian movements, street widths and conditions, parking and land use. Prior to the speed limit change, signs indicating the 30 mph limit were in place, but there appeared to be a tacit understanding by all concerned that speeds of 35 or 40 mph were permissible and safe. Shown in Table 1 are the percentages of violation of the 30 mph speed limit.

The streets selected all had pavements in fair to good condition but represented a variety of other conditions as is illustrated in Table 2.

Study Location and Conditions

Sites for conduct of "before" and "after" studies along the streets were selected insofar as possible where traffic was free-flowing and well removed from turning movements, traffic signals, stop signs, congestion, excessive parking, etc. All studies were conducted in fair weather, with dry pavement and during the off-peak traffic hours. In short, every effort was made to conduct the studies at such a time and place that drivers could select freely their travel speed. "Before" and "after" studies were conducted at approximately the same hours of the day, and on the same day of the week. Although speed limit signs were posted within 1,000 ft of most of the study sites, there were several locations where the distances were greater (Table 3). However, the locations were such that nearly all approaching traffic passed at least one sign prior to passing the study site. Enforcement efforts were moderate and about the same both before and after the speed limit change. The studies were scheduled as much as possible to avoid any unusual circumstances such as street repair, special events, etc.

Shepard Road, although substantial traffic volume increases were expected and occurred, was included in the study since speed zoning studies were necessary in any event because of the impending opening of a newly constructed roadway.

No major effort was made as a part of this study to influence or evaluate the publicity attending the speed limit changes. The proposed changes and the reasons for them were reported in a routine way by newspaper, radio, and television media prior to and at the time of the change.

TABLE 1

OBSERVANCE OF 30 MPH LIMIT

Street	% of Vehicles Exceeding Limit
Como Ave.	71.9
Concord St.	78.5
Dayton Ave.	33.2
Jefferson Ave.	94.5
Marshall Ave.	68.6
McKnight Road	92.7
Pleasant Ave.	76.3
Robert St.	52.0
Seventh St.	54.4
Shepard Road	72.2
Summit Ave.	62.6
Avg	68.8

Speed Measurement Method

Three separate series of speed studies were undertaken, a "before" study, an "after" study two to four months after the speed limit raise, and an "after" study six months or longer after the speed limit raise.

The surveys consisted of spot speed determination by means of stop watch measurements over an 88 or 176 ft measured course. Enoscopes were used for most of the surveys. The stop watches used had 10-sec sweeps and could be read accurately to the nearest 0.1 sec.

Before the field speed checks were started, an estimate of the required sample size was made. The probable standard deviation was estimated, on the basis of several pilot studies, at 5 mph. The maximum desired difference in the mean was designated as 0.5 mph. The desired level of significance assumed was 5 percent. The required sample size was then computed for a normal distribution curve as follows:

TABLE 2

CHARACTER OF STREETS[1]

Street	Approx. Length (mi)	Typical Width (ft)	Typical Parking Use	Typical Daily Volume	Number Signals or Stops	Typical Land Use
Como	2	58-40	Varies[9]	15,000 9,000	2[4]	Commercial - residential
Concord	1	56	Minor	12,000	0[5]	Residential
Dayton[7]	1½	36	One side	9,000	2[4]	Residential
Jefferson	½	44	Negligible	9,000	0[4]	Vacant
Marshall[8]	4½	32-48-52	Varies[9]	9,000 20,000	9[3]	Residential
McKnight	1	(2) 32[2]	Negligible	4,000	0[3]	Residential - vacant
Pleasant	1½	50-56	Negligible	7,000	1[4]	Residential - vacant
Robert	2	56-30-46[6]	Varies[9]	20,000 11,000	2[4]	Commercial - residential
East Seventh	1	56	Varies[9]	26,000 16,000	4[4]	Commercial
East Seventh	1½	40	Minor[9]	11,000 5,000	0[4]	Residential
Shepard Road	1	40	None	8,000	2[4]	Industrial
Summit	4½	48 (2) 28[2]	Varies	8,000 15,000	6[3]	Residential

[1] Figures do not include those frequently existing at one or both ends of project.
[2] Divided parkway type of street.
[3] Stopped or signalized at both ends of project.
[4] Stopped or signalized at one end of project.
[5] Not stopped or signalized at either end of project.
[6] The 30-ft width is on underpass where parking is banned.
[7] One-way street with parking banned on one side.
[8] The narrower portion is one-way with parking banned on one side.
[9] Parking banned in certain areas either rush hours or permanently.

$$N = \left(\frac{C\ S}{D}\right)^2$$

$$N = \left(\frac{1.96\ \ (5)}{0.5}\right)^2$$

N = 384 (use 400)

Where N = required number of samples.

C = Z value for 5 percent of significance.

S = estimated standard deviation.

D = assigned difference in the means.

TABLE 3

DISTANCE TO NEAREST SPEED LIMIT SIGN

Street	Location	Study Reference Number	Direction	Distance to Sign
Como	Elfelt to Galtier	1	WB	600
			EB	200
	E. of Topping	2	WB	700
			EB	200
Concord	Near Brown	3	SB	800
			NB	1,000
Dayton	Avon to Grotto	4	EB	500
Jefferson	E. of Lexington	5	WB	200
			EB	100
Marshall	Avon to Grotto	6	WB	800
			EB	1,500
	W. of Syndicate	7	WB	1,200
			EB	300
	Aldine to Herschel	8	WB	600
			EB	1,000
McKnight	Fourth	9	NB	3,000
			SB	2,000
Pleasant	E. of St. Albans	10	EB	400
			WB	200
Robert	Chicago to Plato	11	SB	200
			NB	200
	N. of Winona	12	SB	200
			NB	200
Seventh	W. of Eichenwald	13	WB	1,100
			EB	800
	W. of Birmingham	14	WB	1,600
			EB	1,000
Shepard Road	W. of Jackson to Elm	15	EB	1,000
Summit	Victoria to Avon	16	EB	1,200
			WB	2,000
	W. of Hamline	17	EB	200
			WB	200
	Pierce to Aldine	18	EB	1,200
			WB	1,000

It was assumed, therefore, that a sample size at each location of about 400 was required for the desired results, and this number was obtained in nearly all cases. Subsequent analysis of the data obtained confirmed the validity of assuming that with this sample size, any change in the "before" and "after" mean of more than 0.5 mph would be 95 percent certain to be due to a factor other than chance.

Speed Limit Revision

On the basis of analysis of the "before" data, determination of the 85 percentile speeds, and a judgment of conditions present, the former speed limits and signs of 30 mph were replaced with 35 or 40 mph (Table 4). Results of the "before" study are shown in Tables 5 through 11.

ANALYSIS OF DATA

Speed Changes

In evaluating the results of the speed limit changes, the effect on driving speeds was considered to be of fundamental importance. A number of comments were received at the time of the speed limit change to the effect that raising the speed limit 5 or 10 mph would mean that all drivers would automatically speed up by that amount. In order to evaluate this characteristic, "before" and "after" comparisons were made of the mean, median, modal and 85 percentile speeds.

In the analysis of the "before" and "after" mean speeds, a test of statistical significance was performed using the standard error of the difference of the means as follows:

$$D = \sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}}$$

TABLE 4

SPEED LIMIT CHANGES

Street	Location	Study Reference Number	Date of Limit Change	New Limit (mph)
Como Ave.	Elfelt to Galtier	1	2-4-58	35
	E. of Topping	2	2-4-58	35
Concord St.	Near Brown	3	6-24-57	35
Dayton	Avon to Grotto (1-way)	4	1-31-58	35
Jefferson	E. of Lexington	5	11-21-57	40
Marshall	Avon to Grotto	6	1-31-58	35
	W. of Snydicate	7	1-31-58	35
	Aldine to Herschel	8	1-31-58	35
McKnight	Near Fourth	9	6-15-56	40
Pleasant	E. on St. Albans	10	6-27-57	40
Robert St.	Chicago to Plato	11	2-3-58	35
	N. of Winona	12	2-3-58	35
Seventh St.	W. of Eichenwald	13	2-5-58	35
	W. of Birmingham	14	2-5-58	35
Shepard Rd.	W. of Wabasha	15	7-11-56	40
Summit Ave.	Victoria to Avon	16	6-25-57	35
	W. of Hamline	17	6-25-57	35
	Pierce to Aldine	18	6-25-57	35

Where D = significant difference in means.
S_1 = standard deviation "before."
S_2 = standard deviation 6 to 24 months "after."
N_1 = number of measurements in "before" sample.
N_2 = number of measurements in "after" sample.

The D value was computed in each case and multiplied by 1.96 to arrive at the numerical difference in means which would be significant for a 5 percent significance level. It may be assumed, therefore, that where a greater numerical difference occurred, there exists a 95 percent certainty that the difference is due to a factor other than chance. The results are shown in Table 5. It will be noted that at the 18 study locations, six had a significantly higher mean, eight had a significantly lower mean, three had a lower but not significant mean, and one an increased but not significant mean.

The median, modal, and 85 percentile comparisons are shown in Tables 6, 7 and 8. Two sets of "after" studies are reported, one within 2 to 4 months and one within 6 to 24 months. This was done to check whether there would be continuing or reversing changes after a longer time period. It will be noted that some "after" values are slightly increased, some slightly decreased, and some unchanged from the "before" values. Changes in the longer time period do not appear appreciably different from those of the shorter period.

TABLE 5

CHANGES IN MEAN SPEED

Street[1]		Reference Number	"Before" mph	"After" (6-24 mo.) mph	Significance[2]
Como	(35)	1	32.5	32.3	No
	(35)	2	35.3	34.2	Yes
Concord	(35)	3	33.9	34.0	No
Dayton	(35)	4	29.8	31.9	Yes
Jefferson	(40)	5	34.6	36.2	Yes
Marshall	(35)	6	32.2	31.4	Yes
	(35)	7	34.0	32.0	Yes
	(35)	8	33.5	32.8	Yes
McKnight	(40)	9	40.9	37.1	Yes
Pleasant	(40)	10	33.3	34.4	Yes
Robert	(35)	11	31.6	31.2	No
	(35)	12	34.5	30.5	Yes
Seventh	(35)	13	30.0	33.3	Yes
	(35)	14	32.3	31.3	Yes
Shepard	(40)	15	33.5	37.4	Yes
Summit	(35)	16	31.0	33.1	Yes
	(35)	17	34.5	33.9	Yes
	(35)	18	32.9	32.6	No
Avg	(35)		32.7	32.5	
	(40)		35.6	36.3	

[1] Values shown in parenthesis are the new limits in each case. The former limits were a blanket 30 mph.
[2] Whether the difference in "before" and "after" means was greater than 1.96 x standard error. This assumes a 95 percent confidence level.

Uniformity of Speeds

Another important speed characteristic is the tendency toward more uniform speeds. In evaluating this trait, two approaches were used. The first, a determination of the percent of vehicles in the 10 mph pace, involved a computation of the percent of vehicles within the 10 mph range having the greatest number of speeds. The second method involved computing the speed range containing a given percentage of drivers. In the latter method, computations were made of the speed range representing one standard deviation from the mean. The results of these two analyses are shown in Tables 9 and 10. Computations are presented for the time period of 6 to 24 months after the speed limit change. It will be noted that in 11 cases the percent of vehicles within the pace increased, and in seven cases there was a decrease.

In the pace analysis, of course, a tendency toward more uniformity of speeds would be shown by increases in the percent of vehicles within the pace. With respect to the standard deviation, a tendency toward more uniformity of speeds would be shown by decreasing values. It will be noted in Table 10 that there were eight increases and ten decreases in the standard deviation.

The absence of any apparent tendency toward more uniformity of speeds is, of course, contrary to some previous findings with respect to speed zoning on rural highways. For example, Matson, Smith, and Hurd (4) report on rural highways a tendency toward greater uniformity after zoning. There are several factors which may explain the discrepancy. The streets reported on herein rather than being rural are urban arteries in built-up areas with a variety of adjacent land use. The average running speeds on the urban streets are much lower than on rural highways. The study reported herein involved raising the limit slightly at locations already zoned but where the former speed limit was lower than most drivers desired to travel. Traffic volumes on the urban

TABLE 6

CHANGES IN MEDIAN SPEED

Street[1]		Reference Number	"Before" mph	"After" (2-4 mo.) mph	"After" (6-24 mo.) mph
Como	(35)	1	31.7	32.6	31.9
	(35)	2	32.8	32.9	33.5
Concord	(35)	3	32.5	31.2	33.1
Dayton	(35)	4	29.0	31.3	31.4
Jefferson	(40)	5	33.0	33.1	35.3
Marshall	(35)	6	31.0	31.4	31.1
	(35)	7	32.9	31.8	31.6
	(35)	8	32.0	32.3	31.9
McKnight	(40)	9	39.4	36.0	36.4
Pleasant	(40)	10	32.2	32.4	34.0
Robert	(35)	11	30.7	32.0	30.7
	(35)	12	29.7	31.4	29.9
Seventh	(35)	13	29.6	30.6	32.8
	(35)	14	31.7	31.4	30.6
Shepard	(40)	15	32.8	-	37.0
Summit	(35)	16	29.3	29.8	32.4
	(35)	17	32.7	31.1	33.3
	(35)	18	31.9	31.4	31.8
Avg	(35)		31.2	31.5	31.9
	(40)		34.5	33.8	35.7

[1] Values shown in parenthesis are the new limits in each cast. The former limits were a blanket 30 mph.

arteries involved in this study were, in general, greater than those typically found on rural highways.

Speeds and Posted Limit

One of the primary aims of speed zoning is to set a limit at the maximum safe speed and to achieve substantial voluntary compliance with the limit set. In order to evaluate these factors and also to further measure any tendency for all drivers automatically to speed up 5 or 10 mph when the limits are raised by these amounts, "before" and "after" determinations were made of the percent of drivers at or below the posted limit. The results are shown in Table 11. It will be noted that substantial increases in compliance were obtained with the higher speed limits, a definite indication that drivers do not tend to speed up by the limit change. The new limits are obviously more enforceable.

Need For Further Study

This report has been concerned only with the change in off-peak speed characteristics resulting from a 5 or 10 mph raise in the speed limit on several urban arterial streets. The typical speed range involved is 25 to 40 mph, and the speed zoning procedure was the so-called 85 percentile method. The conduct of the study and the report thereon have suggested several related areas in which additional study might be fruitful. These include the following:

1. A detailed study of "before" and "after" accident characteristics. In view of the minor nature of the speed changes in this particular study, little or no change was

TABLE 7

CHANGES IN MODAL SPEED

Street[1]		Reference Number	"Before" mph	"After" (2-4 mo.) mph	"After" (6-24 mo.) mph
Como	(35)	1	33.3	33.3	32.4
	(35)	2	33.3	33.3	34.4
Concord	(35)	3	33.3	30.0	35.2
Dayton	(35)	4	30.0	35.3	31.6
Jefferson	(40)	5	33.3	35.3	40.0
Marshall	(35)	6	31.6	35.3	31.6
	(35)	7	35.3	35.3	32.4
	(35)	8	31.6	35.3	31.6
McKnight	(40)	9	42.8	35.3	36.4
Pleasant	(40)	10	33.3	33.3	35.2
Robert	(35)	11	30.0	33.3	30.0
	(35)	12	30.0	33.3	30.0
Seventh	(35)	13	31.6	30.0	34.4
	(35)	14	33.3	33.3	30.0
Shepard	(40)	15	32.4	-	40.0
Summit	(35)	16	30.0	30.0	32.4
	(35)	17	33.3	33.3	34.4
	(35)	18	33.3	31.6	30.8
Avg	(35)		32.1	33.0	32.2
	(40)		35.5	34.6	37.9

[1] Values shown in parenthesis are the new limits in each case. The former limits were a blanket 30 mph.

anticipated in the number or type of accidents traceable to the speed limit revisions. An approximate check on yearly totals of accidents reported to the Police Department did not reveal any apparent change in the accident frequency trends on the streets involved. However, an analysis of the time of day, type, and severity of "before" and "after" accidents could conceivably show some change.

2. "Before" and "after" studies of rush hour speed characteristics. Observation indicates that rush hour speeds on these outlying arterials may tend to be higher than off-peak speeds, both before and after the speed limit changes.

3. A study of the effect of lowering limits where warranted. There are many streets where a blanket 30 mph limit, for example, is too high. A speed zoning program would normally involve reducing limits as well as raising them. It appears reasonable to assume that reducing a limit in accordance with the 85 percentile method would not result in a tendency toward a significant increase in speed.

4. Studies of the relation between speeds and varying but carefully controlled intensities of signing and enforcement on these types of urban arterial streets.

CONCLUSIONS

For urban speed zoning activities on the types of streets involved in this study and with typical spot speeds of 25 to 40 mph, the following conclusions appear warranted:

1. The generally accepted 85 percentile method of speed zoning, which includes trial runs, evaluation of adjacent land use, and related studies is satisfactory for use on urban arterial streets insofar as its effect on actual travel speeds is concerned.

2. Where justifiably higher limits of 5 or 10 mph are set in accordance with item 1 above, there is a definite tendency for the mean, median, modal, and 85 percential

TABLE 8

CHANGES IN 85 PERCENTILE SPEED

Street[1]		Reference Number	"Before" mph	"After" (2-4 mo.) mph	"After" (6-24 mo.) mph
Como	(35)	1	35.4	37.4	35.8
	(35)	2	36.6	37.6	37.3
Concord	(35)	3	36.8	33.7	36.8
Dayton	(35)	4	32.2	35.3	35.1
Jefferson	(40)	5	37.2	37.4	40.6
Marshall	(35)	6	35.4	36.1	34.9
	(35)	7	36.1	36.5	34.9
	(35)	8	37.1	36.5	36.3
McKnight	(40)	9	46.4	43.4	42.0
Pleasant	(40)	10	35.7	36.4	38.3
Robert	(35)	11	34.7	36.9	34.7
	(35)	12	37.3	35.4	33.9
Seventh	(35)	13	33.5	35.0	37.0
	(35)	14	36.8	35.9	34.9
Shepard	(40)	15	38.4	-	42.2
Summit	(35)	16	32.6	33.2	36.4
	(35)	17	36.9	34.7	37.2
	(35)	18	35.3	35.3	36.3
Avg	(35)		35.5	35.7	35.8
	(40)		39.4	39.1	40.8

[1] Values shown in parenthesis are the new limits in each case. The former limits were a blanket 30 mph.

TABLE 9

CHANGES IN PACE

Street[1]		Reference Number	"Before" Pace mph	"Before" Vehicles in Pace %	"After" Pace mph	"After" Vehicles in Pace %
Como	(35)	1	28.2-38.2	76.1	28.2-38.2	78.4
	(35)	2	29.5-39.5	73.5	29.7-39.7	76.8
Concord	(35)	3	29.3-39.3	81.6	29.0-39.0	83.3
Dayton	(35)	4	25.5-35.5	85.0	27.4-37.4	85.5
Jefferson	(40)	5	29.8-39.8	80.3	32.0-42.0	65.7
Marshall	(35)	6	28.0-38.0	73.5	27.0-37.0	80.0
	(35)	7	29.7-39.7	75.8	27.6-37.6	81.4
	(35)	8	28.5-38.5	74.1	28.0-38.0	80.3
McKnight	(40)	9	37.6-47.6	51.2	31.0-41.0	62.0
Pleasant	(40)	10	28.9-38.9	83.2	29.8-39.8	75.3
Robert	(35)	11	27.5-37.5	80.4	26.8-36.8	77.0
	(35)	12	32.1-42.1	63.2	26.7-36.7	77.9
Seventh	(35)	13	26.3-36.3	73.6	29.2-39.2	81.4
	(35)	14	28.7-38.7	68.2	27.2-37.2	77.1
Shepard	(40)	15	27.0-37.0	65.5	33.9-43.9	64.8
Summit	(35)	16	26.0-36.0	82.4	28.3-38.3	80.3
	(35)	17	29.2-39.2	79.3	29.2-39.2	78.5
	(35)	18	28.7-38.7	81.1	28.2-38.2	75.4
Avg	(35)		28.4-38.4	76.3	28.0-38.0	79.5
	(40)		30.8-40.8	70.1	31.7-41.7	67.0

[1] Values shown in parenthesis are the new limits in each case. The former limits were a blanket 30 mph.

TABLE 10

CHANGES IN STANDARD DEVIATION

Street[1]		Reference Number	"Before" Std. Dev. mph	"After Std. Dev. mph
Como	(35)	1	4.27	4.07
	(35)	2	4.65	4.13
Concord	(35)	3	3.77	5.07
Dayton	(35)	4	3.54	3.56
Jefferson	(40)	5	4.08	5.19
Marshall	(35)	6	4.26	4.13
	(35)	7	3.22	3.79
	(35)	8	5.04	4.46
McKnight	(40)	9	7.21	3.74
Pleasant	(40)	10	3.68	4.17
Robert	(35)	11	4.14	4.04
	(35)	12	6.70	4.13
Seventh	(35)	13	4.73	4.44
	(35)	14	4.91	4.89
Shepard	(40)	15	6.38	5.61
Summit	(35)	16	3.64	3.95
	(35)	17	4.05	4.17
	(35)	18	3.88	4.51
Avg	(35)		4.34	4.24
	(40)		5.34	4.68

[1] Values shown in parenthesis are the new limits in each case. The former limits were a blanket 30 mph.

TABLE 11

PERCENT OF SPEEDS UNDER POSTED LIMITS

Street[1]		Reference Number	"Before"	"After" (2-4 mo.)	"After" (6-24 mo.)
Como	(35)	1	35.4	69.4	79.9
	(35)	2	20.7	67.9	66.6
Concord	(35)	3	21.5	89.6	71.6
Dayton	(35)	4	66.8	82.9	84.3
Jefferson	(40)	5	15.5	94.1	82.0
Marshall	(35)	6	37.8	79.3	86.0
	(35)	7	22.9	76.5	86.1
	(35)	8	33.5	75.2	78.5
McKnight	(40)	9	6.8	91.7	77.2
Pleasant	(40)	10	23.7	97.6	94.3
Robert	(35)	11	43.7	76.2	86.9
	(35)	12	16.4	74.4	90.5
Seventh	(35)	13	54.5	85.3	75.2
	(35)	14	36.6	79.3	85.6
Shepard	(40)	15	27.8	-	73.6
Summit	(35)	16	62.6	92.9	76.4
	(35)	17	20.7	87.3	69.4
	(35)	18	28.9	82.9	77.8
Avg	(35)		35.9	79.9	79.6
	(40)		18.5	94.5	81.8

[1] Values shown in parenthesis are the new limits in each case. The former limits were a blanket 30 mph.

speeds after the change to remain very close to those occurring before the change. "After" speeds may frequently be slightly less than the "before" speeds. The tendency is for any speed changes to be small and to bear no relationship to the change in the limit. There appears to be little or no relation between the amount of the limit raise and any changes in actual speeds.

3. On the types of streets and in the speed ranges involved, a tendency toward more uniform speeds will not always occur. Where an urban arterial street speed limit is raised 5 or 10 mph to conform with a "before" 85 percentile speed, some cases of less uniformity, some of more uniformity, and some of no change may be expected. The tendency is for any change to be relatively small.

REFERENCES

1. Henberger, J.C., Matyas, C.A. and Wiley, C.C., "Effect of Speed Limit Signs on Vehicular Speeds." A Research Study, Department of Civil Engineering, University of Illinois (1949).
2. Dixon, Wilfred J. and Massey, Frank J., "Introduction to Statistical Analysis." McGraw-Hill (1957).
3. Manual of Traffic Engineering Studies. Accident Prevention Department of the Association of Casualty and Surety Companies (1953).
4. Matson, Theodore M., Smith, Wilbur S., and Hurd, Frederick W., "Traffic Engineering," McGraw-Hill (1955).
5. Traffic Engineering Handbook, Institute of Traffic Engineers (1950).