An Experiment with Evergreen Trees in Expressway Medians to Improve Roadway Delineation

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Simulated median plantings were installed on selected portions of two Chicago expressways to determine whether this means of providing roadway delineation would significantly reduce the frequency of vehicle encroachment on the median. A complete record of encroachments was obtained during the winter for comparison with the number that occurred during the same portion of the previous year.

There was a significant reduction in the frequency of encroachment on the medians of both expressways, with the greatest reductions occurring on or near curved alignment where the hazard of headlight glare from opposing vehicles had previously been greatest. However, no attempt was made to measure the relative magnitude of the several roadway delineation benefits assumed to have contributed to the observed reductions.

The findings suggest the possibility of substantial improvement in the safety of divided highways through the development and use of median plantings appropriate to the needs of the driver under the various conditions imposed by roadway characteristics, driving conditions, and surrounding land use.

•THIS REPORT covers one phase of a study of medians of divided highways which was conducted by the Department of Civil Engineering, University of Illinois, in cooperation with the National Science Foundation, the Illinois Division of Highways and the U.S. Bureau of Public Roads. It presents the findings from an experimental use of evergreen trees in Chicago expressway medians to improve roadway delineation.

Results from studies of the frequency and nature of accidents involving vehicle encroachment on medians of divided highways in Illinois have suggested the possibility of generally insufficient roadway delineation on modern freeways and expressways. Encroachments on the median were observed to be concentrated at locations where roadway characteristics and the headlight glare from approaching vehicles would appear to make it difficult for drivers to judge roadway alignment (1). As a result of these observations an experiment was designed to determine whether an improvement in roadway delineation would significantly decrease the frequency of vehicle encroachment on highway medians.

Among the many factors affecting the choice of delineation materials in the experiment, the controlling considerations were assumed to be (a) the need to provide drivers with some relief from the headlight glare of opposing vehicles and (b) the need to provide the appearance of a third dimension to wide modern roadways which give the impression of having only two dimensions, length and width, particularly during low-visibility conditions. Plantings in the median have been credited with the achievement

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of these purposes, although the lack of experience and research in this area has been pointed out (2, 3).

One argument in favor of median plantings is that the driver should occasionally have familiar three-dimensional objects relatively close at hand if he is to be kept constantly aware of the routine circumstances of driving. The average adult freeway driver of today has gained most of his driving experience on 2-lane highways and streets with narrow rights-of-way where he has become accustomed to the nearby telephone poles, fences, trees and shrubs that help to keep him almost effortlessly aware of his general speed and position on the roadway. Under the contrasting conditions found on freeways with wide, nearly level right-of-way, it has been noted that adult drivers often behave in such a way as to show basic ignorance of speed and distance relationships and of driver judgment time requirements (4). It has, therefore, been reasoned that the use of certain types of trees or shrubs in the median of modern freeways should increase the vertical angle of driver vision intercepting the median cross-section and give the driver a familiar basis for judging speed, distance and roadway alignment. In consideration of this argument and because of the assumed need to reduce headlight glare, median plantings were chosen for use as the delineating materials in this experiment.

The time and expense normally involved in the establishment of mature median plantings prompted a search for an acceptable type of simulated planting that could be installed immediately. An investigation of the cost and appearance of artificial trees, plastic shrubs and other possibly suitable materials led to the adoption of evergreen trees (leftover Christmas trees) as the most suitable and economical substitute for normal plantings.

The choice of study sites was limited by the need to perform the experiment on highways for which a record of vehicle encroachments on the median had previously been obtained. Furthermore, Chicago expressways were the only previously studied facilities with traffic volumes high enough to have yielded a possibly significant number of vehicle encroachments on the median within the useful life span of a cut evergreen tree. Selected portions of the Edens and Calumet Expressways were utilized to include both a lighted 6-lane facility with a narrow median (17.6 ft) and an unlighted 4-lane facility with a relatively wide median (40 ft).

PROCEDURE

Leftover Christmas trees were obtained free of charge from Chicago area merchants during the last week of December 1959 and installed on the median barrier posts of the two expressway segments. The location and length of each installation and the details of expressway cross-sections are shown in Figures 1 and 2. Details of tree fastening and spacing are shown in Figure 3.

Beginning in January 1960 on the first day after completed installation of trees on each expressway, a complete record of vehicle encroachments was obtained for comparison with the number of encroachments that occurred during the same portion of the previous year without the trees. The collection of encroachment data required carefully planned frequent coverage of the entire length of the study sites to locate and evaluate properly the evidence of each vehicle encroachment. Project personnel worked closely with maintenance personnel and weather forecasters to prevent the loss of encroachment evidence due to changing weather conditions and maintenance activities. Intentional encroachments for the purpose of making U-turns or performing emergency activities across the median were not recorded.

The trees were removed after the first few warmer days of March when they began to defoliate.

FINDINGS

A summary of the results of the experiment is given in Table 1. The possible effects of the differences in weather conditions during the two periods of time were not considered in estimating the significance of the reductions in number of encroachments. Chicago area weather records show that there were 6 more days of low-visibility

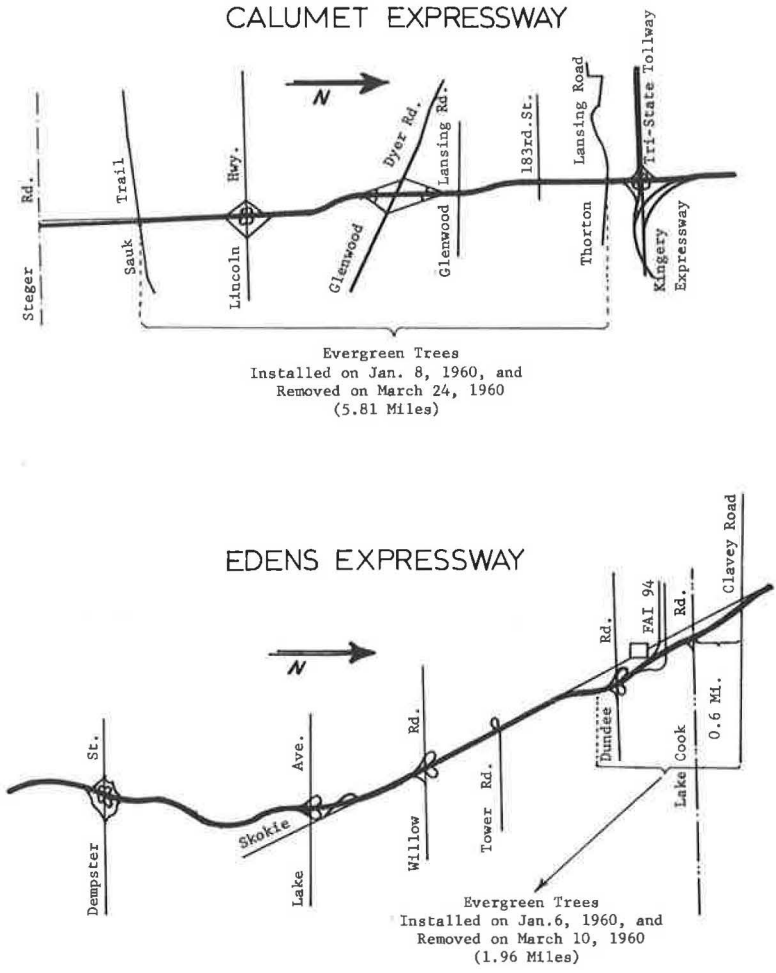


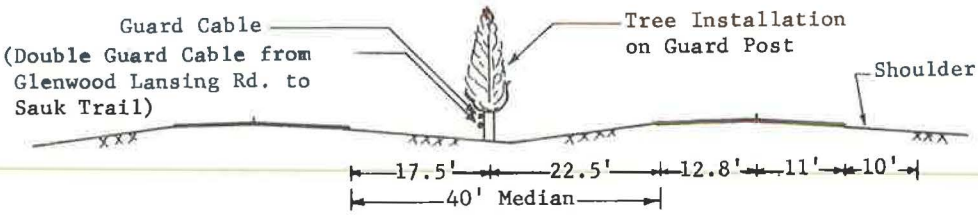
Figure 1. Test sites.

conditions and 5 more days of freezing drizzle or rain during the 1959 period of observation than during the 1960 period (Table 2). This may or may not have been offset by the 11 more days of snowfall and sleet that occurred during the second period. However, it appears that the slightly increased traffic volumes (Table 3) and included extra day of observation during the second period would probably have offset any differences in the effects of weather. The reductions in the number of encroachments due to the effects of the evergreen trees are, therefore, considered significant at the levels indicated in Table 1. That is, for the particular weather and traffic conditions and roadway characteristics involved in this study, it is assumed that the trees effectively reduced the number of vehicle encroachments on the median in that the observed reductions could have occurred by chance less than 2 times in 100.

DISCUSSION OF THE EXPERIMENT

Although this experiment was not based on the analysis of accident data collected by the police, an evaluation of pertinent accident records was made as part of the work on previously reported research (5) aimed at gaining a better understanding of the variables in accident reporting. The numbers of encroachments recorded by project personnel are given in Table 4 for comparison with the number of accidents reported by the police during the same periods of time.

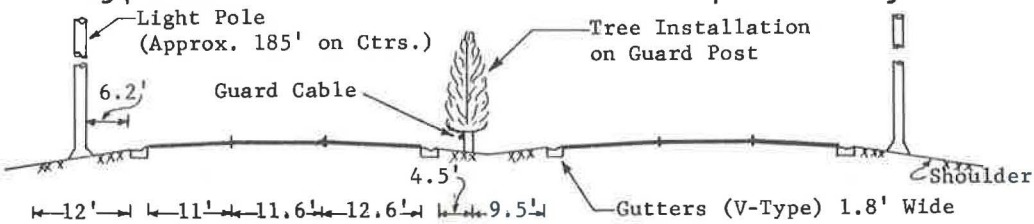
Typical Cross-Section Calumet Expressway



Calumet Expressway Median, Guard Posts and Cable

Calumet Expressway North From 183 rd St.

Typical Cross-Section Edens Expressway



Edens Expressway South From Lake Cook Rd. Overpass (F.A.I. 94 Overpass in Background)

Edens Expressway South From Entrance of F.A.I. 94 (Dundee Road Overpass in Background)

Figure 2.

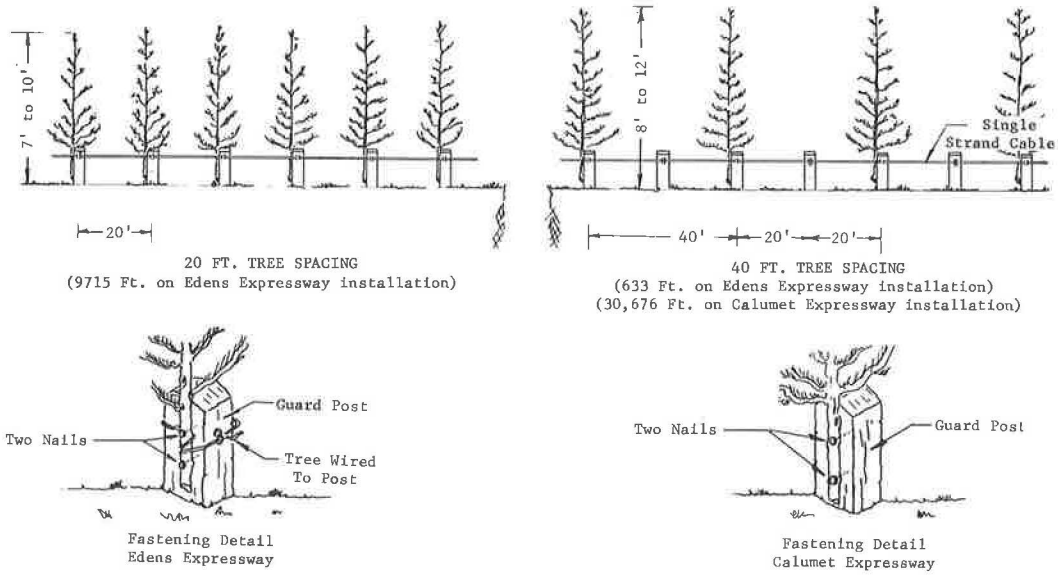


Figure 3. Installation of evergreen trees on expressway median.

TABLE 1

EFFECT OF EVERGREEN TREES ON ENCROACHMENTS

Expressway	Length (mi)	Days of Observation[a]	No. of Veh Encroachments on Median			Change 1959 to 1960 (%)	Significance[c] of Change
			1959	1960[b]	1961		
Edens	1.96	63	11	2	14	-82	P < .02
Calumet	5.81	74	13	3	—	-77	P < .02

[a]1959 and 1961 only (one extra day, Feb. 29, was included in 1960 observations).
[b]With trees.
[c]Mathematical model used for estimating significance is given in Appendix.

TABLE 2

CHICAGO AREA WEATHER
(Jan. 6 through March 24)

Year	Snowfall or Sleet (days)				Total Snow (in.)	Max. Snow on Ground (in.)			Freezing Drizzle or Freezing Rain (days)				Low Visibility[a] (days)			
	Jan.	Feb.	March	Total		Jan.	Feb.	March	Jan.	Feb.	March	Total	Jan.	Feb.	March	Total
1959	13	12	13	38	22.1	8	5	1	4	4	1	9	3	3	2	8
1960	11	23	15	49	32.0	2	7	7	1	3	0	4	0	0	2	2

[a]One-fourth mile or less because of fog, snow, etc.

TABLE 3

TRAFFIC VOLUMES ON CHICAGO EXPRESSWAYS

Expressway	Annual Avg. Daily Traffic				Avg. Daily Traffic for Period[a]				Avg. Daily Traffic During Winter[b]			
	1957	1958	1959	1960	1957	1958	1959	1960	1956-57	1957-58	1958-59	1959-60
Edens (at Lake Cook Rd.)	30,269	29,666	27,000[a]	25,500	24,700	25,560	22,720[c]	26,030	24,770	26,160	23,016[c]	25,810
Calvert (at Glenwood Lansing Rd.)	10,973	11,825	12,954	13,800	9,531	9,865	10,908	12,000	9,519	9,852	10,906	12,065

[a]From Jan. 1 through March 31.
[b]Dec. 1 through March 31.
[c]Opening of Illinois Toll Highway diverted traffic from the north end of Edens Expressway.

TABLE 4

SUMMARY OF ACCIDENTS AND ENCROACHMENTS ON MEDIANS OF CHICAGO EXPRESSWAYS

Expressway Location	All Reported Accidents[a]				Reported Median Accidents[b]			All Reported Accidents During Winter[c]				Reported Median Accidents During Winter[b, c]			Vehicle Encroachments on Median During Winter[c]		
	1957	1958	1959	1960	1958	1959	1960	1956-57	1957-58	1958-59	1959-60	1957-58	1958-59	1959-60	1957-58	1958-59	1959-60
Edens with trees	30	34	24	42	7	1	18	—	13[d]	19	19	1[d]	4	7	—	11[e]	2[e]
All of Edens	215	216	277	430	21	42	128	63[d]	63[d]	117	148	3[d]	14	34	56	73	41
Calumet with trees	13	12	31	63	1	15	28	—	2[d]	11	15	0[d]	5	7	—	13[f]	3[f]
All of Calumet	114	84	133	183	15	23	63	29[d]	32[d]	44	98	6[d]	14	23	—	38	30
Ingery	21	19	36	52			20	6[d]							7	9	14

[a]Does not include accidents at the grade intersection of Edens Expressway and Clavey Rd.
[b]Accidents involving encroachment of vehicles on the median as a part of the accident sequence.
[c]Winter months from Dec. 1 through March 31 except where noted.
[d]Includes accidents for January, February and March only (1957 accident case histories retired).
[e]For the period from Jan. 6 to March 10.
[f]For the period from Jan. 8 to March 24.

The observed decrease in the number of vehicle encroachments on the median after the installation of the trees is not reflected in the number of accidents reported by the police. However, little significance, if any, can be attached to this fact. An increasing amount of police surveillance was provided on these expressways during and immediately preceding the installation of the trees in the median and, because of the activities of project personnel, greater police attention was attracted to all types of accidents on both expressways. The novelty of the experiment and the publicity given to it by news media also served to generate attention. As a result, there was a considerable increase in the percentage of total median encroachments reported as accidents by the police; it quadrupled on Edens Expressway (Table 4). Fourteen of the 73 encroachments (19.2 percent) were reported by the police in the winter of 1958-1959, whereas 34 of the 41 encroachments (83 percent) were reported by the police in the winter of 1959-1960.

If the accident record for Edens Expressway were adjusted so as not to reflect this increased efficiency in accident reporting, it would show a decrease in both the total number of reported accidents and the number of reported median accidents during the winter of 1959-1960 on that portion where the trees were installed. For example, the total of 19 reported accidents during the winter of 1958-1959 would be compared with one-fourth of 19, or about 5, reported accidents for the winter of 1959-1960, and the 4 reported median accidents during the winter of 1958-1959 would be compared with one-fourth of 7, or about 2, for the winter of 1959-1960.

An identical type of adjustment in the accident record for the portion of Calumet Expressway where the trees were installed (from Sauk Trail to Thornton Lansing Rd.) cannot be made because of the grouping of certain types of accident data extracted from the accident reports for both Kingery and Calumet Expressways. However, an adjustment based on the observed average increase in efficiency of accident reporting on these two expressways (75 percent) produces the same type of result as was obtained for Edens Expressway. Both the total number of reported accidents and the number of reported median accidents became smaller during the winter of 1959-1960 where the trees were installed. This suggests that accident records are in general agreement with the previous findings if proper consideration is given to the limitations of accident records that have already been pointed out (5).

The most pronounced effect of the trees was observed on the portion of the installation on Edens Expressway north of Lake Cook Rd. Nearly half of this 0.6-mi length of the expressway is a long* 1-deg curve (Fig. 4) on which over half of the 11 encroachments occurred during the 1959 period of observation. The record of encroachments on this 0.6-mi portion for the period from Jan. 6th to March 10th in 1958, 1959, 1960 and 1961 is 8, 7, 0, and 8 encroachments, respectively. No encroachments occurred there in 1960 while the trees were in the median. It is possible that the greatest benefit from the trees at this location was the increased visibility of the median resulting from a reduction in the headlight glare suffered by northbound drivers approaching or negotiating the curve. However, because of the general lack of information regarding

*L = 1,575.00 ft, Δ = 15 deg 45 min, T = 792.54 ft, R = 5,729.65 ft.

Figure 4. View of evergreen trees in median of Edens expressway north from cross-road overpass structure at Lake Cook Rd.

the time of day during which the encroachments occurred, there is no proof that headlight glare actually contributed to the circumstances producing the encroachments. The direction of travel of the majority of the encroaching vehicles is the only direct evidence indicating that headlight glare reduction might have been the primary reason for such a pronounced decrease in encroachments at the curve. The only two encroachments that occurred along the entire tree installation on Edens Expressway originated from the southbound traffic stream, whereas most of the encroachments during other years originated from the northbound traffic stream on or near the curve (11 out of the 14 in 1961). This suggests the possibility that headlight glare reduction may have been a major factor in reducing the number of encroachments at this location.

Attempted measurements of the change in headlight glare resulting from the use of the trees were unsuccessful due to the malfunctioning of amplifying and recording equipment at low temperatures. The change in glare was quite obvious to observers driving south on Edens Expressway past the end of the portion with trees in the median. The photographs in Figure 5 roughly illustrate the increased night visibility of the left edge of the pavement next to the median due to the decrease in headlight glare on the portion with trees.

There appeared to be little difference in the amount of glare reduction provided by the two different tree spacings (20 and 40 ft), although a staccato effect from headlights flashing across the median between the trees was slightly noticeable with the 40-ft tree spacing. The staccato effect from headlights of opposing vehicles would probably be annoying if trees of this size were placed at a much greater spacing than about 40 ft.

The rising and setting sun produced a markedly annoying staccato effect much like driving along a field of corn when the sun is low. The shadows of the trees are noticeable in Figures 2 and 4. Several of the 186 expressway drivers interviewed at a gasoline

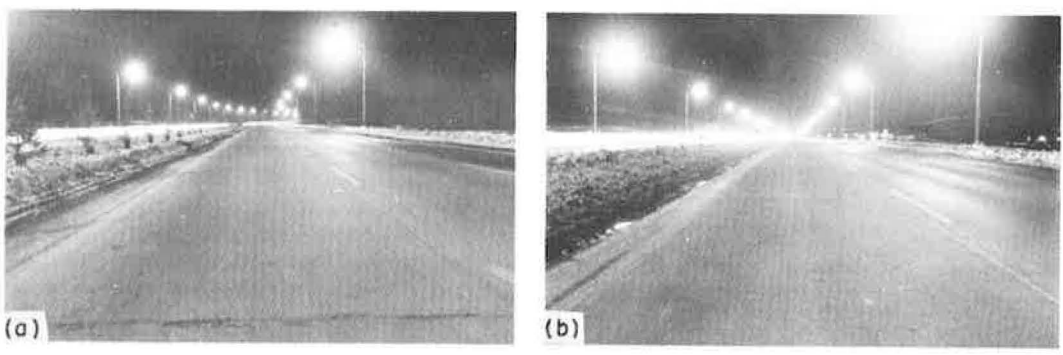


Figure 5. Median visibility from inside lane of Edens expressway: (a) with trees, and (b) without trees in the median (45-sec. exposure, f-16, medium speed panchromatic film, 10 cars passing on opposing roadway).

station near the north end of Edens Expressway mentioned this annoyance, and one user of Calumet Expressway even expressed it in a letter to the District Engineer. This staccato effect from sunlight places a limit on the desirable maximum height of closely and regularly spaced objects in the median. The height of such objects should extend above the driver's line of sight to the headlights of opposing vehicles but not higher than his line of sight to the horizon on the left if the sun rises or sets at any angle on his left. Solid row planting would probably be desirable in cases where these criteria cannot be met.

Nearly all of the drivers interviewed during the many consecutive days of snowfall and sleet in February 1960 expressed appreciation of the benefit of better roadway delineation provided by the trees. However, a great many of these persons were not aware of the fact that the trees had no roots, and, when so informed, most of them quickly changed their minds. The mere mention of the word "artificial" in connection with the trees seemed to alienate a lot of otherwise staunch supporters of the idea of trees in the median. This is unfortunate in one respect. The use of de-icer salts on the expressways has resulted in such high concentrations of chloride in the median soil that ordinary tree and shrub culture is almost out of the question (Fig. 6).

Samples of the upper 5 in. of median soil from random locations contained from 3,300 to 12,000 ppm total chloride calculated as sodium chloride. The effects of this high salt content were illustrated by the recent rapid demise of multiflora rose plantings in the expressway medians. The tolerable limit for most trees and shrubs is below 3,200 ppm soluble salt. Above this concentration there is abnormal development (6). Concentrations as low as 1,500 ppm will result in depressed growth and frequent injury during hot summers with low rainfall.

Below a depth of about 2 ft, the salt content of the median soil becomes tolerable, so there is still a possibility of some form of tree and shrub culture, even if not in the usual sense. The development of salt-resistant plant species or special methods of planting to prevent dissolved salt from seeping down along the trunk and roots of the plant may be possible. However, this approach may be considerably more expensive than the use of some of the more recently developed plastic trees and shrubs, disliked by a large portion of the driving public.

Figure 6. Windrow of de-icer salt piled up by passing vehicles on Edens Expressway.

An adjustment in the types and quantities of chemicals used as de-icing agents may be the best possibility for making the areas near the pavement more suitable for tree and shrub culture. It is reported that calcium chloride is only about one-tenth as toxic to vegetation as sodium chloride (7). Furthermore, calcium chloride is more effective in the control of snow and ice under certain pavement and weather conditions. The fact that it is considerably more expensive than sodium chloride has resulted in the testing and use of various mixtures of the two in many areas of the country (8). Further investigation along these lines may help to improve both the planting conditions and the economy of snow and ice control. In the meantime, types of delineation other than plantings should also be investigated.

Assuming that the greatest benefit from delineation is obtained at night (9), reflective delineators may be a partially acceptable alternate. In trial installations

Figure 7. Reflective delineators on Edens Expressway.

Figure 8. Delineator washing equipment and crew, Illinois Toll Highway Commission (warning vehicle accompanies truck).

on Chicago expressways, such as shown in Figure 7, the reflectors soon became covered with a film of dirt, but the cost of overcoming this fault should be worth the potential benefits (11, 12). The first annual washing of the 20,000 delineators and mile markers on the entire 187-mi Illinois Toll Highway System was accomplished in 12 working days and at a cost of only $3.24/mi. This includes the total cost of labor, materials and equipment (Fig. 8). The unit cost of cleaning delineators on Chicago area expressways should not be any greater, but the operation would have to be performed more frequently. The splash and spray from passing vehicles soon make reflective delineators ineffective in an area with an atmospheric dust loading as high as it is in Chicago (10). After only 2 wk of unusually damp winter conditions, the reflectors in the test installation shown in Figure 7 could barely be seen at night with the aid of high-beam headlights. The need of inexpensive self-cleaning reflective delineators is indicated. However, reflective delineators cannot be expected to provide all of the benefits that appear to be available from the use of trees or shrubs in the median. Some combination of materials, such as actual or simulated median plantings, roadside reflective delineators, and pavement markings will be required in the development of roadway delineation that will be nearly as effective under low-visibility conditions as under normally favorable driving conditions.

SUMMARY AND RECOMMENDATIONS

The simulated median plantings significantly reduced the frequency of vehicle encroachment on the medians of both expressways. The greatest reduction in encroachment frequency occurred on or near curved alignment where the hazard of headlight glare from opposing vehicles was previously most severe. Increased headlight reflection onto the pavement and additional traffic guidance during low-visibility conditions were also noted by observers and expressway users. However, measurement of the relative magnitude of each of these assumed roadway delineation benefits from the median plantings was not attempted. The extent to which each contributed to the observed reductions in encroachment frequency is, therefore, not known.

The safety benefits that appear obtainable from better roadway delineation justify considerably more research and development work on this and all possible means of improving the extent to which the median helps to delineate roadway alignment. Highway transportation has become such a vital part of our economy and daily activities that a constantly increasing amount of highway travel is performed under low-visibility conditions. It takes less than ⅛ mi of visibility to keep most drivers off the highway. One of the greatest limitations of driving under such conditions is the lack of per-

spective provided by the two-dimensional features of the practically level roadways of modern freeways and expressways. Reflective delineators are recognized by experienced state and turnpike authorities as an essential element in highway design (13), but reflectors are not always effective in providing the appearance of a third dimension on wide modern roadways. Median plantings help not only to provide some vertical dimension to the roadway both in daytime and at night but also help to reduce the headlight glare from opposing vehicles and the effects of negative delineation (1) produced by the headlights of vehicles on access ramps, frontage roads and other nearby facilities. Effort should be devoted to the development of the proper type, size, spacing and location of median plantings and the most desirable combinations of plantings, reflective delineators and pavement markings to suit the psychological needs of the driver under the conditions imposed by various combinations of roadway alignment, driving conditions, terrain, and surrounding land use.

The greatest current need from research in this area is information concerning the reasons for the observed effectiveness of delineation materials. Some of the more apparent delineation benefits may be only partially responsible for the accident rate reductions found in research. For example, a reduction in headlight glare may not have been the primary reason for the increased safety provided by the trees in this experiment. Negotiating curved alignment is a driving task requiring considerably more than the ability to see the roadway under the handicap imposed by headlight glare from opposing vehicles. Speed and distance determinations are also critical. Frequently, the most reliable basis for judging speed and distance relationships on modern freeway curves is the convergence illusion that occurs as the angle of driver vision intercepting the visible width of the pavement decreases to zero at the point where the pavement disappears around the curve. The rate of change of the angle of driver vision intercepting the pavement width at a given point ahead varies with degree of curvature, profile, pavement superelevation, and lateral position on the roadway as well as with speed and distance. However, the rate of change of the angle of driver vision intercepting the height of a tree ahead in the median varies almost exclusively with speed and distance. Such an improved basis for judging speed and distance relationships on curved alignment may have been a considerably more important safety factor than the decrease in headlight glare that was achieved through the use of trees in the 40-ft median of Calumet Expressway. If so, could an equal improvement be expected from the use of solid row plantings or glare screens (14) in the median? Do continuous screens or guardrails reinforce the convergence illusion sufficiently to eliminate the driver's need for individual three-dimensional objects that can be used as fixed reference points? Answers to such questions concerning the reasons for the observed effectiveness of delineation materials are needed.

Some measure of the relative extent to which each of the assumed delineation benefits contributes to increased safety is essential to the systematic development of ways and means of obtaining maximum effectiveness of the various types and combinations of delineation materials.

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Appendix

MATHEMATICAL MODEL FOR ESTIMATING SIGNIFICANCE OF RESULTS OF EXPERIMENT

In choosing a mathematical model for testing the significance of this use of evergreen trees in the median as an encroachment reducing measure, it was assumed that vehicle encroachments on the median occur according to a generalized Poisson process on the portions of Edens and Calumet Expressways chosen for study. In particular, the following is assumed:

1. The number of vehicle encroachments on the median occurring in non-overlapping time intervals are independent;
2. During any day, the probability that an encroachment on the median occurs in a small time interval, from t_0 to $t_0 + \Delta t$, is approximately proportional to the length of the time interval, Δt, and the factor of proportionality is a function of t, designated as λ (t); and
3. The probability of more than one encroachment on the median in a small time interval, Δt, is negligible when compared to the probability of a single encroachment within that time interval.

This permits incorporating the observed phenomenon that λ (t) varies during any day, being high for rush hour traffic and rather low at certain other times. If X is the random variable which describes the number of accidents that occur within the observed period,

$$P\left\{ X = k \right\} = \frac{e^{-\lambda} \lambda^k}{k!} \tag{1}$$

where λ is $T \int \lambda$ (t) dt and T is the number of days in the period of observation.

Another model leads to the same formulas. The assumptions are that each car passing over the portions of the expressways chosen for study has some unknown probability p (t) of encroaching on the median and that the time of passing is distributed according to a density function f (t). The dependence on t is allowed so as to emphasize that the probability does not remain constant throughout some time unit (day, week, etc.). Under these assumptions we have,

$$P\{\text{the probability of an encroachment}\} = \int P\{\text{encroachment, given that a car passes at time } t\}\, f(t)dt = \int p(t)\, f(t)dt = p_0 \tag{2}$$

Then, the probability that there are k encroachments when there is a total of N cars passing by on the expressways is given by

$$P\left\{ k \text{ encroachments} \right\} = \begin{bmatrix} N \\ k \end{bmatrix} p_0^{\,k} (1-p_0)^{N-k} \tag{3}$$

However, since N is large and p_0 is small, this may be closely approximated by

$$P\left\{ k \text{ encroachments} \right\} = \frac{e^{-\lambda} \lambda^k}{k!} \tag{4}$$

where $\lambda = Np_0$.

This model necessitates assuming that the cars act independently, but has the advantage over the usual formulation that it does not assume a constant probability of an accident (a vehicle encroachment on the median).

The conclusion with respect to the statistical analysis must be phrased with respect to the average probability p_0. λ_1 and λ_2 denote the values of the parameter before and after the evergreen trees were installed and X_1 and X_2 the corresponding random variables equal to the number of vehicle encroachments on the median. The total number of cars passing by on the expressways is assumed to be the same for the equal periods of observation before and after the evergreen trees were installed. This assumption makes the test more conservative because the traffic volume was slightly greater for the period of time during which the trees were employed in the median (see Table 3).

The following is to be tested:

$$H_0 : \lambda_1 = \lambda_2$$

$$H_1 : \lambda_1 > \lambda_2$$

Assuming that H_0 is true, the distribution of X_2, given $X_1 + X_2 = n$, is binominal based on n with $p = \frac{1}{2}$, i.e.,

$$P\left\{ X_2 = k \mid X_1 + X_2 = n \right\} = \begin{bmatrix} n \\ k \end{bmatrix} \left[\tfrac{1}{2}\right]^n \tag{5}$$

The test: reject H_0 if $X_2 \leq c$, where c is chosen so that

$$P\left\{ X_2 \leq c \mid X_1 + X_2 = n \right\} \leq \alpha \tag{6}$$

or

$$\sum_{k=0}^{c} \begin{bmatrix} n \\ k \end{bmatrix} \left[\tfrac{1}{2}\right]^n \leq \alpha \tag{7}$$

For $n = 13$, $X_1 = 11$ and $X_2 = 2$,
$c = 3$ if $\alpha = 0.05$, and
$c = 2$ if $\alpha = 0.0112$.
For $n = 16$, $X_1 = 13$ and $X_2 = 3$,
$c = 4$ if $\alpha = 0.04$, and
$c = 3$ if $\alpha = 0.0106$.

Therefore, the observed results are judged significant at the indicated levels (1.12 and 1.06 percent) and it is concluded that the employment of evergreen trees in the medians of Edens and Calumet Expressways at the locations and under the conditions chosen for this study was effective in lowering the expected number of vehicle encroachments on the median.

Michaels (15) suggests that a more conservative test, chi square, should be used when X_1 values do not represent the data for two or more years. Results of chi square testing of this data indicate that the observed reductions are significant at the 5 percent level.