Two-Way Left-Turn Lane Guidelines for Urban Four-Lane Roadways

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Two-way left-turn lane (TWLTL) medians are commonly used to solve the safety and operational problems on four-lane undivided roadways caused by conflicts between through- and left-turning traffic. Although the potential safety and operational effects of TWLTL medians are well-recognized, there are no generally accepted guidelines that define the circumstances under which the costs of TWLTL medians are justified by the benefits they provide. The objectives of the research on which this paper was based were (1) to evaluate the safety and operational effects of TWLTL medians on urban four-lane roadways, (2) to develop a methodology for evaluating their cost-effectiveness, and (3) to use this methodology to develop guidelines for their cost-effective use. The formulation of the cost-effectiveness methodology was based on a benefit-cost analysis approach. The benefits were the accident and operational cost savings provided by TWLTL medians. The costs were the costs of installing and maintaining them. The cost-effectiveness methodology was used to develop guidelines that indicate the average daily traffic levels (ADTs), left-turn percentages, and driveway densities at which TWLTL medians on urban four-lane roadways are cost-effective. Their development was based on conditions and costs representative of those on urban four-lane roadways in Nebraska during 1986. Over the range of conditions considered, TWLTL medians were cost-effective at lower ADTs on roadways with higher left-turn percentages and fewer driveways per mile. The minimum ADT required for TWLTL medians to be cost-effective ranges from 6,200 to 6,600 vehicles per day (vpd), depending on the left-turn percentage and driveway density.

Two-way left-turn lane (TWLTL) medians are commonly used to solve the safety and operational problems on four-lane undivided roadways caused by conflicts between through- and mid-block left-turn traffic. Left turns from a four-lane undivided roadway are made from through traffic lanes causing through vehicles in these lanes to change lanes or be delayed. But on a roadway with a TWLTL, the deceleration and storage of left-turn vehicles are removed from the through lanes. Thus, conflicts between through-and left-turn vehicles are eliminated, and through-vehicles can pass left-turn vehicles without changing lanes and without delay.

Although the potential safety and operational effects of the TWLTL are recognized by highway engineers, there are no generally accepted guidelines that define the circumstances under which the costs of providing TWLTL medians are justified. Numerous before-and-after studies of the safety effectiveness of TWLTLs have been conducted. However, empirical data pertinent to the assessment of the operational effectiveness of the TWLTL are limited. Therefore, previous attempts to develop guidelines for the use of the TWLTL have focused on the safety benefits and have not adequately considered the operational effectiveness of the TWLTL.

The overall objective of the research on which this paper was based was to develop guidelines for the use of TWLTL medians that would account for the operational as well as the safety effects of these medians. Specific objectives of the research were (1) to evaluate the safety and operational effectiveness of TWLTL medians on urban four-lane roadways, (2) to develop a methodology for evaluating the cost-effectiveness of the TWLTL, and (3) to apply this methodology to develop guidelines for the cost-effective use of TWLTL medians on urban four-lane roadways. The methodology and guidelines were developed to enable the identification of sections of urban four-lane undivided roadways on which the cost of providing TWLTL medians is justified.

An analysis of accidents on the urban four-lane sections of the state highway system in Nebraska was conducted to assess the effectiveness of TWLTL medians in reducing accidents on urban four-lane roadways. Computer simulation was used to determine the operational effects of TWLTL medians. Results of the accident analysis and computer simulation study were used in the formulation of the cost-effectiveness methodology. Formulation of the cost-effectiveness methodology was based on a benefit-cost evaluation of these medians. The benefits were the accident and operational cost savings provided by TWLTL medians. The costs were those of installing and maintaining TWLTL medians. According to the methodology, if the benefits of a TWLTL exceed its costs, the TWLTL would be cost-effective.

Finally, the cost-effectiveness methodology was applied to a range of traffic volumes and driveway densities. This was done to determine the combinations of traffic volumes and driveway densities for which the construction and maintenance of TWLTL medians on urban four-lane roadways in Nebraska are cost-effective. The total annual cost savings provided by the TWLTL medians were evaluated over the range of traffic volumes and driveway densities. These savings were compared to the annual costs of constructing and maintaining TWLTL medians for the same range. Traffic volumes and driveway densities for which the total annual cost savings were greater than the annual cost of the TWLTL medians were determined to be those conditions for which TWLTL medians are cost-effective. The results of the cost-effective-

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ness analysis provided guidelines for the cost-effective use of TWLTL medians on urban four-lane roadways in Nebraska. The procedure, findings, and conclusions of this analysis are presented in this paper. The development of the cost-effectiveness methodology and other findings of this research are presented elsewhere (*1*).

PROCEDURE

The cost-effectiveness analysis was conducted for the addition of TWLTL medians on urban four-lane roadways. The results were intended to be representative of conditions on urban four-lane roadways in Nebraska during 1986. TWLTL medians were evaluated over the following range of traffic volumes and driveway densities:

- ADT: 5,000 to 25,000 vpd at 5,000-vpd increments
- Left-turn percentage: 2.5 to 12.5% at 2.5% increments
- Driveway density: 30 to 90 driveways/mile at 15 driveways/mile increments.

Thus, five levels of each variable were evaluated, which amounted to an evaluation of 625 combinations of ADT, left-turn percentage, and driveway density.

The same truck percentages were used to evaluate each combination. The truck percentages used were 2.1% single unit trucks and 1.3% combination trucks. These percentages were the average truck percentages reported at the continuous traffic count stations maintained by the Nebraska Department of Roads (*2*) on urban arterial streets.

A brief description of the evaluation procedure relative to the calculation of the benefits and costs of TWLTL medians follows.

Accident Cost Savings

During the 4-year period from January 1, 1980, to January 1, 1984, the accident rate on urban four-lane roadways with TWLTL medians on the state highway system in Nebraska was 8.4 accidents per million vehicle miles (*1*). Urban four-lane undivided sections on the state highway systems, which had similar prevailing roadway and traffic conditions as the TWLTL sections, had an accident rate of 12.7 accidents per million vehicle miles during the same period. Thus, the accident rate on the TWLTL sections was 34% lower than that on the four-lane undivided sections. A Poisson comparison of means test indicated that the rates were significantly different at the 5% level of significance. Also, the observed 34% difference was comparable to the TWLTL accident reduction factors of 20 to 40%, which were determined from before-and-after accident studies reported in the literature (*3–8*). Therefore, for the purpose of this cost-effectiveness analysis, it was concluded that the installation of a TWLTL median on an urban four-lane undivided roadway would reduce the accidents by 30%.

Overall, accidents on the TWLTL sections were more severe than those on the four-lane undivided sections. On the TWLTL sections, 35% of the accidents were fatal and nonfatal injury accidents. On the four-lane undivided sections, only 27% of the accidents were that severe. A chi-square test showed this difference to be significant at the 5% level of significance. However, previous before-and-after studies (*3, 5, 9*) have found that TWLTL medians reduce, rather than increase, accident severity. This suggested that perhaps the comparative study used in this analysis confounded the effects of the TWLTL medians on accident severity with those of other factors not considered. However, the limitations of the available data did not permit further examination of this contradiction of previous research findings. Therefore, for the purpose of this cost-effectiveness analysis, the accident severity for four-lane undivided roadways (i.e., 0.10% fatal, 26.5% nonfatal injury, and 73.4% property-damage-only) was used to compute the safety benefits of installing TWLTL medians on urban four-lane roadways.

The accident experience to which the 30% reduction factor was applied was the mean mid-block accident rate on urban four-lane undivided sections of the state highway system in Nebraska during the 2-year period from July 1, 1984, to July 1, 1986. Signalized intersections often have left-turn bays and left-turn phasing even on undivided roadways. In such cases, the installation of TWLTL medians would have little effect on safety at these intersections. Therefore, the accidents at signalized intersections were excluded from the calculation of the accident reduction. On the other hand, TWLTL medians would improve safety at unsignalized intersections, which usually do not have left-turn bays on undivided roadways. However, the available mean accident rate data (*10*) did not distinguish between signalized and unsignalized intersections. Therefore, the mid-block accident rate was used to avoid overstating the accident cost saving provided by TWLTL medians.

The mean mid-block accident rate was 6.17 accidents per million vehicle miles (*10*). Application of the 30% reduction factor to the mean mid-block accident rate provided an accident reduction of 1.85 accidents per million vehicle miles.

The 1986 unit accident costs used by the Nebraska Department of Roads were $220,000 per fatal accident, $9,300 per non-fatal injury accident, and $1,190 per property-damage-only accident. Applying these costs to the average severity, the average cost of an accident on a four-lane undivided roadway was computed to be $3,560. Thus, the rate of accident cost savings used in this analysis was $6,590 per million vehicle miles.

Operational Cost Savings

The operational cost savings provided by TWLTL medians are the savings in road-user stopping and travel time costs that result from the reductions in stops and delay provided by TWLTL medians. The regression equations in table 1, which were determined in the computer simulation study (*1*), are used in the methodology to predict the reductions in stops and delay provided by TWLTL medians.

Stopping Cost Savings

The savings in stopping costs were computed from the reductions in stops provided by TWLTL medians. The hourly stopping cost savings were computed as follows:

$$SCS = 0.00528 \, \Delta S \cdot L \sum_{i=1}^{3} P_i S_i M_i \tag{1}$$

TABLE 1 REGRESSION EQUATIONS FOR PREDICTING REDUCTIONS IN STOPS AND DELAY

Traffic Volume[a] (vph)	Reduction	Equation[b]	R^2
<800	stops	$\ln S = 0.00579\,V_t + 0.0117\,V_l - 0.00678D$	0.975
	delay	$\ln D = 0.00845\,V_t + 0.0330\,V_l - 0.00561D - 0.0000308P$	0.978
≥800	stops	$\ln S = 0.00610\,V_t + 0.0282\,V_d$	0.996
	delay	$\ln D = 0.00898\,V_t + 0.0652\,V_d$	0.996

[a]Traffic volume in each direction.

[b] S = reduction in stops (number per hour per 1,000 ft.)

D = reduction in delay (seconds per hour per 1,000 ft.)

V_t = average traffic volume per direction (vph)

V_l = sum of left-turn volumes in both directions (vph)

V_d = average left-turn volume per driveway (vph per driveway)

D = driveway density (driveways per mile)

$P = V_t \cdot V_l$

where:

- SCS = stopping cost savings provided by a TWLTL on an urban four-lane roadway (\$/hour);
- ΔS = reduction in stops from table 1 (number/hour/1,000 ft);
- L = length of roadway section (miles);
- P_i = proportion of vehicle type i in the traffic stream (%/100%);
- S_i = stopping cost for vehicle type i from table 2 (\$/1,000 stops); and
- M_i = updating multiplier for vehicle type i from table 3.

The stopping costs in table 2 were those published by AASHTO (*11*) for the year 1975. Three vehicle types were included: passenger cars, single unit trucks, and 3 – S2 combination trucks. The speeds used to determine the stopping costs shown for each level of traffic volume are the same speeds used in the computer simulation study (*1*), which approximated the speed-volume relationships on urban arterial roadways (*12*). The updating multipliers, in table 3, enable the 1975 stopping costs, in table 2, to be updated to the current year. These multipliers were computed according to the AASHTO (*11*) procedures based on changes in consumer and wholesale price indices (*13*). For the vehicle mix of 96.6% passenger cars, 2.1% single-unit trucks, and 1.3% 3 – S2 combination trucks, the cost per stop was \$0.03849 for directional volumes of 700 vph or less, and \$0.03290 for directional volumes above 700 vph.

Travel Time Cost Savings

The savings in travel time costs were computed from the reductions in delay provided by TWLTL medians. The hourly time costs savings were computed as follows:

$$TCS = 0.00147\ \Delta D \cdot L\,\frac{CPI}{156.1}\sum_{i=1}^{3} P_i T_i \tag{2}$$

where:

- TCS = travel time cost savings provided by a TWLTL on an urban four-lane roadway (\$/hour);
- ΔD = reduction in delay from table 1 (seconds/hour, per 1,000 feet);
- L = length of roadway section (miles);
- CPI = consumer price index;
- P_i = proportion of vehicle type i in the traffic stream (%/100%);
- T_i = value of time for vehicle type i from table 4.

The values of time in table 4 were those established by AASHTO (*11*) for the year 1975. However, these values were updated to the current year by the ratio (CPI/156.1), which is the current consumer price index divided by the 1975 consumer price index. The 1986 consumer price index was 326.3 (*13*). Thus, for the vehicle mix of 96.6% passenger cars, 2.1% single unit trucks, and 1.3% 3 – S2 combination trucks, the hourly time cost was \$1.23 per hour.

TABLE 2 STOPPING COSTS ($/1,000 STOPS)[a]

Vehicle Type	Traffic Volume[b] ≤650 vph[c]	Traffic Volume[b] >650 vph[d]
Passenger Car	21.00	17.75
Single Unit Truck	48.47	43.88
3-S2 Combination Truck	163.99	151.47

[a]Source: Reference 11.

[b]Traffic volume in each direction.

[c]Speed = 40 mph.

[d]Speed = 35 mph.

TABLE 3 UPDATING MULTIPLIERS FOR STOPPING COSTS

Vehicle Type	Updating Formula
Passenger Car	$M = 0.0022\ CPI_F + 0.0001\ CPI_O + 0.0033\ CPI_T + 0.0001\ CPI_M + 0.0017\ CPI_D$
Single Unit Truck	$M = 0.0018\ WPI_F + 0.0031\ WPI_T + 0.0002\ CPI_M + 0.0008\ WPI_D$
3-S2 Combination Truck	$M = 0.0008\ WPI_{FD} + 0.0047\ WPI_T + 0.0001\ CPI_M + 0.0003\ WPI_D$

where:

CPI_F - Consumer Price Index - Private Transportation, Gasoline Regular and Premium

CPI_O - Consumer Price Index - Private Transportation, Motor Oil, Premium

CPI_T - Consumer Price Index - Private Transportation, Tires

CPI_M - Consumer Price Index - Private Transportation, Auto Repairs and Maintenance

CPI_D - Consumer Price Index - Private Transportation, Automobiles, New

WPI_F - Wholesale Price Index - Regular Gasoline to Commercial Users (Code No. 05710203.05)

WPI_{FD} - Wholesale Price Index - Diesel Fuel to Commercial Users (Code No. 05730301.06)

WPI_T - Wholesale Price Index - Truck Tires (Code No. 07120105.07)

WPI_D - Wholesale Price Index - Motor Truck (Code No. 141106)

[a]Source: Reference 11.

Annual Operational Cost Savings

The annual operational cost savings provided by TWLTL medians were computed by summing the hourly stopping and travel time costs savings from Equations 1 and 2 as follows:

$$OSC = 365 \sum_{i=1}^{24} (SCS_i + TCS_i) \qquad (3)$$

where:

OCS = annual operational cost savings provided by a TWLTL on an urban four-lane roadway ($/year);
SCS_i = stopping cost savings from Equation 1 for the ith hour of an average day ($/hour); and
TCS_i = travel time cost savings from Equation 2 for the ith hour of an average day ($/hour).

TABLE 4 VALUES OF TIME[a]

Vehicle Type	$/vehicle-hour
Passenger Car	0.35[b]
Single Unit Truck	7.00
3-S2 Combination Truck	8.00

[a]Source: Reference 11.

[b]For low time savings, average trips, and 1.56 adults per vehicle.

In Equation 3 stopping and travel time cost savings were computed for each of the 24 hours in an average day. The hourly volumes were obtained by applying the hourly distribution shown in table 5 to the ADT being considered. This distribution was the average hourly distribution of daily traffic on the urban arterial-street sections of the state highway system in Nebraska (*2*). Savings were not computed for any hours with traffic volumes outside the traffic volume range (100 to 1,100 vph in each direction) of the regression equations in table 1. The stopping and travel time cost savings were assumed to be zero for hours with volumes less than 100 vph in each direction, and cases with hourly directional volumes above 1,100 vph were not considered.

TWLTL Cost

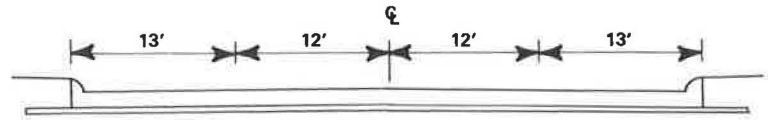
The cost of a TWLTL was computed to be the additional cost required to construct and maintain a TWLTL on a typical four-lane undivided roadway in Nebraska. The first cost of the TWLTL was computed as the difference between the first costs for a 50-ft. back-to-back section of urban four-lane undivided roadway and a 62-ft. back-to-back section of urban four-lane divided roadway with a painted median. These typical sections are shown in figure 1. The 1986 first costs of these sections were estimated by the Nebraska Department of Roads to be $1,190,000 per mile and $1,373,000 per mile, respectively. Thus, the estimated first cost of the TWLTL was $183,000 per mile. This estimate included the following cost items: right-of-way, earthwork, concrete pavement, drainage, utilities, and engineering. The first cost was annualized using a 6% interest rate, 20-year project life, and zero salvage value. Thus, the annualized first cost was $15,950 per mile.

The 1986 annual maintenance cost of the TWLTL was estimated by the Nebraska Department of Roads to be $800 per mile. This estimate included the maintenance cost items of pavement repair, pavement markings, and snow removal. Therefore, the total annual cost of the TWLTL was $16,750.

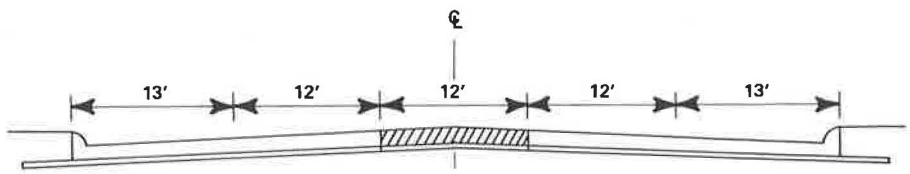
In each case evaluated the total annual cost savings (accident plus operational cost savings) was compared to the annual TWLTL cost to determine whether or not the TWLTL was cost-effective. The combinations of ADT, left-turn percentage, and driveway density, for which the savings were greater than the cost, were identified as those for which TWLTL medians on urban four-lane roadways are cost-effective.

TABLE 5 AVERAGE HOURLY DISTRIBUTION OF ADT

Hour	%ADT	Hour	%ADT
12:00 a.m. - 1:00 a.m.	1.45	12:00 p.m. - 1:00 p.m.	6.95
1:00 a.m. - 2:00 a.m.	0.98	1:00 p.m. - 2:00 p.m.	6.65
2:00 a.m. - 3:00 a.m.	0.49	2:00 p.m. - 3:00 p.m.	6.58
3:00 a.m. - 4:00 a.m.	0.33	3:00 p.m. - 4:00 p.m.	7.16
4:00 a.m. - 5:00 a.m.	0.31	4:00 p.m. - 5:00 p.m.	8.13
5:00 a.m. - 6:00 a.m.	0.86	5:00 p.m. - 6:00 p.m.	7.84
6:00 a.m. - 7:00 a.m.	2.53	6:00 p.m. - 7:00 p.m.	5.89
7:00 a.m. - 8:00 a.m.	5.65	7:00 p.m. - 8:00 p.m.	4.88
8:00 a.m. - 9:00 a.m.	4.80	8:00 p.m. - 9:00 p.m.	4.02
9:00 a.m. - 10:00 a.m.	4.58	9:00 p.m. - 10:00 p.m.	3.71
10:00 a.m. - 11:00 a.m.	5.15	10:00 p.m. - 11:00 p.m.	2.82
11:00 a.m. - 12:00 p.m.	6.09	11:00 p.m. - 12:00 p.m.	2.15



a. Four-lane undivided.



b. Four-lane divided with painted median.

FIGURE 1 Typical urban sections.

FINDINGS

The results of the cost-effectiveness analysis are presented in figure 2. Shown in this figure are the combinations of ADT, left-turn percentage, and driveway density for which the use of TWLTL medians on urban four-lane roadways in Nebraska is cost-effective. For a given driveway density, the combinations of ADT and left-turn percentage for which TWLTL medians are cost-effective are located to the right of the curve that corresponds to the particular driveway density. The combinations for which TWLTL medians are not cost-effective are located to the left of the driveway-density curve. For example, on an urban four-lane roadway with a driveway density of 30 driveways per mile, a TWLTL would be cost effective over the range of left-turn percentages if the ADT is above 6,600 vpd. If the ADT is below 6,200 vpd a TWLTL would not be cost-effective in any case.

Thus, figure 2 provides guidelines for the cost-effective use of TWLTL medians on urban four-lane roadways. It should be noted that the left-turn percentage used in figure 2 is the combined percentage of the ADT that turns left from both directions. Also, in using figure 2 it must be remembered that

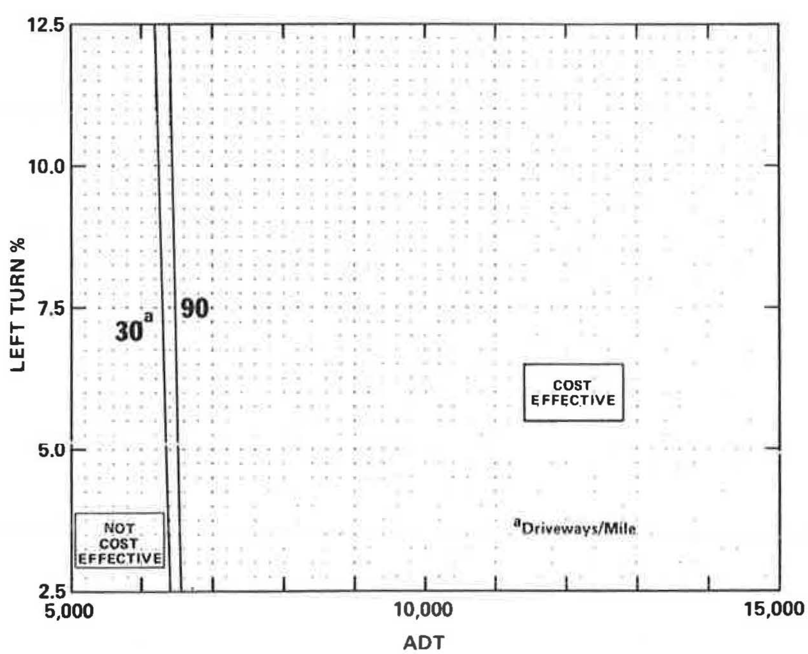


FIGURE 2 Cost-effectiveness of TWLTL based on total cost savings.

its development was based on conditions and costs that were intended to be representative of those on urban four-lane roadways in Nebraska during 1986. This figure is not applicable to cases in which the conditions and costs are substantially different. In such cases, the cost-effectiveness methodology presented elsewhere (*1*) should be used instead of figure 2 to determine the cost-effectiveness of TWLTL medians.

Because of the effects of driveway density found in the computer simulation study reported elsewhere (*1*), TWLTL medians are shown in figure 2 to be cost-effective at lower ADTs on roadways with lower driveway densities than they are on roadways with higher driveway densities. The reductions in stops and delays provided by a TWLTL were all found to be lower as driveway density increased. This was because in the computer simulation the left-turn volume was apportioned equally among the driveways. Therefore, the left-turn volume per driveway at 30 driveways per mile was two and three times greater than it was at 60 and 90 driveways per mile, respectively. Consequently, more queuing of left-turn vehicles would tend to occur at 30 driveways per mile; and, at 60 and 90 driveways per mile, vehicles waiting to turn left at several driveways would be more likely to turn left through the same gap in the oncoming traffic stream.

Assuming equal left-turn volume per driveway may result in an understatement of the benefits provided by TWLTL medians. If the left-turn volume had not been apportioned equally among the driveways, multiple use of gaps would have occurred less frequently. Less-frequent multiple use of gaps would have increased the stops and delays experienced by traffic on the four-lane undivided roadways, which, in turn, would have increased the operational cost savings provided by TWLTL medians.

Operational Cost Savings

The conditions for which TWLTL medians are cost-effective based solely on operational cost savings are shown in figure 3. Over the range of left-turn percentages considered, TWLTL medians are not cost-effective under any conditions on urban four-lane roadways with ADTs below 10,500. Conversely, TWLTL medians are cost-effective solely on the basis of operational cost savings on urban four-lane roadways with ADTs above 16,200.

TWLTL medians provide greater operational cost savings on roadways with higher left-turn volumes. Therefore, as shown in figure 3, TWLTL medians are cost effective at lower ADTs on roadways with higher left-turn percentages at a given driveway density. For example, at 30 driveways per mile, the minimum ADT at which TWLTL medians are cost-effective ranges from 10,800 on roadways with 12.5% left turns to 14,400 on roadways with only 2.5% left turns. Also, as explained earlier, TWLTL medians provide greater operational cost savings on roadways with lower driveway densities. Therefore, as shown in figure 3, TWLTL medians are cost-effective at lower ADTs on roadways with lower driveway densities, at a given left-turn percentage. For example, at 7.5% left turns, the minimum ADT at which TWLTL medians are cost-effective ranges from 12,200 on roadways with 30 driveways per mile to 13,700 on roadways with 90 driveways per mile.

Accident Cost Savings

The combinations of ADT and left-turn percentage for which TWLTL medians on urban four-lane roadways are cost-effective solely on the basis of the accident cost savings are shown

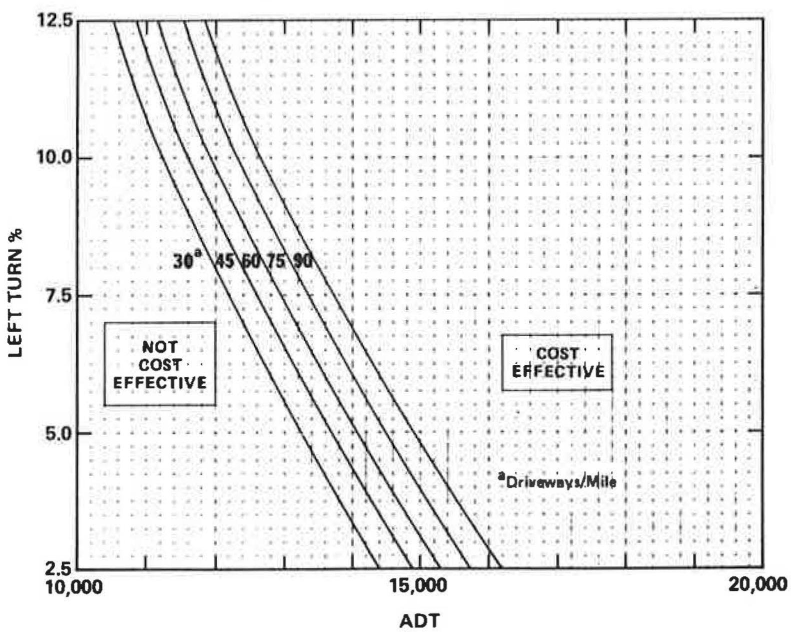


FIGURE 3 Cost-effectiveness of TWLTL based on operational cost savings.

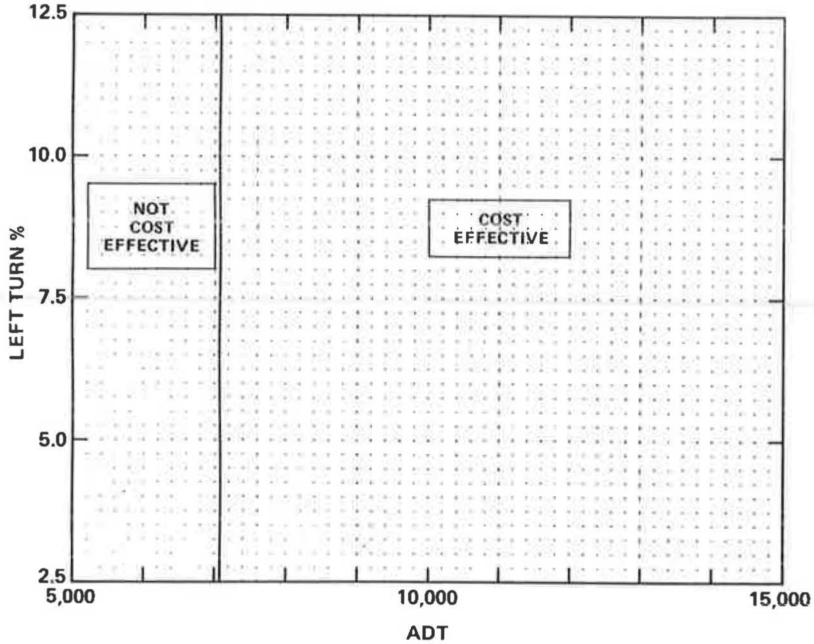


FIGURE 4 Cost-effectiveness of TWLTL based on accident cost savings.

in figure 4. Based on accident cost savings alone, TWLTL medians are cost-effective at ADTs above 7,100 vpd, regardless of left-turn percentage or driveway density.

CONCLUSIONS

Based on the results of the cost-effectiveness analysis, the following conclusions were reached with respect to the provision of TWLTL medians on urban four-lane roadways in Nebraska:

- The ADTs at which TWLTL medians are cost-effective depend on the left-turn percentage and driveway density on the roadway. TWLTL medians are cost-effective at lower ADTs on roadways with higher left-turn percentages and fewer driveways per mile. The minimum required ADT ranges from 6,200 to 6,600 vpd, depending on the left-turn percentage and driveway density.
- On the basis of operational cost savings alone, the minimum ADT required for TWLTL medians to be cost-effective ranges from 10,500 to 16,200 vpd, depending on the left-turn percentage and driveway density.
- On the basis of accident cost savings alone, TWLTL medians are cost-effective at ADTs above 7,100 vpd, regardless of left-turn percentage or driveway density.

However, in using the guidelines presented in this paper, it must be remembered that they were developed based on accident experience, traffic conditions, road-user costs, and TWLTL costs that were considered representative of urban four-lane roadways in Nebraska during 1986. Thus, on urban four-lane roadways with higher than average accident rates, truck percentages, and/or peak-hour volumes, TWLTL medians would be cost-effective at ADTs lower than those indicated by these guidelines. Conversely, on urban four-lane roadways with lower than average accident rates, truck percentages, and/or peak-hour volumes, TWLTL medians would be cost-effective only at higher ADTs than indicated by these guidelines. In addition, the use of different road-user costs and TWLTL costs would also change the results of this analysis. Higher road-user costs and lower TWLTL costs would reduce the minimum ADTs at which TWLTL medians are cost-effective. On the other hand, lower road-user costs and higher TWLTL costs would increase these ADTs. Therefore, in cases where the conditions and/or costs differ substantially from those used in developing these guidelines, the cost-effectiveness methodology presented elsewhere (*1*) should be used instead of these guidelines to determine the cost-effectiveness of TWLTL medians.

Finally, it must be remembered that factors other than cost-effectiveness must also be considered before making the final decision on the installation of TWLTL. Even though a TWLTL may be evaluated as being cost-effective, other factors may indicate that it is not appropriate in a particular situation. Previous research, experience, and opinions of others (*7, 8, 14, 15, 16, 17*) have indicated that TWLTL medians are not appropriate on streets with the following characteristics: (a) little conflict between left-turn and through movements (b) major-arterial street classification, (c) low driveway density, (d) short intersection spacing, (e) potential for interlocking left-turn movements between access points, (f) inadequate sight distance, (g) high pedestrian volumes, (h) few accidents associated with left-turn maneuvers, and (i) adequate indirect left-turn access. Thus, application of the guidelines must be tempered with engineering judgment.

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