Safety Improvements at Intersections on Rural Expressways: A Survey of State Departments of Transportation

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The current state of the practice of measures used to improve traffic safety at intersections on rural expressways is described. The description is based on the results of a recent survey of 49 state highway departments. In general, highway departments use their access control policy and a variety of safety improvement measures at locations with poor safety records to minimize accident potential. The access control policy typically specifies the justification for and frequency of access openings and median openings. Most states indicated that one access opening is provided per abutting parcel that cannot be served by other means. In contrast, median openings are typically provided only at intersections of the expressway and other public roads. Safety improvement measures identified by the survey respondents were categorized as either traffic control measures or geometric design measures. Seventy-four percent of the states indicated that they consider traffic signal control and flashing beacons for application at high-accident locations. Thirty percent of the states consider turn lane additions or modifications at high-accident locations. One modification of expressway left-turn lane design that appears to have particular merit is the offset left-turn bay. In this design, opposing left-turn bays on the expressway are laterally offset such that stopped vehicles in the bay do not block the sight lines of opposing left-turn vehicles.

A rural expressway can be functionally classified as a minor arterial that in most situations is designed as a four-lane divided facility. A rural expressway is commonly used as a high-speed linkage between cities and larger towns and as a bypass around urban areas.

Rural expressways can be characterized as high-speed facilities having partial control of access. Access to a rural expressway is usually limited to intersections with all public roadways, provided that a minimum spacing can be maintained. Access to adjacent properties from the expressway is provided only when access by alternative routes cannot be obtained. A typical at-grade intersection on a rural expressway is shown in Figure 1.

The combination of high-speed operation and only partial access control can adversely affect the safety of rural expressways. Contributing factors to accidents at intersections on rural expressways commonly include the following:

- Some turning and crossing drivers are unable to judge the speed and distance (i.e., arrival time) of approaching expressway drivers.
- Some crossing drivers are unable to judge the lengthy crossing time required to clear an at-grade intersection.
- Some left-turn drivers are unable to see oncoming expressway drivers because the median design is such that opposing left-turn vehicles block one another's line of sight.
- An at-grade intersection may be inconsistent with the expressway driver's expectancy. Because of partial access control, at-grade intersections on expressways are infrequently encountered and thus generally unanticipated by expressway drivers. Moreover, typical driver expectancy for high-speed roadways is that they have full access control like that found on the more frequently occurring freeways and Interstate highways.
- High deceleration rates are sometimes required of a stopping expressway vehicle.
- The speed differential between expressway through traffic and traffic entering or exiting the expressway may be large.

To offset the adverse impact of these factors on safety, state highway departments incorporate both proactive and reactive measures. One of the most important proactive measures is the access control policy because it preserves the quality of traffic service by regulating the frequency and location of all access to the expressway. Reactive measures usually relate to various safety improvement measures, which can generally be categorized as either traffic control measures or geometric design measures. Traffic control measures may include signalization, delineation, and signing. Geometric design measures commonly include auxiliary lanes, channelization, and grade separation.

SURVEY OF STATE HIGHWAY DEPARTMENTS

The Nebraska Department of Roads is currently examining the design and operation of at-grade intersections on rural expressways. Accident histories at several of these intersections suggest that safety problems exist stemming from the combination of high-speed operation and partial access control policies. Potential corrective measures include offsetting the expressway left-turn lanes, signalization, and conversion to an interchange design.

To weigh the relative merit and cost-effectiveness of these and other potential corrective measures, a review of the literature was conducted. The review indicated that there is relatively little published about traffic safety at intersections

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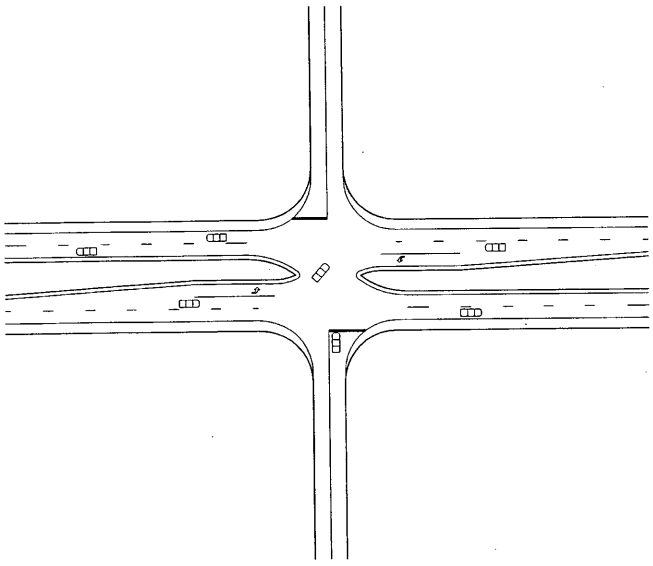

FIGURE 1 Typical unsignalized intersection on a rural expressway.

on rural expressways. Similarly, little published material was found that addressed the relative merits of alternative left-turn bay designs.

Although the literature review did not yield anything that was directly applicable to safety problems at rural expressway intersections, a considerable amount of information was found that dealt with areas related to this subject. For example, the literature review indicated that there was a large body of research examining traffic accidents at signalized intersections and at interchanges on the Interstate system. In the event that more directly relevant research is not found, it is anticipated that some of the findings and conclusions from this research could be extended to intersections on rural expressways.

The literature was also consulted for research on warrants or guidelines for the installation of traffic signals and for the construction of an interchange. In this regard, the U.S. Department of Transportation's *Manual on Uniform Traffic Control Devices* (MUTCD) (*1*) provides warranting criteria for the signalization of rural intersections. These warrants provide some guidance regarding the need for traffic signals based on traffic volume and accident history. In contrast, there are no nationally recognized warranting criteria for interchanges.

Concurrent with the literature review, a questionnaire was sent to highway departments in 49 states. Questions pertained to the state's current rural expressway design practice. Specific questions were asked about the access control policy, traffic control measures, and geometric design considerations used by each state.

The response to the survey questionnaire was quite good with 42 (86 percent) of the 49 states responding. On the basis of these responses, it was found that 30 states (71 percent) are building (or have built) rural expressways with at-grade intersections. In addition to completing the questionnaire, most of these 30 states sent additional information detailing particular design or policy issues that were relevant to rural expressways.

ACCESS CONTROL POLICY

One question included in the survey inquired about the state's access control policy for rural expressways. Twenty-eight states responded to this question; 9 of the 28 sent copies of their access control policy. In general, most of the 28 states have formal policies for rural expressways that provide for some form of partial access control. A few states indicated that they apply their Interstate highway access control policy to their rural expressways, which implies full access control.

In general, access to the expressway is regulated by the permit of access openings, median openings, and interchanges. In most cases, responses to the survey referred to one or more of these access types. Each of these access types and a summary of the comments made about them will be discussed in the following subsections.

Access Openings

Access openings refer to a point of direct access to the through lanes of the expressway. An access opening will always provide for right turns into and out of the property. However, if a median opening is provided opposite to the access opening, the access will also include left turns into and out of the property.

Almost all of the states that responded indicated that one access is provided per parcel that cannot be served economically by another means (e.g., frontage road, service road, and parallel street). Some states indicated that access is not provided to commercial properties in new construction or major reconstruction. However, these few states also indicate that commercial access will be permitted on existing rural expressways or on those under minor reconstruction.

Several states have adopted minimum, desirable, and/or maximum spacings of access openings to minimize the interruption to the through traffic flow. Typical minimum spacings range from 440 to 880 ft. Desirable and maximum spacings recommended by one state are 1,320 and 1,760 ft, respectively. Another state specified that access openings should not be located within 300 ft of other median openings unless the access opening is coincident with the median opening.

Median Openings

Median openings (or crossovers) refer to locations along the expressway where traffic can legally access or cross over to the far-side through lanes. Median openings are generally provided at at-grade intersections; however, they are also provided at various locations along the expressway to facilitate U-turn movements.

Responses varied as to the provision of median openings. In general, most states indicated that median openings were provided only at public roads (i.e., county, state, and federal highways) and subject to a minimum spacing requirement. Median openings are not typically provided for adjacent properties (i.e., residential, agricultural, or commercial), although a few states recognized the possibility of special situations wherein a median opening would be acceptable (e.g., existing opening, no median crossing for ½ mi in either direction

One state indicated that a median opening was acceptable when the commercial property generated relatively high traffic demands (i.e., 350 left-turn vehicles per day).

Most states specified minimum, desirable, and/or maximum spacing requirements for median openings. Minimum requirements ranged from 330 to 2,640 ft. The most frequent minimum spacing was about 1,300 ft. Desirable spacings ranged from 2,500 to 5,000 ft. Only one state recommended a maximum spacing for median openings, which it specified as 1.0 mi.

SAFETY IMPROVEMENT MEASURES

One question on the survey asked for information about the types of corrective measures that the states apply (or would apply) to high-accident unsignalized at-grade intersections on rural expressways. The response to this question was varied. In general, treatments considered range from low-cost solutions such as signing to high-cost solutions such as grade separation. The survey responses are summarized in Table 1.

As Table 1 indicates, the most frequently cited corrective measure was signalization (which includes both traffic signal control and flashing beacons), followed by signing improvements. Corrective measures relating to geometric design elements were also cited frequently; however, within this category, the specific improvement type ranged widely from left-turn bays to rumble strips. An examination of the measures given in Table 1 suggests that almost all are intended to increase the likelihood of attracting the expressway driver's attention, to attract the driver's attention further in advance of the intersection, and to provide more restrictive traffic regulation through the intersection.

Traffic Control Measures

In general, the selection of appropriate corrective measures is based on the type of accidents occurring at each location. The accidents are the result of a wide variety of factors that are individually insignificant but in combination create unsafe situations, which can be causally related to an increase in accidents. Because of the wide variety of accident contributing factors and the variability in their overall impact, there are many potential accident reduction treatments.

The questionnaire asked the state highway departments to list the various corrective measures that they had used at high-accident at-grade intersections on rural expressways. Responses varied widely; however, the more commonly used techniques could be categorized as traffic control measures. Measures requiring geometric design improvements were cited much less frequently.

In general, the responding states indicated that traffic signals (i.e., traffic control signals, traffic beacons) were the most commonly applied corrective measures. Other traffic control measures that were mentioned included specialized or enhanced signing and marking applications. The following paragraphs elaborate on the frequency and extent to which traffic control devices are used as a corrective measure.

Signalization

In general, two types of signalization are considered by the states as corrective measures at at-grade intersections on rural expressways: traffic signal control and flashing beacons. Traffic signal control refers to the regulation of traffic by means of

TABLE 1 Summary of Corrective Measures at Unsignalized Intersections

Corrective Measures	Number of States	Percent[1] of States
Signalization	17	74
Traffic signal control	12	52
Flashing beacon	11	48
Intersection control beacon	9	39
Stop sign beacon	2	9
Hazard identification beacon	2	9
Signing Improvements	8	35
Advance signing	6	26
Increase sign size	2	9
Reduce sign clutter	1	4
Exclusive Lanes for Turning Traffic[2]	7	30
Grade Separation/Interchange	5	22
Reduce Speed Limit	4	17
Partial Lighting	3	13
Rumble Strips	2	9

[1]Frequencies based on responses from 23 states.

[2]Treatments mentioned include: add right-turn bay, lengthen left-turn bay, add median acceleration lane, add right-turn acceleration lane, offset left-turn lanes, and prohibit turns by closing median.

a single signal controller regulating signal heads for each of the entering movements. Flashing beacons include those used to draw attention to warning signs and those used to control the intersection. Seventy-four percent of the states indicated that they consider one (or both) of the two types of signalization at high-accident locations. Each measure was listed by about one-half of the responding states as a corrective measure used at locations with high accident rates.

When asked whether other criteria were used (in addition to accidents) to justify traffic signalization, 30 percent of the responding states indicated that their decision was based on traffic volume only. In contrast, 52 percent of the states use accident rates or a combination of accident rates and traffic volume in determining the need for traffic signal control. Thirty percent of the states responding indicated that they did not signalize at-grade intersections on rural expressways or that they did so only when alternative measures had been considered first.

The most commonly cited criteria used to determine the need for signalization were the state's traffic signal warrants. In two instances, the states indicated that they used the signal warrants specified in the MUTCD (*1*). Warrants of this type include both traffic demand and traffic accidents as the warranting criteria. A few states were not specific as to the criteria used but indicated that both accidents and traffic volume were considered when determining the need for traffic signal control.

Other criteria were also used by some states to determine the need for traffic signal control. One state indicated that the installation of a traffic signal was justified at all intersections of a rural expressway with other marked routes. Another state indicated that all major intersections on six-lane expressways were signalized.

Median width was another criterion considered in the decision to use traffic signal control. Several states indicated that they consider signalization only at intersections with "narrow" medians. This restriction relates to the inefficient and unsafe nature of an intersection with a wide median. Specifically, a wide median can lead to longer lost times between signal phases and a larger area of uncontrolled pavement. One state defined a narrow median as being less than 20 ft wide. Another state suggested that medians more than 50 ft wide were too wide for efficient signalization.

Flashing beacons are used by many states as a corrective measure. Flashing beacons include intersection control beacons, Stop sign beacons, and hazard identification beacons. An intersection control beacon is suspended over the intersection and has flashing yellow and red indications for the major and minor approaches, respectively. A Stop sign is typically located on each minor approach in conjunction with this beacon. Thirty-nine percent of the responding states use intersection control beacons in situations where high accident rates indicate a hazardous location.

A Stop sign beacon is suspended over the intersection and has flashing red indications for both the major and minor roadways. This type of beacon implies four-way stop control and is typically used in conjunction with Stop signs on all approaches. Nine percent of the responding states indicated that they considered this treatment at high-accident intersections on rural expressways.

Hazard identification beacons are used to supplement warning or regulatory signs. Nine percent of the responding states indicated that they have installed this type of beacon at high-accident expressway intersections.

Other Traffic Control Measures

Other traffic control measures used as accident countermeasures include signing improvements, reduced speed limits, and rumble strips. Signing improvements were considered by 35 percent of the states responding. These improvements typically include the addition of advance signing, increase in sign size, and reduction of existing sign clutter. Advance signing was cited as a corrective measure most frequently (26 percent). Increasing sign size to 48 × 48 in. was considered by 9 percent of the states, whereas reduction of existing sign clutter was mentioned in only 4 percent of the responses.

Reducing the speed limit on the expressway was considered by 17 percent of the states as a viable accident reduction measure. Nine percent of the states indicated that they had considered the use of rumble strips on the minor road approaches to the intersection.

Geometric Design Measures

Expressway Left-Turn Bay and Median Width

Left-turn bay and median designs for efficient operation are frequently in conflict with those designs for maximum safety. This conflict has been the subject of some controversy regarding the optimal design combination. The underlying problem is the lengthy sight distances crossing and left-turning drivers need as a result of the high-speed operation of the expressway. The problem is often aggravated by the relatively wide medians commonly found on rural expressways. Wide medians increase the clearance distance of both crossing and turning drivers and thereby increase the sight distance needed to ascertain the safety of the crossing or turning maneuver.

To investigate the magnitude and extent of the left-turn safety problem on rural expressways, a series of questions about median and left-turn bay design was included in the survey. One question inquired about the median width used between intersections. The response to this question was varied. Some states have only a minimum width criterion, others have minimum and desirable widths, and still others have minimum and maximum widths. A summary of the responses to this question is presented in Table 2.

TABLE 2 Summary of Rural Expressway Median Widths

Median Width Between Intersections	Range (feet)	Median Value (feet)
Minimum	4 - 84	46
Desirable	40 - 66	48
Maximum	40 - 104	48

As Table 2 suggests, median widths of 40 to 50 ft are most commonly used for rural expressways. Widths in this range have generally been found to provide a good balance between overall right-of-way width and safe traffic operations. Medians less than 40 ft wide may not provide adequate protection from errant vehicles, whereas medians more than 70 ft wide are probably not cost-effective with respect to added safety.

Although wide medians provide protection from encroachment by opposing traffic, they can introduce operational problems at unsignalized at-grade intersections. In the case of the left-turn maneuver off the expressway, two potential problems exist. First, a wide median combined with traditional left-turn bay design places opposing left-turn movements directly in each other's line of sight to oncoming traffic (see Figure 2). Second, the travel paths of these left-turn movements tend to be overlapped such that simultaneous movement of opposing left-turn movements can result in a head-on collision. Wide medians also increase the size of the intersection conflict area and make it difficult for crossing drivers to safely clear the intersection.

In recognition of the safety problems associated with wide medians at intersections, about one-third of the states that build rural expressways consider alternative median widths or left-turn bay designs, or both. Alternative median widths include those that are less than 20 ft (narrow) and those that are more than 100 ft (wide). The benefits of narrow median widths are reduced sight distance blockage and turn path conflict among opposing left-turn movements as well as shorter clearance path lengths. Medians of 100 ft or more also separate opposing left-turn movements and minimize clearance paths by forming two closely spaced but separate intersections.

The most common alternative left-turn treatment has left-turn bays that are laterally offset to eliminate the sight distance obstruction created by opposing left-turn movements. Figure 3 shows two methods of offsetting left-turn bays. The method shown in Figure 3a has both left-turn bays angling through the median. Experience with this configuration indicates that some obstruction to opposing left-turn driver sight distance can be incurred when the storage area contains several stopped vehicles. The method shown in Figure 3b has both left-turn bays offset and parallel to the through lanes. With this design all queued left-turn vehicles are removed from the opposing left-turn driver's line of sight.

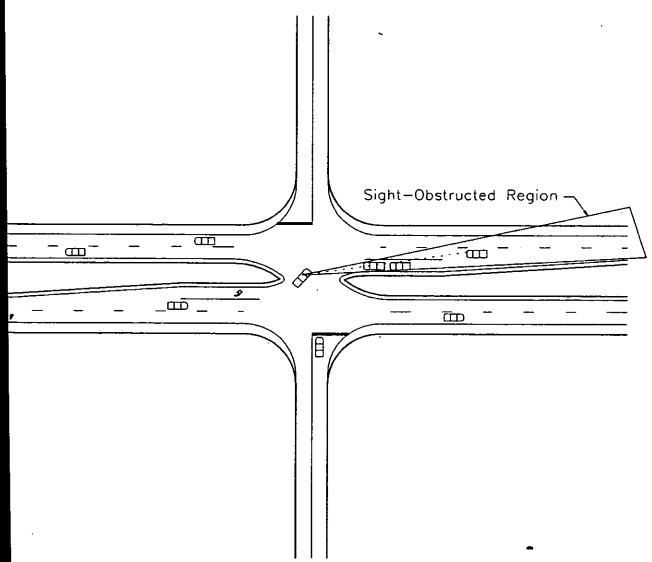

FIGURE 2 Sight obstruction to left-turning vehicles.

Responses to the survey indicate that laterally offset left-turn bays are generally considered for medians that are more than 30 ft wide. This trend stems from the fact that sight distance restrictions and turn path conflicts associated with traditional turn bay designs (as shown in Figure 2) tend to increase in severity with increasing median width. Although most states consider the offset left-turn bay design, they point out that it is not a design standard. It is most often considered where wide medians exist and left-turn accident problems have been encountered. In addition, several states indicated that this design was considered primarily for signalized intersections with permitted or protected/permitted left-turn signal phasing.

Concerns have been raised about the safety of the offset left-turn bay design. Although the design improves left-turn sight distance and lessens turn path conflicts, several states suggest that the small island on the right side of the offset turn bay may introduce some safety problems. This problem stems from the unusual nature of this design—most drivers are unaccustomed to driving in offset turn bays. There is a concern that drivers would not use the bay as intended since the small island would be flush and painted in all rural applications. If turning drivers do not respect the intended channelization, the safety benefits that this design offers may be negated.

Another, less frequently used left-turn treatment is shown in Figure 4. This treatment prohibits left turns at the intersection but permits them at one-way median U-turn lanes downstream of the intersection. This indirect left-turn arrangement requires a relatively wide median width and is used primarily as a part of stage construction where the right-of-way is ultimately used for an interchange.

Interchanges

Interchanges provide the safest access to a high-speed facility. Traffic can access the expressway through lanes via ramps that promote high-speed merge or diverge maneuvers rather than the direct entry and slower turn speeds associated with access openings or median openings. In general, 22 percent of the states responding consider interchanges to be a corrective measure for intersections with high accident rates.

Two states that responded to the survey indicated that they design all new rural expressways that bypass cities as full-access control facilities. In this regard, they construct interchanges at all major intersections along the bypass. This policy was adopted because of the high accident rates found at many existing at-grade intersections on rural bypass/expressways. Potential benefits of this design, in addition to improved safety, include the up-front dedication of right-of-way and the provision of surplus capacity for future traffic growth.

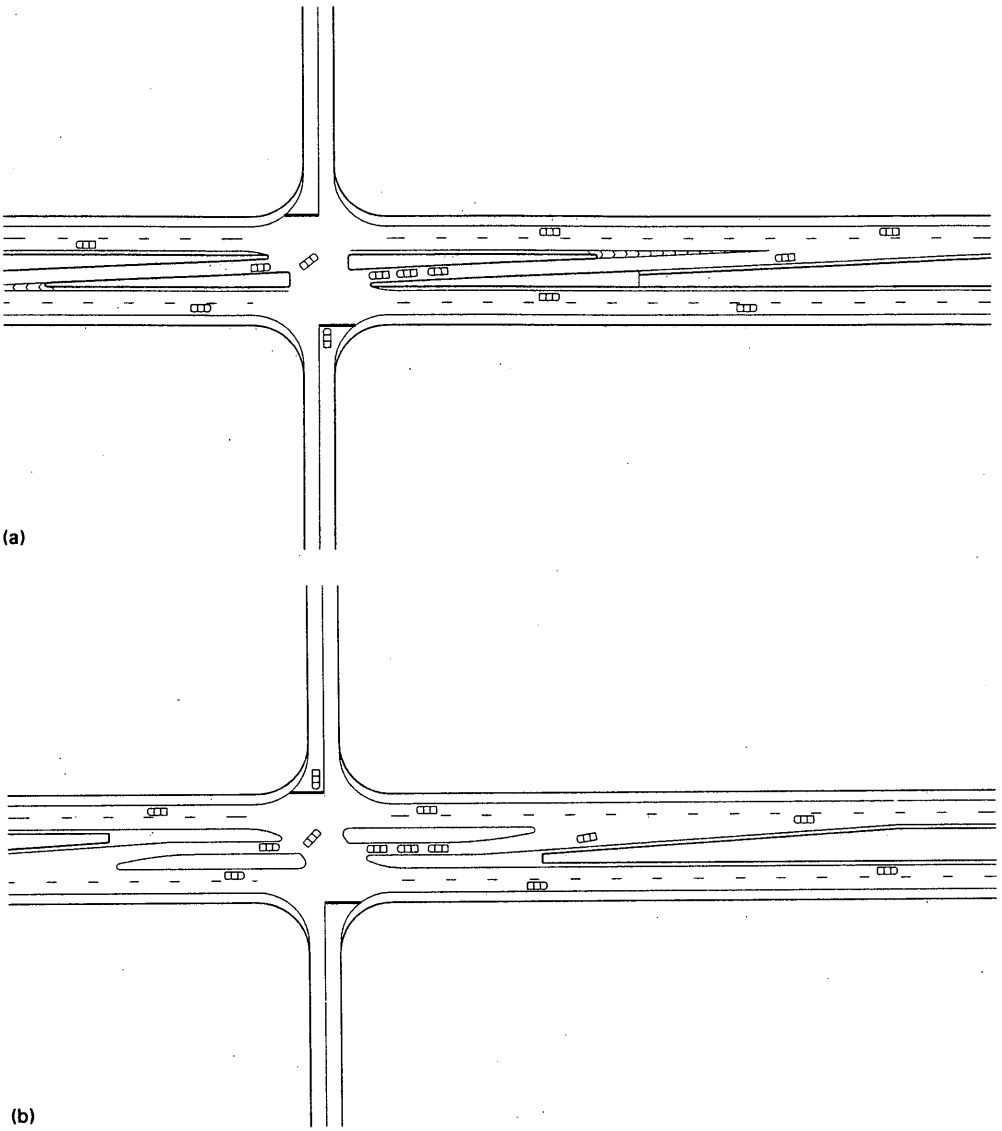

FIGURE 3 Alternative left-turn bay designs: (*a*) tapered offset left-turn bays, (*b*) parallel offset left-turn bays.

Other Geometric Design Measures

Other geometric design measures that were considered varied in application but shared the goal of increasing the separation between turning and through traffic. The impetus for this common goal stems from the higher accident potential associated with traffic streams having high speed differentials. Typical measures recommended included adding a right-turn bay, lengthening the left-turn bay, adding a median acceleration lane, and adding a right-turn acceleration lane. The fact that none of these measures was cited by more than one state reflects their less frequent application resulting from higher implementation costs.

In general, specific "warranting" criteria were not cited for the turn bay or acceleration lane improvements other than the fact that they would be considered at all locations where they could potentially reduce turning or merging accidents. One state, however, indicated that its design policy for rural multilane highways recommends the use of left- and right-turn bays at all public road access points when the design speed of the highway is 40 mi/hr or more.

CONCLUSIONS

The combination of high-speed operation and only partial access control can have an adverse impact on the safety of rural expressways. To mitigate this impact, several measures are frequently used by state highway departments. One is the access control policy, which is used to regulate the frequency and location of all access to the expressway. Measures used at at-grade intersections along the expressway include traffic control devices and geometric design features.

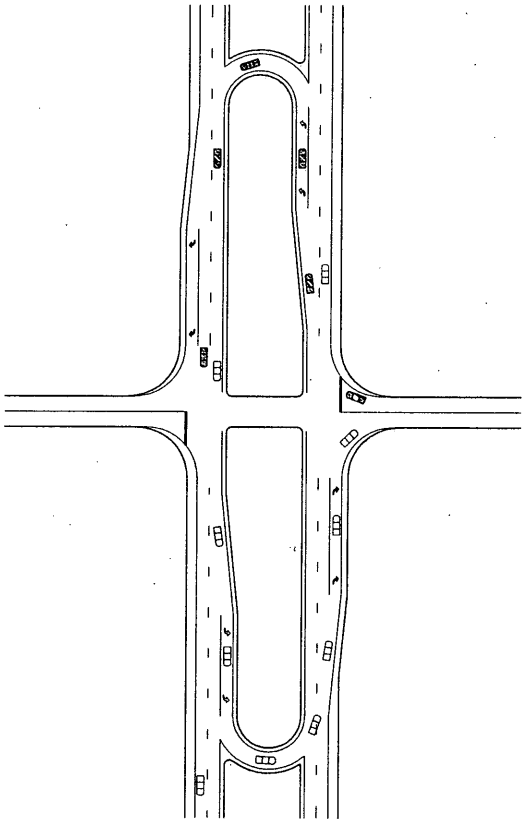

FIGURE 4 Indirect left-turn design.

A recent survey of state highway departments conducted by the Nebraska Department of Roads indicates that most states build rural expressways with at-grade intersections. When accident problems are found at these intersections, most states consider some type of signalization or signing improvement. One of the more novel corrective measures is the offset left-turn bay. This design attempts to minimize the sight distance blockage created by opposing left-turn vehicles. The blockage becomes more restricted with increasing median width. At present there has been no substantial research conducted on the safety benefits of offset left-turn paths; however, at least one-third of the state highway departments have successfully used this design at selected locations.

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1. *Manual on Uniform Traffic Control Devices.* U.S. Government Printing Office, Washington, D.C., 1989.

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