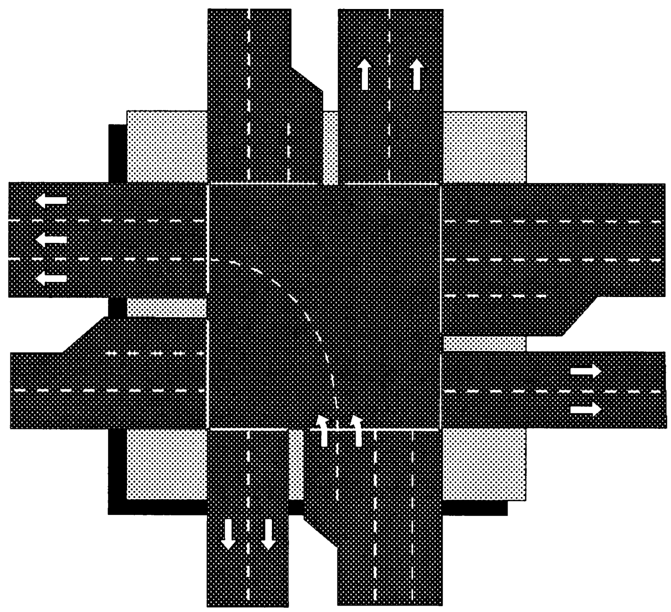
TECHNICAL ASSISTANCE
REPORT

# POSITIVE GUIDANCE PAVEMENT MARKINGS FOR DUAL LEFT-TURN LANES

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Transportation Research Council
(A Cooperative Organization Sponsored by the
Virginia Department of Transportation and
the University of Virginia)

Charlottesville, Virginia

September 1993
VTRC 94-TAR7

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## INTRODUCTION

As the capacity of signalized intersections are being reached, traffic engineers are being faced with dwindling financial resources and limited transportation systems management (TSM) techniques to increase their capacity. One TSM technique that has been successfully used in many states, including Virginia, is the installation of dual left-turn lanes at intersections that experience high left-turn volumes. It has been shown that dual left-turn lanes operate at approximately 1.8 times the capacity of a single left-turn lane(1). Although this added capacity is very attractive to the engineer, other measures need to be considered in conjunction with implementing this technique. One such measure is the installation of positive guidance pavement markings (skip lines).

In an October 31, 1991 memorandum to Virginia Department of Transportation (VDOT) District Administrators, the State Traffic Engineer, Mr. J. L. Butner, strongly recommended that positive guidance pavement markings "be considered at ALL locations where dual left-turn lanes are employed." Eight of the nine districts responded that they currently provide positive guidance at such locations. The district not using such markings stated that "limited resources in maintenance replacement funds and manpower" prevented them from marking each location and that these locations are marked on a case-by-case basis.

In addition to Mr. Butner's position that skip lines be deployed consistently throughout the State, the Traffic Engineering Division (TED) was also concerned about the placement of the skip lines when the receiving roadway has more than two lanes, and the number of approaches that should be marked if the intersection has more than two dual left-turn lane approaches.

As a result of the above, the TED requested the Virginia Transportation Research Council (VTRC) to review VDOT's current practice on the subject and provide guidance on the installation of these markings.

## OBJECTIVES

The objectives of this technical assistance effort were to: 1) examine VDOT's current practice on the use of positive guidance pavement markings for dual left-turn lanes, and 2) provide guidance to VDOT on installing such markings when the receiving roadway has more than two lanes.

## METHODOLOGY

Two major tasks were undertaken to complete this study. The first task was a comprehensive review of the literature regarding dual left-turns lanes and the pavement marking that are typically used with them. The second task was to survey each of VDOT's nine District Traffic Engineers (DTEs), as well as TED staff, on their policies regarding the use of skip lines and the costs associated with installation and upkeep of these markings. The survey also provided space for each respondent to depict how the skip lines should be installed for two different intersection scenarios.

## RESULTS AND DISCUSSION

### Literature Review

The literature states that "years of experience" reveals that using skip lines to separate turning lanes is recommended(1). As stated in the Roadway Delineation Practices Handbook, the primary purpose of roadway delineation, in this case skip lines, is to provide the visual information needed by the driver to steer his/her vehicle safely through the intersection in a variety of situations(2). The Manual on Uniform Traffic Control Devices (MUTCD) reinforces the above by stating that "where road design or reduced visibility conditions make it desirable to provide control or to guide vehicles through an interchange or intersection, (such as at complex multi-legged intersections or where multiple turn lanes are used) a dotted line may be used to extend markings as necessary through the interchange or intersection area(3)."

In 1975, the Institute of Transportation Engineers (ITE) conducted a study entitled, "The Use and Effectiveness of Double Left-Turn Movements." This study surveyed practicing engineers that had a vested interest in the subject. Sixty-three percent of the engineers surveyed reported that they consistently use "lane line extensions through the intersection to delineate the proper path for double left-turn movements(4)."

In 1993, the ITE Technical Council Committee 5P-5 conducted interviews with twenty-five agencies to investigate the current practices and experiences with using multiple (dual and triple) left-turn lanes (MLTL). A majority of these agencies stated they use "special markings to delineate the common limit between inner and outer turning vehicle paths(5)."

In a 1993 study, conducted by Dr. Amy O'Leary of the VTRC, that addressed the transportation needs of older drivers indicated that older drivers in Virginia view "the absence of (pavement) markings in divided highway crossovers as a problem(6)." In the same study, people were asked about problems associated with intersections and left-turns. The most frequent complaint from these individuals was with the "poor visibility in intersections and too much traffic(6)." These comments indicate areas of deficiencies that are felt by older drivers; moreover, a majority of these same respondents, seventy-percent, indicated that pavement markings were liked or were found helpful(6).

There have not been any studies conducted to determine where the lane delineation should be placed if the receiving roadway has more than two travel lanes. However, the Code of Virginia does provide guidelines for turning vehicles. Section 46.2-846, entitled **Required position and method of turning at intersections; local regulations**, states:

> A. Except where turning is prohibited, a driver intending to turn at an intersection or other location on any highway shall execute the turn as provided in this section.
>
> 3. Left-turns on other than two-way roadways: At any intersection where traffic is restricted to one direction on one or more of the roadways, and at any crossover from one roadway of a divided highway to another roadway thereof on which traffic moves in the opposite direction, the driver intending to turn left at any such intersection or crossover shall approach the intersection or crossover in the extreme left lane lawfully available to traffic moving in the same direction of travel of such vehicle and after entering the intersection or crossover the left-turn shall be made so as to leave the intersection or crossover, as nearly as practicable, in the left lane lawfully available to traffic moving in such direction upon the roadway being entered(p.450).

Appendix A of this report includes a set of guidelines for using dual left-turn lanes that have been adapted from the National Cooperative Highway Research Program Report (NCHRP) 279. These guidelines supply the engineer with some design insight for intersection throat requirements, pavement markings, and signing when installing these types of turn lanes.

The preponderance of what is in the literature coincides with VDOT's practice on installing positive guidance pavement markings at all locations where dual left-turn lanes are employed. The prevailing opinion is that this type of pavement markings for dual left-turn lanes facilitates safe and efficient movement through the intersection. Unfortunately, no studies with quantifiable measures of performance for skip lines were revealed in the literature review.

## Survey Results

The survey consisted of eight questions and two diagrams. The DTE's, and select TED staff, were asked how many dual left-turn lane intersections they had in their district, what type of material is used for skip lines, costs associated with installation and upkeep, frequency of reinstallation, and how and when these markings are installed. The DTE's were also asked to divulge their districts annual pavement marking budget for primary roadways. Sixty percent, six out of ten, of the surveys distributed were returned and used for this report. A spreadsheet was then developed from the data supplied by the respondents to assess the types of material used and their associated costs, and the annual cost of installing skip lines for a single approach. The spreadsheet also displayed the percentage of the districts' annual pavement marking budget for primary roads that is dedicated to these particular markings. The results from each of the spreadsheets are contained in Tables 1 and 2 of this report.

### Costs

Table 1 exhibits the data from the six responding districts, including a break down of costs for installing the skip lines. Table 2 depicts a cost comparison for initially installing skip lines at one location and 94 locations, and the costs associated with reinstalling the skip lines at one location and 94 locations within the Richmond District. (Ninety-four locations represents the total number of dual left-turn lane approaches in the Richmond district.) The only change in the "initial" scenario and the "reinstallation" scenario in Table 2 is the "number of hours" required to install/reinstall these markings. Several DTEs stated that once an intersection has been laid out and marked initially, the amount of time required to remark the intersection would be substantially reduced.

Survey results suggest that skip lines represent only a very small percent, from 0.008 percent to 1.549 percent, of the annual pavement marking budget for each district. The highest percentage figure, 1.549 percent, represents the percentage of the Richmond District's annual pavement marking budget if each of its 94 dual left-turn lanes were marked with skip lines for the first time(See Table 2). After the initial markings are installed, remarking the skip lines will represent 0.871 percent of the annual pavement marking budget. Although the initial costs maybe somewhat substantial, future annual costs are expected to be 56 percent less since the time required to remark an intersection will be reduced by two-thirds.

# TABLE 1

| SPECIFICS | DISTRICT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Fredricksburg | Lynchburg | Richmond | Salem (6 Sites) | | Staunton | Suffolk(20 Sites) | | |
| Number of locations | 5 | 2 | 1 | 2 | 4 | 3 | 16 | 2 | 2 |
| Type of material used | Th (100%) | Th (100%) | T (100%) | P (30%) | T (70%) | P (100%) | P(80%) | Th(10%) | T(10%) |
| Reinstall/12 mos. | 0.5 | 0.5 | 0.5 | 2.5 | 0.5 | 1.0 | 1.0 | 0.33 | 1.0 |
| Number of hours | 1.5 | 1.0 | 3.0 | 0.25 | 0.75 | 0.3 | 1.0 | 1.0 | 1.0 |
| Number of people | 3 | 3 | 5 | 6 | 3 | 6 | 6 | 6 | 6 |
| Labor ($/person/hr) | $14.47 | $11.63 | $15.33 | $16.96 | $12.57 | $16.96 | $15.35 | $15.35 | $15.35 |
| Total labor ($) | $65.12 | $34.89 | $229.95 | $25.44 | $28.28 | $25.44 | $92.10 | $92.10 | $92.10 |
| Equipment | $11.46 | $5.66 | $45.00 | $14.77 | $2.56 | $14.77 | $33.87 | $5.66 | $9.28 |
| Material | $40.50 | $20.77 | $75.00 | $2.52 | $88.20 | $2.52 | $4.18 | $20.77 | $41.80 |
| Total Cost (For 1 approach) | $117.08 | $61.32 | $349.95 | $42.73 | $119.04 | $42.73 | $130.15 | $118.53 | $143.18 |
| Annual Cost | $292.69 | $61.32 | $174.98 | $451.74 | | $128.19 | $2,446.99 | | |
| Annual P.M. Budget | $1,047,365.00 | $625,000.00 | $1,062,000.00 | $698,454.00 | | $1,425,354.00 | $1,309,090.00 | | |
| % of Annual P.M. Budget | 0.028% | 0.010% | 0.016% | 0.065% | | 0.009% | 0.187% | | |

## Legend

Types of material:
- P - Paint
- T - Tape
- Th - Thermoplastic

**TABLE 2**

| SPECIFICS | RICHMOND DISTRICT | | | |
|---|---|---|---|---|
| | INITIAL | | REINSTALLATION | |
| No. of locations | 1 | 94 | 1 | 94 |
| Type of material used | T (100%) | T (100%) | T (100%) | T (100%) |
| Reinstall/12 mos. | 0.5 | 0.5 | 0.5 | 0.5 |
| No. of hours | 3.0 | 3.0 | 1.0 | 1.0 |
| No. of people | 5 | 5 | 5 | 5 |
| Labor ($/person/hr) | $15.33 | $15.33 | $15.33 | $15.33 |
| Total labor ($) | $229.95 | $229.95 | $76.65 | $76.65 |
| Equipment | $45.00 | $45.00 | $45.00 | $45.00 |
| Material | $75.00 | $75.00 | $75.00 | $75.00 |
| Total Cost (1 approach) | $349.95 | $349.95 | $196.65 | $196.65 |
| Annual Cost | $174.98 | $16,447.65 | $98.33 | $9,242.55 |
| Annual P.M. Budget | $1,062,000.00 | $1,062,000.00 | $1,062,000.00 | $1,062,000.00 |
| % of Annual P.M. Budget | 0.016% | 1.549% | 0.009% | 0.870% |

## Materials

The survey responses revealed that paint is the most widely used material for skip lines (57 percent), even though the average frequency of reinstallation is once every 10.5 months. Thermoplastics are the second most commonly used material (24 percent), while tape is the least at 19 percent. The surveys indicated that, on the average, thermoplastics need to be reinstalled once every 26 months, and tape needs to be reinstalled once every 19 months. The survey also pointed out that the majority of the skip lines, 68 percent, are installed when other intersection markings are being installed.

Delineation

The responses to the two different intersection scenarios varied greatly. For a receiving roadway of three lanes, half of the respondents said they would delineate the turning path for the outside left-turn lane to the right most receiving lane. The other half of the respondents said they would delineate the inside left-turn lane to the left most receiving lane, which is in accordance with the State Code. In the scenario with the receiving roadway having four lanes, 25 percent of the respondents indicated that they would delineate the outside left-turn lane to the right most receiving lane. Another 25 percent displayed the delineation as divided equally between the four receiving lanes (two lanes for the outside left-turn lane and two lanes for the inside left-turn lane). Fifty percent depicted the delineation in such a manner as to have the left most turn lane enter the left most travel lane, which is once again in accordance with the State Code.

## OTHER MARKING ISSUES

The number of dual left-turn lane approaches that should be marked per intersection is of interest to the TED and other traffic engineers throughout the State. Although the available literature does not make note of the maximum number to mark per intersection, it is perceived that an intersection should not have more than two approaches marked. This is to avoid over marking the intersection and inadvertently causing confusion to the driver. It should be noted that the presence of more than two dual left-turn lane approaches at an intersection is not likely to be a common occurrence.

There is also some concern over the placement of lane delineation with respect to vehicle tracking. This effort did not address any design issues or criteria other than the general placement of delineation, since its main objective centered on the installation of skip lines at all existing and proposed dual left-turn lane locations. These turn lanes have already been, or will be, designed with a minimum turn radius of 50 feet. In addition, these turn lanes are designed to be 15 feet wide in the middle part of the turn to provide added lateral clearance in an effort to reduce the potential for sideswipe accidents. The TED and Location and Design (L&D) Division both feel that the 50 feet minimum turn radius and the 15 feet lane widths are adequate standards for the wide variety of vehicles that traverse these lanes. Therefore, the presence of skip lines has no impact on the turning radii design, since these markings are only delineating the center line of the turn lanes and are supplementary to the intersection.

## CONCLUSIONS

The literature coincides with VDOT's practice on installing positive guidance pavement markings at all locations where dual left-turn lanes are employed. In addition, the survey results revealed that the installation and upkeep costs that are associated with these markings is relatively small with respect to the annual pavement marking budget for primary roads. Although the benefits of these markings are difficult to quantify in this case, the provision of positive guidance to the unfamiliar or older driver enables them to traverse the intersection safely and efficiently. This is of benefit to these drivers as well as to all drivers.

## RECOMMENDATIONS

1. It is recommended that TED continue to utilize its practice that supports the installation of positive guidance pavement markings at ALL dual left-turn lane locations.

2. In cases where the receiving roadway has more than two lanes, the skip lines should be installed to have the left-most turn lane enter the left most travel lane on the receiving roadway(See Figures 1 and 2). This action will ensure that VDOT will remain consistent with the Code of Virginia (46.2-846). In addition, this will reduce the confusion to the motorist traversing the intersection, be consistent with driver expectancy, and most importantly, maintain a level of uniformity throughout the State where dual left-turn lanes exist.

3. In instances where an intersection has more than two dual left-turn lane approaches, the engineer should determine which two approaches require positive guidance the most in order to traverse the intersection safely and mark only these two approaches. This reduces the confusion of the motorist caused by having too many markings within the intersection, whereby promoting safe and efficient movement through the intersection.

Figure 1

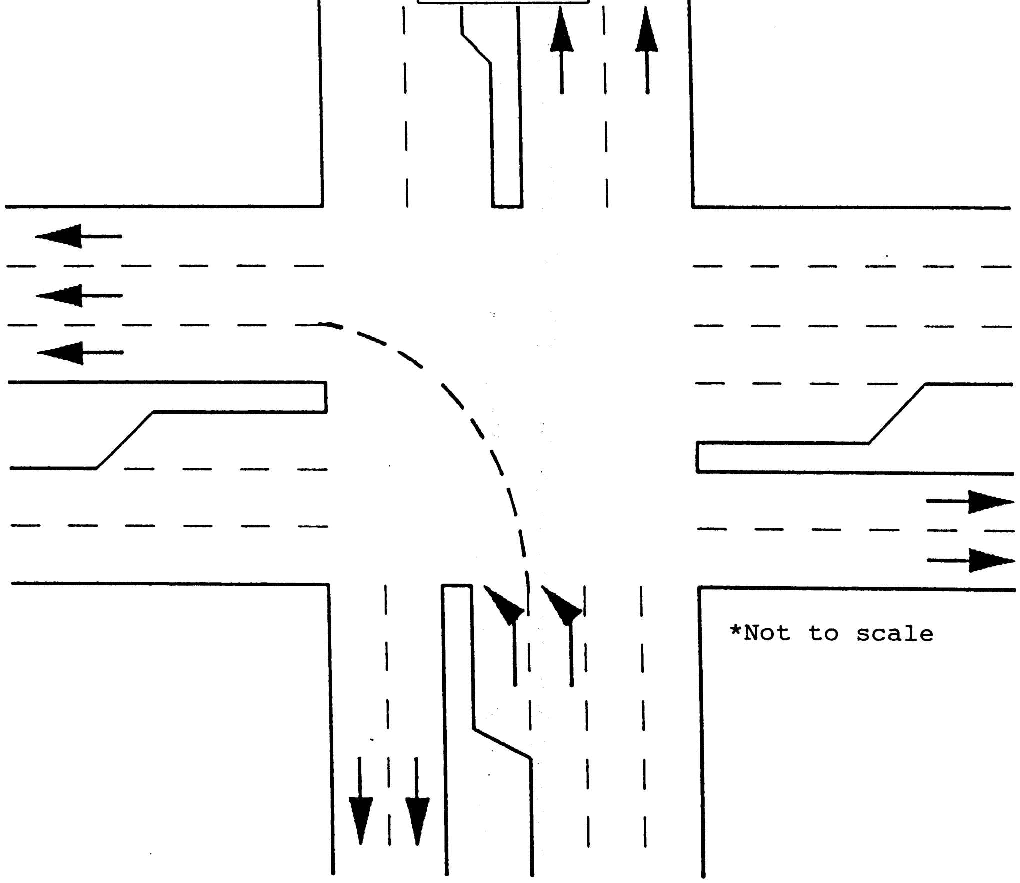
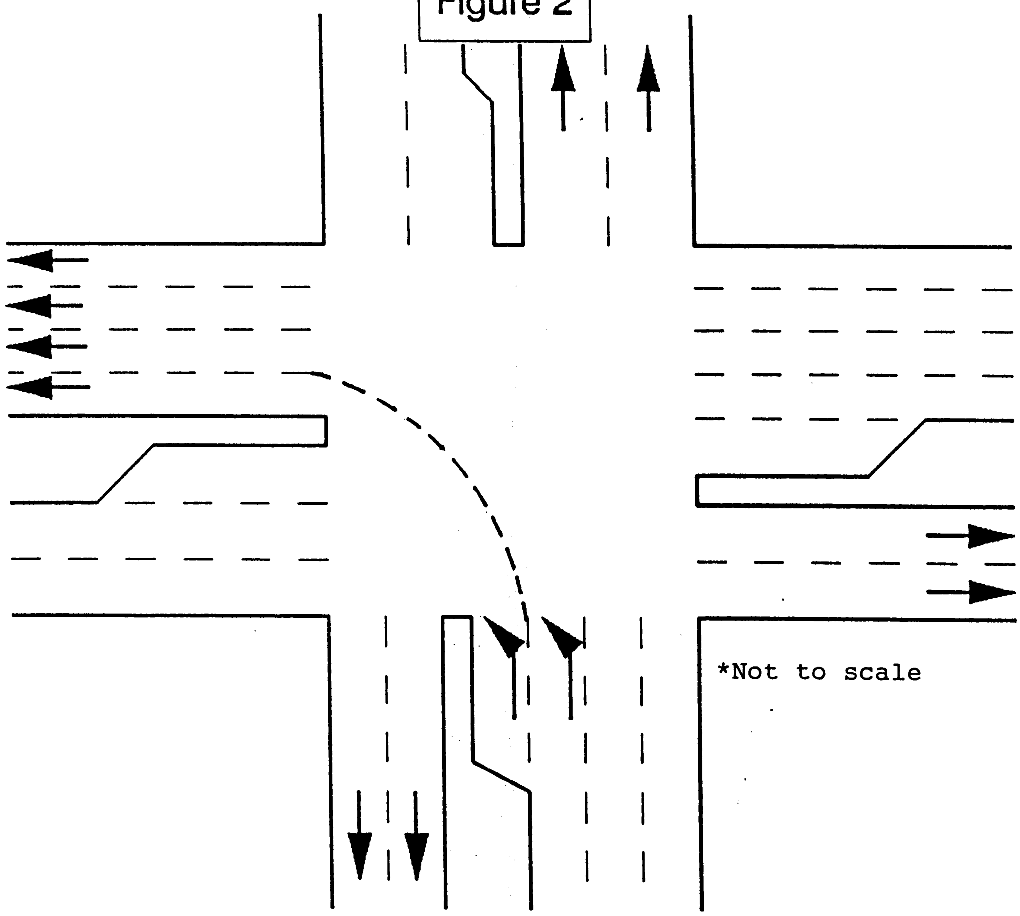



Figure 2



## REFERENCES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2. Federal Highway Administration. 1981. *Roadway Delineation Practices Handbook.* Washington, D.C.

3. Federal Highway Administration. 1988. *Manual on uniform traffic control devices.* Washington, D. C.

4. "The Use and Effectiveness of Double Left-Turn Movements." Traffic Engineering, Vol. 45, No. 7, July, 1975, pp.52-57.

5. "Capacities of Multiple Left-Turn Lanes." Institute of Transportation Engineers Journal, Vol. 63, No. 9, September, 1993, pp. 31.

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APPENDIX A

## Double Left-Turn Lanes—Guidelines For Use

Double left-turn lanes have been applied successfully nationwide at locations with severe capacity or operational problems. Their applicability is generally greatest at high-volume intersections with significant left turning volume in one or more directions. Often, double left-turn lanes are necessary for overall intersection capacity reasons.

Double left-turn lanes should be considered at any signalized intersection with high design hour demand volumes for left turns. As a general "rule-of-thumb," left turn demands of 300 vph or more are appropriate for consideration of double left-turn lanes.

The need or desirability of double lefts should be determined from typical capacity analyses. Alternative lane arrangement and signal phasing schemes should be tested. In terms of capacity, double left-turn lanes operate at about 1.8 times the capacity of single left-turn lanes.

Because of the high volumes associated with double left-turn lanes, and their relatively unusual nature, fully protected signal phasing is generally warranted.

## Design of Double Left-Turn Lanes

Years of experience and research have provided a number of design guidelines for double left-turn lanes:

- The throat width for turning traffic is the most important design element. Drivers are most comfortable with extra space between the turning queues of traffic. Because of the offtracking characteristics of vehicles and the relative difficulty of two-abreast turns, a 36-ft throat width is desirable for acceptance of two lanes of turning traffic. In constrained situations, 30-ft throat widths are acceptable minimums.
- Guiding pavement markings to separate the turning lanes are recommended. The MUTCD recommends 2-ft long dashed lines with 4-ft gaps to channelize turning traffic. These channelization lines should be carefully laid out to reflect offtracking and driving characteristics.
- Designers should carefully sign and mark double turning lanes to prevent inadvertent "trapping" of through traffic. Fully shadowed lanes should be designed wherever possible. Up to a full lane width of recovery area should be provided in the median opposite the double turning lane for recovery of trapped vehicles.
- Designers should check for possible conflicts involving left turns opposing double left turns. Where such simultaneous movements occur, special pavement markings to separate opposing turns may be necessary.