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THE DEVELOPMENT OF CRITERIA FOR THE TREATMENT OF RIGHT TURN MOVEMENTS ON RURAL ROADS

by

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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.)

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ABSTRACT

The objective of this research was to develop criteria or guidelines for the treatment of right turn movements at non-signalized intersections on rural roads. It was necessary for the criteria to be applicable for a wide range of conditions.

A survey of state departments of transportation and Virginia Department of Highways and Transportation district traffic engineers identified the criteria presently used and the factors to be considered in establishing criteria. The decisions for right turn treatments are primarily based on judgement or rule of thumb. Field work identified the range of conditions and effectiveness of the treatments.

The guidelines were developed through an analysis of the field data, the survey, and judgement. They are based on the peak hour (or design hour) volumes for right turn traffic and total traffic on the approach to the right turn treatment. Guidelines are available for 2-lane and 4-lane roadways. Other factors to be considered are noted.

It is recommended that the guidelines presented in this report be adopted by the Virginia Department of Highways and Transportation as an aid in selecting the appropriate treatment for right turn movements on rural roads.

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INTRODUCTION AND PROBLEM

Unless properly accommodated, right turn movements tend to adversely affect the flow of through traffic. The through traffic following a right-turning vehicle that slows to make the maneuver may have to slow, stop, or change lanes. The right turn maneuvers may result in delays to the through traffic or in traffic conflicts that indicate the safety and operational problems resulting from right turn movements.

Three basic treatments are used to facilitate right turn movements: (1) no special treatment other than the radius, (2) a taper, and (3) a full-width lane (Figure 1). The type of treatment employed should be tailored to the prevailing traffic conditions.

The Virginia Department of Highways and Transportation's standard plans for intersections in rural areas employ a 150-ft. (45.7m) taper to facilitate right turn movements.[1] On low volume intersections, the right turn movements may not require special treatment. On the other hand, where there are a large number of right turn movements, the 150-ft. (45.7m) taper may be inadequate and a full-width lane should be provided.

At present there are no criteria to aid in the selection of the appropriate treatment of right turn movements at intersections in rural areas. The selection is based on engineering judgement, and assessments of the same intersection by several engineers would probably result in different types of treatment. Consequently, there is a need to develop criteria for such treatments as an aid in roadway design. The criteria would also be useful in determining the requirements to be imposed on land developers for treating right turn movements.

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No treatment other than the turning radius

Taper

Full-width lane

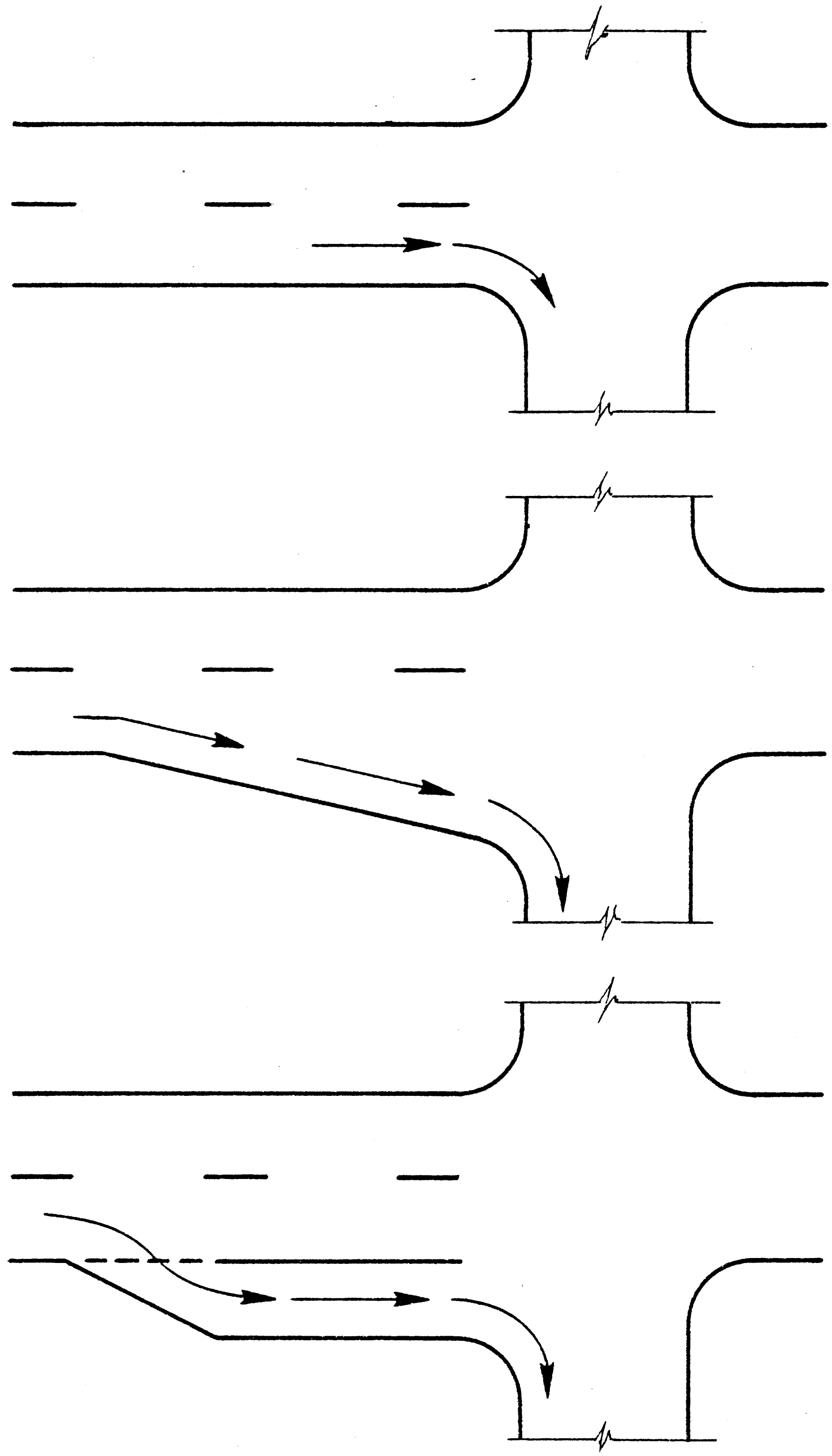

Figure 1. Types of treatment for right turn movements.

OBJECTIVE AND SCOPE

The objective of this research was to develop criteria for the treatment of right turn movements on rural roads, criteria that would be applicable for a wide range of conditions at intersections. The volumes and speeds of right turn and through traffic were the primary factors considered.

The research was limited to treatments for nonsignalized intersections and comprised the six tasks listed below.

A. Review of literature on the treatment of right turn movements.
B. A survey of state departments of transportation and Virginia Department of Highways and Transportation district traffic engineers to obtain criteria currently being used.
C. Classification of intersections to group the wide range of possible conditions.
D. Selection of parameters to be used in the criteria.
E. Field work to identify the range of conditions for the three basic types of treatments used and their effectiveness.
F. Analysis of field work and development of criteria.

LITERATURE REVIEW

A search of the available literature was conducted through the facilities of the Highway Research Information Service. Reports selected from the abstracts received through the literature search were obtained. Additional reports were identified by transportation professionals and through a less formal literature search. Information derived from the literature review is documented throughout the report. It was found that only limited data are available on treating right turn movements. Most studies of intersections focus on gap acceptance and left turn lanes.

SURVEYS

Survey of State Departments of Transportation

The survey of state departments of transportation (DOTs) was conducted by telephone. If a policy or procedure was in use, a written document was requested. Responses were obtained from 41 of the 48 contiguous states. The results are summarized in Tables 1 and 2. The state DOTs without criteria are listed in

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Table 1 and those with criteria in Table 2. Of the 25 states without criteria, most consider speeial right turn treatment on a project-by-project basis. Several states seldom consider special treatment for right turns in rural areas. It is reasonable to assume that the states with no standard use a radius. The reference to no standard was probably confused with no criteria.

Thirty-seven percent, or 15, of the state DOTs contacted used some form of criteria, most of which address conditions that warrant a right turn lane in lieu of either a taper or radius, but not a taper in lieu of a radius. Five base their criteria on volume conditions, 4 on roadway type, 2 on capacity, and 4 use rule of thumb. About half (8 of 15) of the state DOTs have the criteria written in design guidelines. Several comments were made on experiences with right turn treatments and their usage. Table 2 and Appendix A present details of the criteria.

Survey of District Traffic Engineers

The eight district traffic engineers of the Virginia Department of Highways and Transportation were surveyed on their criteria for determining appropriate right turn treatments and their concerns over other traffic problems. The treatment of right turn movements varies among districts because decisions are based on judgement. The primary benefit from this survey was the identification of the concerns of the district traffic engineers.

A major concern involves establishing a firm policy for dealing with land developers on the issue of providing facilities to accommodate the traffic to be generated by proposed developments. Flexibility in the criteria is desired. The factors suggested for consideration include safety, volume, speed, capacity, sight distance, grade, delay, traffic conflicts, availability of right-of-way, angle of turn, and standards for entrances to state highways.

CLASSIFICATION OF INTERSECTIONS

Intersections were classified to group the wide range of possible conditions. The type of right turn treatment, average daily traffic volumes, type of intersection, and types of roadways were the variables considered. These variables are interrelated. Two classes of roadway were used to classify the

Table 1

Survey Results: States Without Criteria

State	Standard Right Turn Treatment No Standard	Radius	Taper	AASHTO	Comments
Arizona	X				
Connecticut	X			X	Criteria for newer designs
Delaware	X			X	
Florida	X				
Georgia	X				
Maine	X				
Maryland	X				Use of wider shoulder
Massachusetts	X				
New Hampshire	X				
South Carolina	X				
Texas	X				
Utah	X				
Wisconsin	X				
Alabama		X			
Arkansas		X			
Louisiana		X			
Montana		X			
New Jersey		X		X	
Oklahoma		X			
Rhode Island		X			
South Dakota		X		X	
Tennessee			X		
Kentucky			X		
North Carolina			X	X	
Virginia			X		

Table 2

Survey Results: States with Criteria

State	Types of Treatment: Radius	Taper	Lane	Criteria
California	X		X	Use full lane for high speed two-lane roads
Colorado	X		X	R.O.T. - Use full lane if >200 VPD turn right
Connecticut (newer designs)	X		X	AASHTO with special attention; R.O.T. - greater than 20% right turn movements use a full lane
Idaho	X		X	Vehicle conflict table with right turn and total DHV - (See Appendix A)
Illinois	X		X	R.O.T. - For right turns >60 vph on two-lane roads, use full lane
Indiana	X	X	X	R.O.T. - Use full lane if right turns >50 VPH
Iowa	X	X	X	Exposure index - Through x turn volumes (See Appendix A)
Kansas	X	X	X	Road type - Full lane used on FAS roads except for very low VPH; R.O.T. - For 300-600 VPD turning right, use a taper
Michigan	X	X	X	Right turn volumes - For right turns >600 VPD, use full lane, 300-600 VPD-radius
Nebraska	X		X	R.O.T. - Use full lane if 30-60 VPH turn right
New York	X		X	Used on capacity basis only - Focus on left turns
North Dakota	X	X	X	Traffic and road types
Ohio	X		X	Specific intersection types (use lane on all 4 lane highways where sign route makes a turn
Oregon	X		X	R.O.T. - Consider lane if through volume > 600 VPH
Vermont	X	X	X	Traffic type and volume - For right turn DHV >50, use full lane
West Virginia	X	X	X	Right turn volumes –

DHV For Right Turn Traffic:	Treatment:
< 30	Radius
> 30	Taper
> 250 and DHV Through > 500	Full Lane

(criteria for divided highways only)

Legend

R.O.T. - rule of thumb
VPD - vehicles per day
VPH - vehicles per hour
DHV - design hourly volume
FAS - Federal-aid secondary

intersections; namely,

a) 4-lane arterial and 2-lane road, and
b) 2-lane arterial or primary route and 2-lane road, and two 2-lane secondary routes

The 2-lane roadway may be an arterial, primary route, or secondary route. Within these two basic classes, a distribution of traffic volumes, right turn treatments, and intersection types are available.

SELECTION OF PARAMETERS FOR CRITERIA

Information on several parameters is necessary for obtaining a data set representative of the typical intersection. Based on the literature review and surveys, the parameters selected in developing the criteria were:

a) through traffic volume
b) right turn traffic volume
c) speed prior to intersection
d) traffic conflicts due to right-turning vehicles
e) capacity as derived by the critical lane analysis

The through and right turn volumes were the primary parameters suggested by the state DOTs in the survey, with speed being the next most frequently mentioned one. Safety was a primary concern but no parameters were suggested other than a review of the accident history of the intersection. Traffic conflicts were said to be useful as a surrogate measure for safety and accident records were examined when available. Several state DOTs who said they had no criteria did perform a capacity analysis as an aid in identifying deficiencies.

FIELD WORK

In developing criteria for the treatment of right turn movements, information on the traffic conditions that exist for the three basic treatments was desired. The objective of the field work was to obtain data on sites selected as representative of the different classes of intersections. Various aspects of this work are discussed below.

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Test Procedure

The parameters selected for use in developing criteria were obtained in the field tests. Average daily traffic counts were obtained for the through traffic on the approach to the right turn treatment and for the right turning traffic and peak period volume counts were obtained on all approaches to the intersection. Speed and traffic conflicts were measured on the study approach. The traffic conflict measured was a right-turn, same-direction conflict. The definition for this conflict states that "a right-turn, same-direction conflict occurs when the first vehicle slows to make a right turn, thus placing a second, following vehicle in danger of a rear-end collision. The second vehicle brakes or swerves, then continues through the intersection."(2)

Sample Size and Period of Observation

Since traffic conflicts occur less frequently than turning movements, the sample size for statistical significance was based on traffic conflicts. The minimum sample size was determined as

$$N = \frac{pqk^2}{E^2} \quad (1)$$

where

N = minimum number of counts to be taken of each movement for each type of traffic conflict to be checked and should not be less than 30;
p = proportion of the vehicles involved in a specific traffic conflict for the observed flow of traffic (a conservative or reasonable estimate is p = 0.5);
q = 1-p;
k = constant corresponding to the desired confidence level (CL) (k=1.64 for CL=90%, k=1.96 for CL=96%, and k=2.00 for CL=95.5%); and
E = permitted error in the proportion estimate of traffic conflicts (generally in the range of $\pm$0.01 to $\pm$0.10).(3)

For p=0.5, k=1.96, E=0.1, and N=96. Since conflicts caused by right turns are being measured, this equation indicates that a minimum of 96 right turn movements among intersections would result in a wide range of observation periods.

Glauz and Migletz found that the mean hourly count for right-turn, same-direction conflicts was 4.89, and that the number of hours of data required to estimate the mean hourly count was 5.1 (within $\pm$50% with 90% confidence).(2) This would imply that p would be much less than 0.5 for most intersections, and thereby result in a lower value of N in equation 1 (e.g. if p=0.1, N=35). Because of the above discrepancies, time constraints, and a desire for a uniform observation period, four hours of observation were deemed to be sufficient.

Procedures

The traffic data were collected in two stages: a 48-hour count and two 2-hour peak period observations. For the 48-hour traffic count, counters were placed prior to the intersection for total volume counts on the approach to the study site and at the intersection for right turn volume counts. The peak 2-hour period was determined through a computer analysis. In the next stage, observations were made during the 2-hour peak periods to obtain volume counts for all approaches and speed readings and traffic conflicts due to right-turning vehicles on the study approach. Data were collected over 15-minute intervals.

Typical field setups of the observers for peak period observations are shown in Figure 2. Two observers, one to measure speeds and one to count volumes and conflicts, were stationed 100 to 300 ft. (30.5 to 91.5m) from the beginning of the treatment (radius, taper, or lane). The observers and radar scope were positioned so as to minimize distractions to the motorists. Observations were made from a Department truck when problems were encountered with the typical field setup.

Accident records were used to supplement the data collected.

Method of Analysis

The Statistical Package for the Social Sciences (SPSS), a system of computer programs, was used to analyze the data.[4] The two programs used were Pearson correlation and multiple regression. The Pearson correlation subprogram tested for correlation between the parameters measured in the field tests. The multiple regression subprogram developed linear relationships between parameters that were highly correlated.

To supplement the results of the SPSS analysis, the field data were examined with respect to criteria employed by the Idaho and Iowa state departments of transportation.

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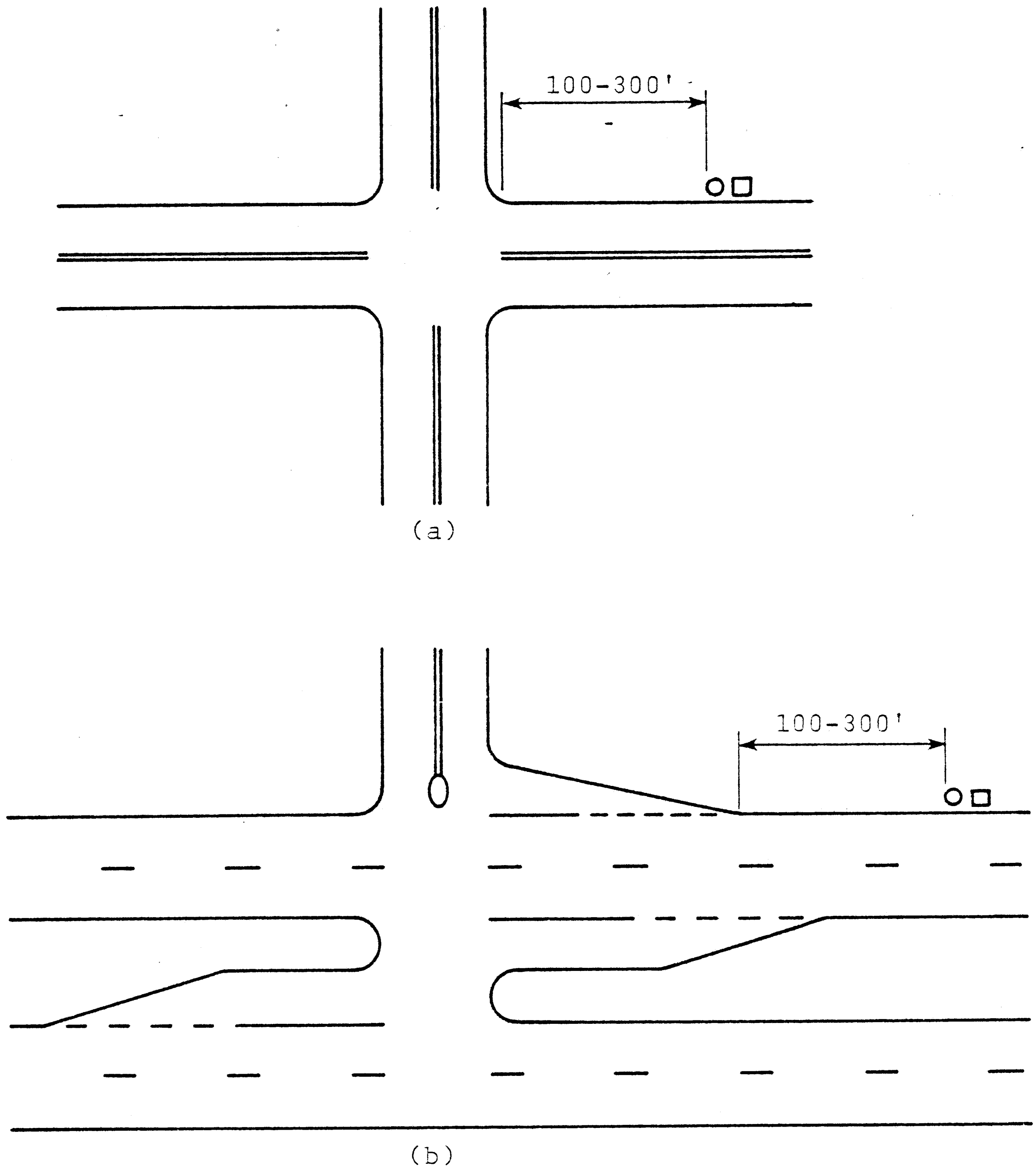

O conflict observer

□ speed observer

1 m = .305 foot

Figure 2. Typical field work setups.

Pilot Tests

Pilot tests were conducted to examine the adequacy of the test procedure and method of analysis. The pilot tests also provided training in collecting data on traffic conflicts, traffic volumes, and speeds. The pilot tests, which were conducted for each type of treatment for right turn movements, showed that the test procedure and method of analysis were adequate.

Site Selection

Study sites were selected with the assistance of two assistant district traffic engineers and a regional traffic engineer of the Virginia Department of Highways and Transportation. Seven sites for each type of right turn treatment — radius, taper, and turn lane — were selected. A variety of speed limits, types of roadways and intersections, and volume conditions was obtained.

Table 3 identifies the sites by district, county, type of treatment, and the approach leg of the intersection studied. The distribution of sites by roadway intersection classification was as follows:

Classification	No. of sites
a) 4-lane arterial and 2-lane road	8
b) 2-lane arterial and 2-lane road	8
two 2-lane secondary roads	5
	21

More information on the sites is provided in the following section of the report.

FIELD WORK RESULTS

The results of the field work are divided into four sections: description of sites, field work data, capacity and accident analysis, and SPSS analysis.

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Table 3

Field Sites Identification

County	Intersecting Routes	Study Approach Leg	Treatment
Culpeper District Study Sites			
Albemarle	250 & 616	250 EB	Radius
	250 & 676	250 WB	Radius
	601 & 676	601 WB	Radius
	29 & 692	29 SB	Taper
	29 & 1520	29 NB	Lane
	250 & 6	250 EB	Lane
	250 & 690	250 WB	Lane
	250 & West Leigh Subdivision*	250 WB	Lane
Culpeper	29 & 718	29 SB	Taper
	29 & 663	29 NB	Lane
Fairfax	645 & Shiplett Blvd*	645 EB	Taper
	645 & 5910	645 EB	Lane
Greene	29 & 607	29 SB	Taper
Orange	33 & 20	33 WB	Taper
Staunton District Study Sites			
Augusta	340 & 611	340 SB	Radius
Rockingham	33 & 996	33 EB	Radius
	659 & 689	659 EB	Radius
	659 & 825 & 955	659 EB	Radius
	33 & 276 & 620	33 EB	Taper
	276 & 659	276 NB	Taper
	33 & 704	33 EB	Lane

*Not in the state system

Description of Sites

The sites were identified by the route numbers of the intersecting roadways. The site descriptions are given in Table 4. The parameters are types of treatment, dimensions of the treatment, types of roadways, types of intersections, and average and posted speeds.

Field Work Data

The data collected at the field sites and shown in Table 5 reflect a wide range of values for traffic volumes, right-turning movements, and conflicts. Note that the volume is given in terms of average daily traffic, the 2-hour peak period, and the peak hour of the 2-hour peak period. The peak hour period was selected as the design period for establishing guidelines based partly on the following statement from the AASHTO Blue Book.

> Traffic volume during an interval of time shorter than a day more appropriately reflects the operating conditions which should be used for design if traffic is to be properly served. The brief but frequently repeated rush-hour periods are significant in this regard. In nearly all cases a practical and adequate time period is one hour.(5)

Capacity and Accident Analysis

The results of these two analyses are given below.

Capacity Analysis

The purpose of the capacity analysis was to determine a measure of effectiveness of the intersection in accommodating the traffic it carried. The type of analysis used focuses on the critical volume movements in the intersection.(6) The method is simpler and easier than conventional methods, but is a general technique and not suitable for use in roadway design. In this study it was used to screen intersections for possible further capacity analysis. The results indicate that all 21 sites were operating at the A level of service, which is described as free flow. Therefore, capacity was not a consideration in determining the guidelines for treating right turn movements.

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Table 4

Description of Sites

No.	Site	Treatment	Design Dimensions: Turn Radius(ft)/ Intersection Angle	Design Dimensions: Taper Length(ft)/ Width(ft)	Design Dimensions: Lane Length(ft)/ Width(ft)	Intersection Type (+ or T)	Number of Lanes	Speed mean/posted (mph)
R1	250&616	Radius				+	2	42/55
R2	250&676					+	2	47/55
R3	340&611					+	2	43/45
R4	601&676					T	2	35/45
R5	659&825		40/102			+	2	34/35
R6	659&689		50/81			+	2	43/55
R7	33&996		50/90			T	4	53/55
T1	33&20	Taper	60/67	120/12		T	2	46/55
T2	276&659		50/67	200/10		+	2	48/55
T3	645&SHIPL			200/12		T	2	33/35
T4	33&276		60/105	170/14		+	4	50/55
T5	29&692		60/102	150/10		+	4	54/55
T6	29&718		80/124	150/		T	4	50/55
T7	29&607		60/100	75/13		+	4	49/55
L1	250&6	Lane		180	97/10	T	2	41/55
L2	250&690			90	144/12	T	2	49/55
L3	250&WL			160	95/11	T	2	49/55
L4	645&5910			90	184/16	T	2	41/35
L5	29&663		60/101	100	95/12	+	4	55/55
L6	33&704			160	114/10	T	4	54/55
L7	29&1520			80	120/12	T	4	49/55

1 foot = .305 m
1 mph = 1.6 km/hr.

Table 5

Field Data

No.	Average Daily Traffic				Average Peak Period					Average Peak Hour				
	Total	Thru	Right	%RT	Total	Thru	Right	%RT	Conflict[a]	Total	Thru	Right	%RT	Conflict[a]
R1	1,757	1,416	341	19	479	385	94	20	50	276	213	63	23	66
R2	3,488	3,227	261	7	782	700	57	7	43	464	430	34	7	52
R3	2,793	2,721	72	3	593	573	20	3	13	425	414	11	3	13
R4	1,534	857	677	44	343	214	129	38	110	189	115	74	40	127
R5	1,168	575	593	51	260	146	114	44	68	140	80	60	43	59
R6	1,971	1,779	192	11	421	370	51	12	33	250	214	36	14	36
R7	3,543	3,496	47	1	790	781	9	1	3	435	430	5	1	5
T1	1,795	1,448	347	19	257	208	49	19	32	144	118	26	19	21
T2	1,365	1,327	38	3	129	122	7	5	0	70	67	3	4	0
T3					826	805	21	3	4	421	412	9	2	2
T4	5,678	4,812	866	15	1,228	1,017	211	17	27	656	530	126	19	32
T5	3,424	3,161	263	8	645	571	74	11	13	371	322	49	14	18
T6	6,721	6,198	523	8	1,170	1,056	114	10	13	666	595	71	11	14
T7	6,694	6,504	190	3	671	633	38	6	0	363	341	22	6	0
L1	2,501	1,261	1,250	50	369	178	191	52	59	212	105	107	50	66
L2	2,047	1,810	237	12	473	426	47	10	19	286	262	24	8	18
L3	4,786	4,430	356	7	1,063	986	77	7	16	600	533	47	8	23
L4			510		739	656	83	11	3	419	360	59	14	4
L5	4,908	4,846	62	1	504	495	9	2	0	272	266	6	2	0
L6	6,414	6,094	320	5	1,411	1,352	64	5	4	770	729	41	5	3
L7	11,131	10,450	681	7	2,178	1,976	202	9	9	1,285	1,175	110	9	8

[a]Conflict - conflict per 1,000 vehicles

Note: All field data are for the study approach only

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Accident Analysis

An inventory was compiled of accidents at all of the sites (except the two in Fairfax County) during the three-year period from January 1, 1977, to December 31, 1979. Accidents on all approaches and up to 500 ft. (152.5m) from the intersection were included. There were 37 accidents for the sites with a radius treatment, 50 for those with a taper, and 31 for those with a full-width lane. None of the 37 accidents for the radius treatment was caused by a vehicle turning right off of the approach leg under study. A lane change to avoid a right-turning vehicle contributed to an accident at the intersection of Routes 29 & 607, which has a taper. However, the accident occurred on the approach opposite to the leg under study. Of the 31 accidents at sites with a full-width turn lane on the study approach, none involved or were caused by right-turning vehicles.

Based on the above, it is concluded that accidents are not a significant factor in determining the treatment of right turn movements. In general, failure of the vehicles on the minor approach to yield the right-of-way was a common cause of accidents at the intersections. Rear-end accidents, the type of accident most likely to result from a right-turning maneuver, may often go unreported provided that the estimated damage is under the minimum amount required for reporting.

The accident history of an intersection is conventionally the reason for recommending improvements. This is particularly true of the highway safety improvement projects.

SPSS Analysis

The SPSS analysis was composed of two parts: the Pearson correlation and multiple regression. The Pearson correlation examined the linear relationship between the parameters selected for criteria. This step screens out parameters to be used in the multiple regression. Table 6 gives the parameters and the corresponding abbreviations employed in the analysis.

Pearson Correlation

The Pearson correlation coefficient, R, is a measure of the association between two variables and an indication of the strength of the linear relationship between them. Tables 7, 8, and 9 display the Pearson correlation matrix for the radius, taper, and lane, respectively. Note that the matrices are symmetric. The cases equal the number of sites included in the subfile and for which data on a specific parameter were

Table 6

List of Parameters Used in SPSS Analysis

PHVTOT: peak hour volume — total

PHVTHRU: peak hour volume — through

PHVRTURN: peak hour volume — right turn

PHVRPCT: peak hour volume — percent of right turns

NLANES: number of lanes

PHSPEED: peak hour average speed

ACCIDENT: number of accidents in recent 3-year period

PHVCONFL: peak hour volume-conflict rate — conflicts/1,000 vehicles

available. Significance represents the level of significance resulting from a one-tailed test of significance applied to R. The objective in this part is to identify the parameters that consistently have high R values for all three subfiles. Based on the results of this test the selected parameter pairs are PHVRTURN and PHVCONFL, PHVPRCT and PHVCONFL, PHVCONFL and PHSPEED, and PHVPRCT and PHSPEED. Pearson correlation matrices were also obtained for peak period (2-hour) and average daily traffic volumes. The similarity found in matrices for peak hour and period observations was expected, since the peak hour is included in the peak period.

Multiple Regression

The multiple regression subprogram was used with the intent of identifying the best linear prediction equation and its accuracy, defining relationships between parameters, and providing explanations for the treatment of right turn movements with respect to the parameters. When two or more independent parameters are considered, the hierarchical test, where the variables are introduced into the equation in a predetermined order, is employed. This test is selected because there are causal relations between many of the parameters. Various combinations of the parameters selected in the Pearson correlation were used for the multiple regression analysis.

Table 7

Pearson Correlation Matrix - Radius

	PHVTOT	PHVTHRU	PHVRTURN	PHVPRCT	PHVCONFL	NLANES	PHSPEED	ACCIDENT
PHVTOT	1.0000 (0) P=******	.9948 (7) P= .001	-.8110 (7) P= .013	-.9246 (7) P= .001	-.6388 (7) P= .061	.4208 (7) P= .174	.8603 (7) P= .006	99.0000 (7) P=******
PHVTHRU	.9948 (7) P= .001	1.0000 (0) P=******	-.8664 (7) P= .006	-.9466 (7) P= .001	-.7037 (7) P= .039	.4620 (7) P= .148	.8756 (7) P= .005	99.0000 (7) P=******
PHVRTURN	-.8110 (7) P= .013	-.8664 (7) P= .006	1.0000 (0) P=******	.9039 (7) P= .003	.9100 (7) P= .002	-.5904 (7) P= .081	-.8111 (7) P= .013	99.0000 (7) P=******
PHVPRCT	-.9246 (7) P= .001	-.9466 (7) P= .001	.9039 (7) P= .003	1.0000 (0) P=******	.7990 (7) P= .016	-.4533 (7) P= .153	-.9073 (7) P= .002	99.0000 (7) P=******
PHVCONFL	-.6388 (7) P= .061	-.7037 (7) P= .039	.9100 (7) P= .002	.7990 (7) P= .016	1.0000 (0) P=******	-.5022 (7) P= .125	-.7192 (7) P= .034	99.0000 (7) P=******
NLANES	.4208 (7) P= .174	.4620 (7) P= .148	-.5904 (7) P= .081	-.4533 (7) P= .153	-.5022 (7) P= .125	1.0000 (0) P=******	.7085 (7) P= .037	99.0000 (7) P=******
PHSPEED	.8603 (7) P= .006	.8756 (7) P= .005	-.8111 (7) P= .013	-.9073 (7) P= .002	-.7192 (7) P= .034	.7085 (7) P= .037	1.0000 (0) P=******	99.0000 (7) P=******
ACCIDENT	99.0000 (7) P=******	99.0000 (7) P=******	99.0000 (7) P=******	99.0000 (7) P=******	99.0000 (7) P=******	99.0000 (7) P=******	99.0000 (7) P=******	1.0000 (0) P=******

(COEFFICIENT / CASES / SIGNFICANCE) (99.0000 MEANS UNCOMPUTABLE)

Table 8

Pearson Correlation Matrix - Taper

	PHVTOT	PHVTHRU	PHVRTURN	PHVPRCT	PHVCONFL	NLANES	PHSPEED	ACCIDENT
PHVTOT	1.0000	.9905	.7796	.2296	.4408	.7090	.1023	99.0000
	(0)	(7)	(7)	(7)	(7)	(7)	(7)	(7)
	P=******	P= .001	P= .019	P= .310	P= .161	P= .037	P= .414	P=******
PHVTHRU	.9905	1.0000	.6863	.1159	.3281	.6764	.0192	99.0000
	(7)	(0)	(7)	(7)	(7)	(7)	(7)	(7)
	P= .001	P=******	P= .044	P= .402	P= .236	P= .048	P= .484	P=******
PHVRTURN	.7796	.6863	1.0000	.6914	.8413	.6694	.4528	99.0000
	(7)	(7)	(0)	(7)	(7)	(7)	(7)	(7)
	P= .019	P= .044	P=******	P= .043	P= .009	P= .050	P= .154	P=******
PHVPRCT	.2296	.1159	.6914	1.0000	.9427	.3196	.5226	99.0000
	(7)	(7)	(7)	(0)	(7)	(7)	(7)	(7)
	P= .310	P= .402	P= .043	P=******	P= .001	P= .242	P= .114	P=******
PHVCONFL	.4408	.3281	.8413	.9427	1.0000	.3621	.4101	99.0000
	(7)	(7)	(7)	(7)	(0)	(7)	(7)	(7)
	P= .161	P= .236	P= .009	P= .001	P=******	P= .212	P= .180	P=******
NLANES	.7090	.6764	.6694	.3196	.3621	1.0000	.6721	99.0000
	(7)	(7)	(7)	(7)	(7)	(0)	(7)	(7)
	P= .037	P= .048	P= .050	P= .242	P= .212	P=******	P= .049	P=******
PHSPEED	.1023	.0192	.4528	.5226	.4101	.6721	1.0000	99.0000
	(7)	(7)	(7)	(7)	(7)	(7)	(0)	(7)
	P= .414	P= .484	P= .154	P= .114	P= .180	P= .049	P=******	P=******
ACCIDENT	99.0000	99.0000	99.0000	99.0000	99.0000	99.0000	99.0000	1.0000
	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(0)
	P=******	P=******	P=******	P=******	P=******	P=******	P=******	P=******

(COEFFICIENT / CASES / SIGNFICANCE)   (99.0000 MEANS UNCOMPUTABLE)

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Table 9

Pearson Correlation Matrix - Full-width Turn Lane

	PHVTOT	PHVTHRU	PHVRTURN	PHVPRCT	PHVCONFL	NLANES	PHSPEED	ACCIDENT
PHVTOT	1.0000	.9953	.4508	-.3521	-.3768	.5566	.2504	99.0000
	(0)	(7)	(7)	(7)	(7)	(7)	(7)	(7)
	P=*******	P= .001	P= .155	P= .219	P= .202	P= .097	P= .294	P=*******
PHVTHRU	.9953	1.0000	.3624	-.4386	-.4521	.5913	.3277	99.0000
	(7)	(0)	(7)	(7)	(7)	(7)	(7)	(7)
	P= .001	P=*******	P= .212	P= .162	P= .154	P= .081	P= .237	P=*******
PHVRTURN	.4508	.3624	1.0000	.6549	.5410	-.0936	-.6116	99.0000
	(7)	(7)	(0)	(7)	(7)	(7)	(7)	(7)
	P= .155	P= .212	P=*******	P= .055	P= .105	P= .421	P= .072	P=*******
PHVPRCT	-.3521	-.4386	.6549	1.0000	.9262	-.4775	-.7421	99.0000
	(7)	(7)	(7)	(0)	(7)	(7)	(7)	(7)
	P= .219	P= .162	P= .055	P=*******	P= .001	P= .139	P= .028	P=*******
PHVCONFL	-.3768	-.4521	.5410	.9262	1.0000	-.5599	-.5970	99.0000
	(7)	(7)	(7)	(7)	(0)	(7)	(7)	(7)
	P= .202	P= .154	P= .105	P= .001	P=*******	P= .096	P= .078	P=*******
NLANES	.5566	.5913	-.0936	-.4775	-.5599	1.0000	.7372	99.0000
	(7)	(7)	(7)	(7)	(7)	(0)	(7)	(7)
	P= .097	P= .081	P= .421	P= .139	P= .096	P=*******	P= .029	P=*******
PHSPEED	.2504	.3277	-.6116	-.7421	-.5970	.7372	1.0000	99.0000
	(7)	(7)	(7)	(7)	(7)	(7)	(0)	(7)
	P= .294	P= .237	P= .072	P= .028	P= .078	P= .029	P=*******	P=*******
ACCIDENT	99.0000	99.0000	99.0000	99.0000	99.0000	99.0000	99.0000	1.0000
	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(0)
	P=*******	P=*******	P=*******	P=*******	P=*******	P=*******	P=*******	P=*******

(COEFFICIENT / CASES / SIGNFICANCE)   (99.0000 MEANS UNCOMPUTABLE)

In general, it was found that equations with more than one independent variable did not explain the variance much more than did the primary independent variable. The equations relating PHVCONFL and PHVPRCT are as follows:

	Y	R^2	Significance, α
Radius	PHVCONFL = 1.88 * PHVPRCT -16	0.64	0.031
Taper	PHVCONFL = 1.66 * PHVPRCT -5	0.89	0.001
Lane	PHVCONFL = 1.3 * PHVPRCT -1	0.86	0.003

The coefficient of determination, R^2, indicates the degree of variance in the dependent variable, Y, accounted for by the regression line. Significance, α, represents the level of significance as determined by the F test. The three equations indicate fairly high accountability in variance with a significance level under 0.05. These equations have the highest R^2 values overall for all the equations derived. Figure 3 displays the equation in graph form. For PHVPRCT under 12, more conflicts are estimated for the lane than for a taper. Above 12 PHVPRCT, the difference between the taper and lane line increases due to the higher slope of the taper line. This figure indicates the relative abilities of the three treatments to accommodate increasing percentages of right turns with minimal interference to the through traffic. In general, the lane incurs the least amount of conflicts, followed by the taper, and then the radius. In terms of conflicts, tapers are influenced more by volume than are lanes.

Figure 4 illustrates the regression relations between PHVRTURN and PHVTOT. For the radius treatment, PHVRTURN decreases as PHVTOT increases. In other words, there are more right turns when the total volume is low and right turns would therefore make up a higher percentage of the total volume. Right turns represent a higher proportion of the total volume for tapers than for lanes. Note that the equation for the lane treatment has a low R^2 value; therefore, the previous statement is made with caution.

Additional multiple regression equations were derived for PHVCONFL and PHVPRCT for right turn treatments on 2-lane and 4-lane roadways (see Figure 5). For 2-lane roadways, the lane has more conflicts than the taper at all points, although they have equal slopes. The slope of the taper is more than two times the slope of the lane for 4-lane roads. Note that the sample sizes, N, for these equations are small.

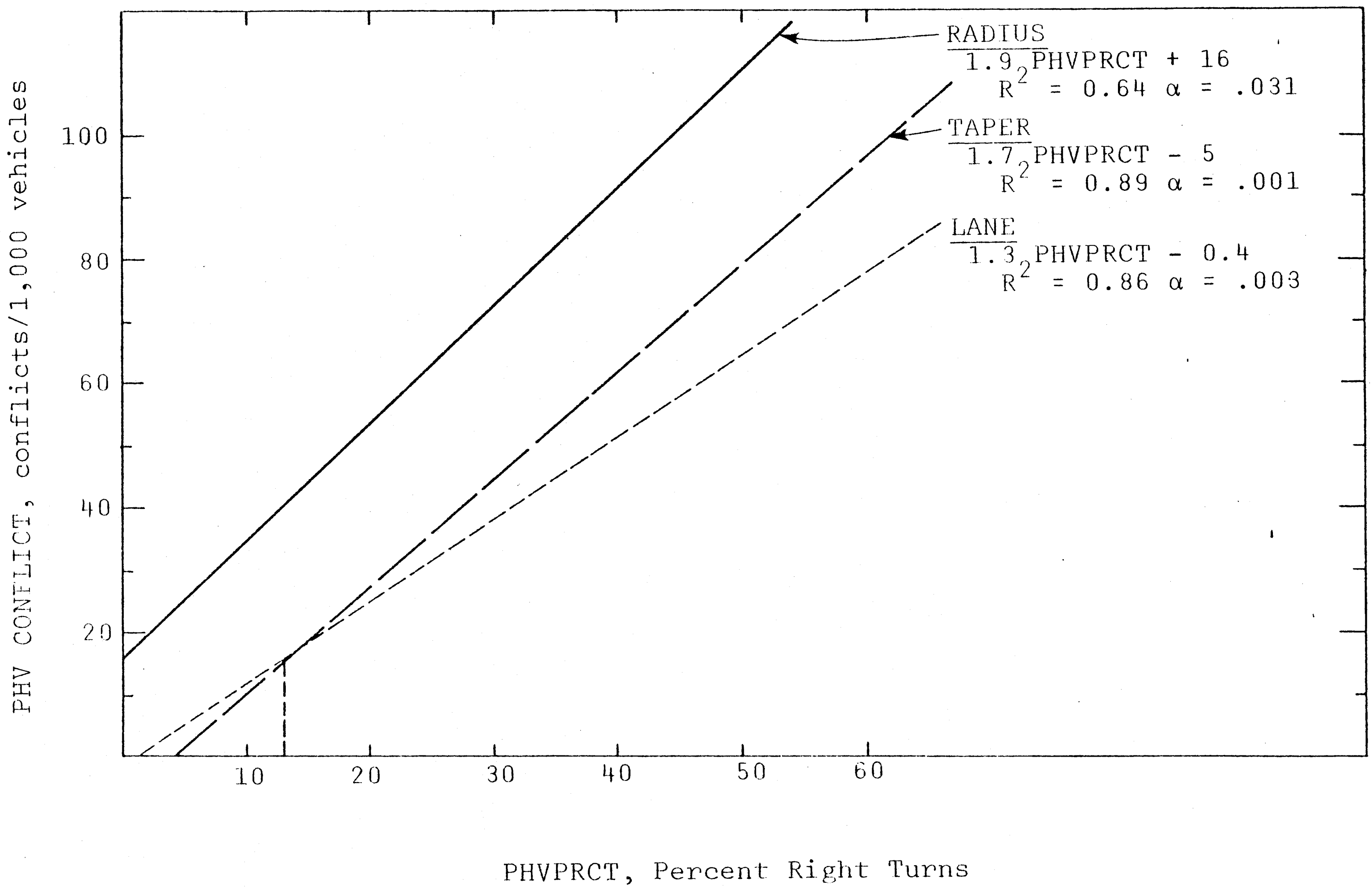

Figure 3. Peak hour volume conflicts (PHVCONFL) versus peak hour volume percent of right turns (PHVPRCT).

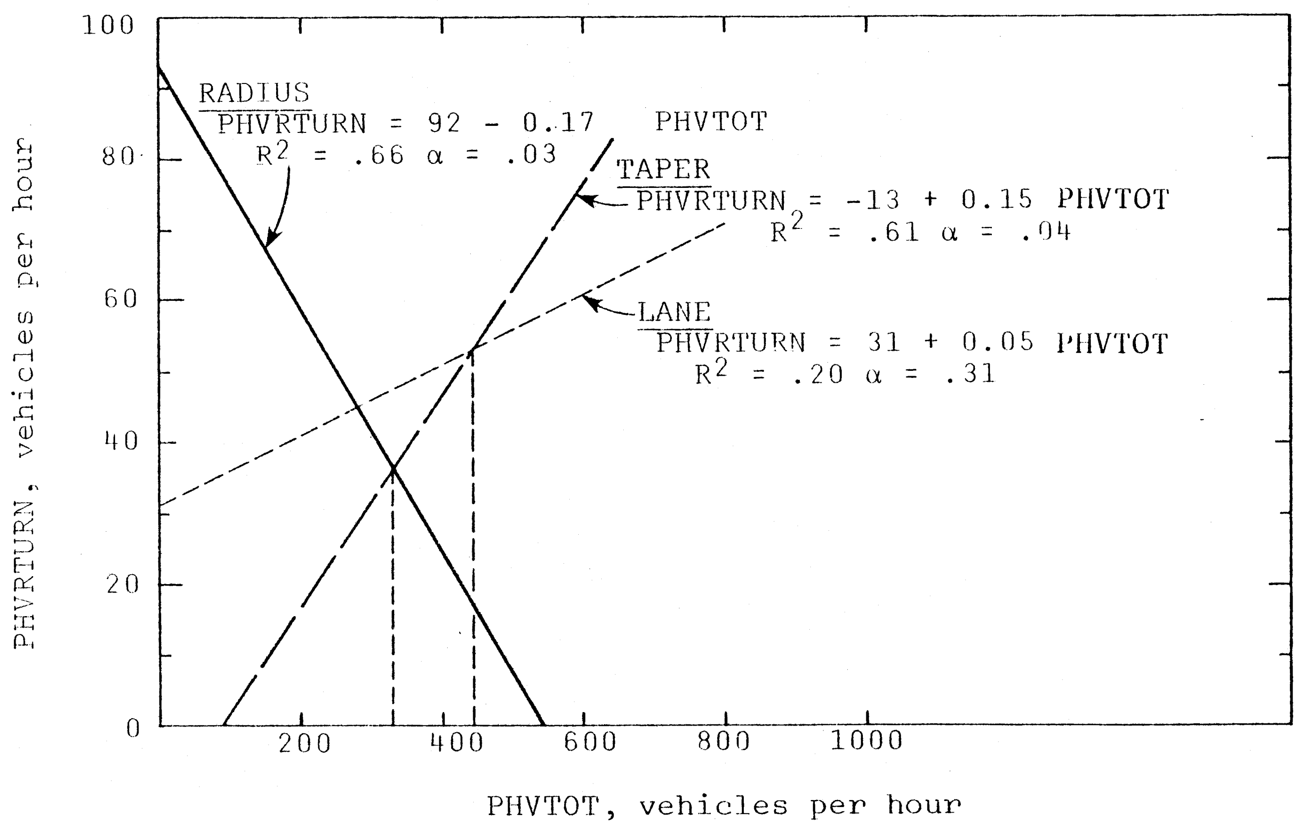

Figure 4. Peak hour volume right turns (PHVRTURN) versus peak hour volume total (PHVTOT).

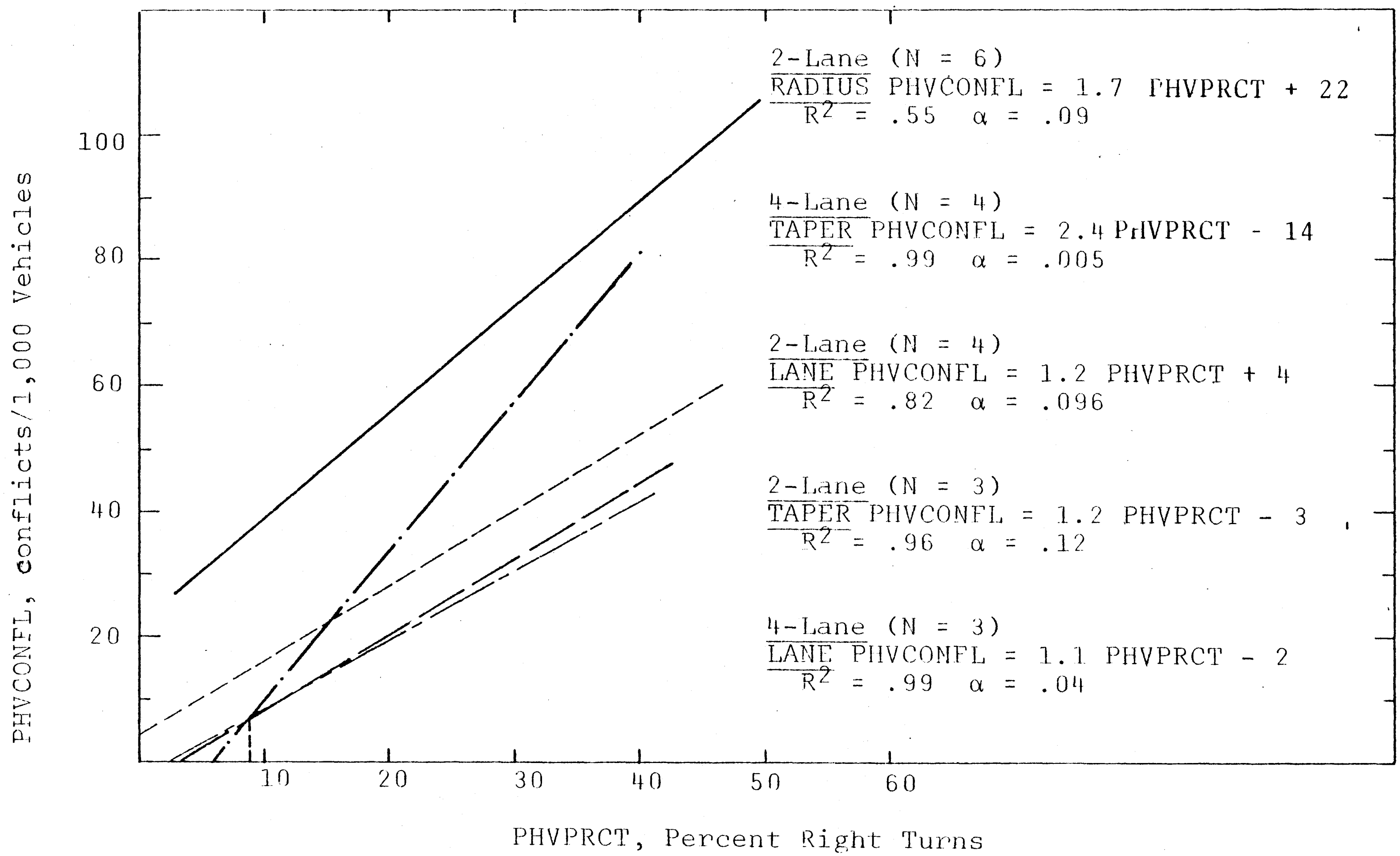

Figure 5. Peak hour volume conflicts versus peak hour volume percent of right turns for 2- and 4-lane roads.

Comparison of Field Data with Other States' Standards

The standards of the Idaho and Iowa departments of transportation were of particular interest (see Appendix A). For this reason, the data for the study sites were applied to these standards, which were limited to 2-lane roadways.

Idaho

A vehicle conflict table (Figure A-1) provides the threshold conditions that warrant a right turn lane (or bay). Of the thirteen 2-lane sites studied, only one, T2, would warrant a radius under this guideline. All other sites exceed the right turn lane conditions and, therefore, warrant special consideration. Under such a guideline most intersections in the Commonwealth of Virginia would require special consideration.

Iowa

The Iowa Department of Transportation employs a thorough procedure that includes the two steps discussed below. The first step (Figure A-2) is a screening process to determine if the warrants may be used, the next step employs the rural intersection exposure warrants (Figure A-3). Only intersection T2 falls below the minor right turn warrant curve. Site R3 requires a minor right turn warrant. All other 2-lane sites with average daily traffic data available require a major right turn warrant. Figure A-4 determines the design dimensions to be used.

Conclusion

The two previously described standards provide interesting techniques for treating right turns. The large difference between the study sites and intersections for which these guidelines were developed probably lies in the inherent differences in the nature of traffic conditions in Virginia relative to those in the western part of the United States.

The standards for Idaho and Iowa consider the volumes of both the turning traffic and the combined turning and through traffic. This is an ideal way for representing the standards, however, these relations were shown to have low correlations (PHVRTURN and PHVTOT, PHVRTURN and PHVTHRU see Tables 7-9). Therefore, another method, a synthesis, discussed below, was developed to obtain a relationship between the total volume and right turning volume.

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GUIDELINES FOR TREATING RIGHT TURN MOVEMENTS

Although significant relations were derived from the field work, no clear-cut criteria for the development of guidelines for the treatment of right turn movements were found. Therefore, guidelines were developed by a synthesis of relationships resulting among the field data, standards employed by other states. and judgement. The field work provided a framework for the performance of existing treatments, additional input was obtained from the survey of state departments of transportation, and judgement was employed to integrate the information from those sources and to address inconsistent or incomplete information. The guidelines developed are separated according to the number of lanes on the major roadway. Only the volumes along the study approach are considered.

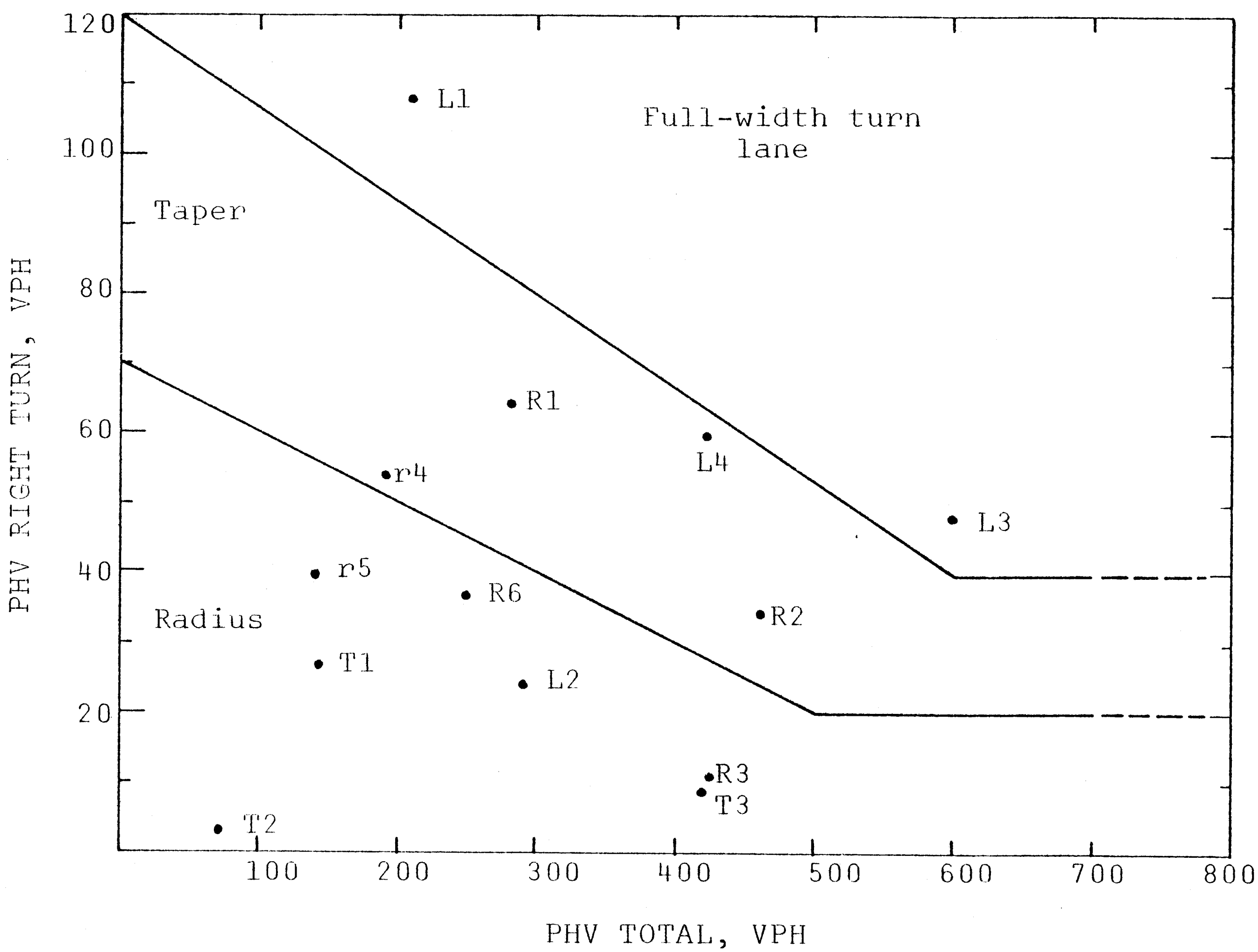
The procedure explained on page B-3 may be used to obtain the data needed for application of the guidelines.

Two-Lane Roadway

The guidelines for 2-lane roadways and the position of the study sites relative to the guidelines are shown in Figure 6. The predominantly used treatment for 2-lane roadways is the radius. Many 2-lane roads carry local traffic that often is traveling at speeds under 55 mph (89.1 km/hr). Arterial roadways tend to carry higher volumes of traffic traveling at higher speeds; local traffic tends to include a higher number and percentage of right-turning vehicles. Figure 6 also shows the location of the 2-lane roadway study sites. The following adjustment is made for posted speeds at or under 45 mph (72 km/hr):

Adjusted Number of Right Turns = Number of Right Turns
-20 for number of right turns > 40 and total volume < 300

Two radius sites, Routes 601 and 676 (r4) and Routes 250 and 616 (R1), are in the taper range. Route 601 turns right at the intersection with Route 676. Neither site has the right-of-way available for a taper treatment. All three taper treatment sites fall within the range of the radius treatment. The site at Routes 33 and 20 (T1) is special in that both routes share the study approach and Route 20 makes a right turn. A taper is suggested for a primary route with a right turn, unless the volume conditions require a full-width turn lane or the percentage of right-turning vehicles make up less than 10% of the total traffic. At the intersection of Routes 276 and 659 (T2), tapers were installed as part of a highway safety improvement project because of its history of accidents not because of traffic volumes. The taper at Route 645 and Shiplett Blvd (T3) is in Northern Virginia, where many unique right turn treatment designs were observed. Longer and wider than normal tapers and lanes are employed there in anticipation of road widening. The full-width turn lane at the intersection of Routes 645 and 5910 (L4), is attributable to this incremental planning.



Legend

PHV - peak hour volume
Ri, Ti, Li, - site numbers
ri - site numbers
after adjusting for
posted speeds of or under
45 mph (72 km/hr),
total volume under
300 VPH and right
turn volume above
40 VPH.

Figure 6. Guidelines for right turn treatment: 2-lane roads.

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This site is in the taper range. The intersection of Routes 250 and 690 (L2), with a full-width lane, falls into the radius range. The use of a full-width lane may have been influenced by the presence of a winding, upgrade roadway that must be negotiated after the turn. The remaining two sites with full-width turn lanes are in the turn lane range.

Four-lane Roadway

The guidelines for 4-lane roadways are shown in Figure 7. These roadways tend to have a taper or turn lane to facilitate turning movements, and many of them are divided highways with a speed limit of 55 mph (89.1 km/hr). Figure 7 also shows the position of the study sites.

There was only one site with a radius turn (at Routes 33 and 996-R7) and it is in the radius range. One taper-treated site, at Routes 29 and 607 (T7), with a 75 ft.(22.8m) taper was in the radius range. The site at Routes 33 and 276 (T4) is in the range for the full-width turn lane. This taper was wider (14 ft. [4.27m]) and longer (170 ft. [51.85m]) than most tapers and no problems were noted at this intersection. Two of the three full-width turn lanes, at Routes 29 and 663 (L5) and Routes 33 and 704 (L6), were installed as highway safety improvement projects. They fall in the radius and taper ranges, respectively.

The guidelines are also given in Appendix B.

Limitations within the Guidelines

These guidelines were developed based primarily for currently used right turn treatments. Although the study sites represented a broad range of traffic conditions, it is difficult to identify typical intersections for the different treatments for right turns. The ranges of peak hour traffic volumes are from 70 to 600 vehicles for 2-lane roads and from 272 to 1,285 vehicles for 4-lane roads. Consideration of volumes outside of these ranges is based on judgement and extrapolation. Therefore, guidelines should be employed for such volumes with caution. The determination of the maximum number of right turns (and conflicts) for a given volume using a particular treatment is primarily a judgmental decision. The points of intersection of the regression lines in Figures 3, 4, and 5 provided direction in locating the boundaries of the treatments.

Specific design elements were not reviewed; however, it is noted that the lane lengths for the study sites are shorter than AASHTO recommended lengths (Figure 8). Nevertheless,

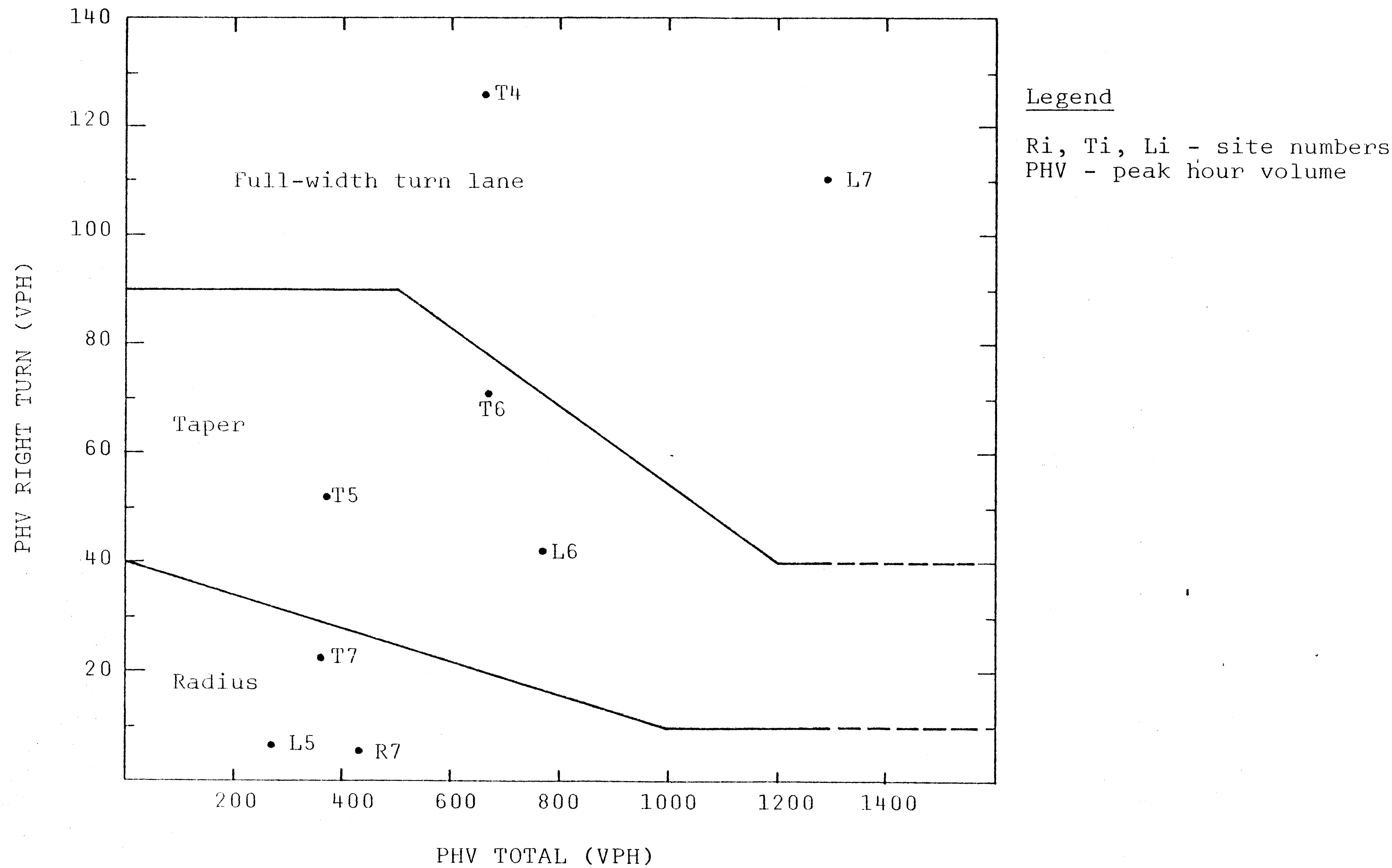

Figure 7. Guidelines for right turn treatments: 4-lane highways.

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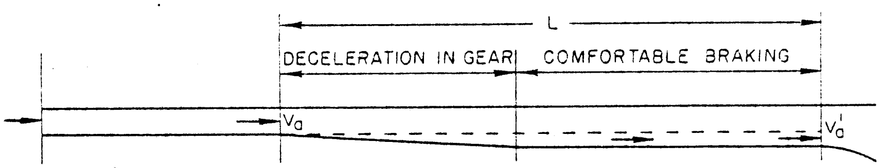
HIGHWAY DESIGN SPEED, MPH (V)	AVERAGE RUNNING SPEED MPH (V_a)	L = LENGTH OF DECELERATION LANE - FEET FOR DESIGN SPEED OF EXIT CURVE - MPH (V')								
		STOP CONDITION	15	20	25	30	35	40	45	50
		FOR AVERAGE RUNNING SPEED ON EXIT CURVE - MPH (V_a')								
		0	14	18	22	26	30	36	40	44
30	28	235	185	160	140	---	---	--	---	---
40	36	315	295	265	235	185	155	---	---	---
50	44	435	405	385	355	315	285	225	175	---
60	52	530	500	490	460	430	410	340	300	240
65	55	570	540	530	490	480	430	380	330	280
70	58	615	590	570	550	510	490	430	390	340
75	61	660	630	610	590	560	530	470	440	390
80	64	700	680	660	640	610	580	530	490	450



V — Design speed of highway

V_a — Average running speed on highway

V' — Design speed of exit curve

V_a' — Average running speed on exit curve

1 mph = 1.6 km/hr
1 ft = .305 m

Figure 8. Derivation of lengths for deceleration lanes.

Source: Reference 5 - AASHTO Blue Book

the shorter lanes are operationally effective. In general, the lane design elements are too short to meet the "Minimum Standards of Entrances to State Highways" (see Table 10).(7)

Other factors of concern that are not addressed in the criteria are sight distance, grade, delay, availability of right-of-way, and angle of turn. The influence of these factors was not measurable from the field data.

OTHER CONSIDERATIONS

Three related concerns — cost of constructing the right turn treatments, pavement markings, and superelevation - are discussed below.

Because of the wide range of conditions under which right turn treatments are employed, a range of cost estimates is provided. The presence of and condition of a shoulder are primary factors. A range of \$10 - \$40/lin. ft. of 24-ft. (\$0.04 - 0.16/m^2) pavement was obtained from the Materials Division of the Virginia Department of Highways and Transportation.(8) This range includes costs for light secondary roads to 4-lane primary roads and is for the finished pavement. In developing the cost estimates, a cost of \$30/per lin.ft. of 24-ft. (\$0.12/m^2) pavement was assumed.

In the cost comparison, the radius treatment was taken as the base condition. On this assumption, the installation of a 150 ft. (45.8m) taper 12 ft. (3.7m) wide was esimated to cost \$1,125. For a lane with a 100-ft. (30.5m) taper, conversion to a 100-ft. (30.5m) full-width turn lane 12 ft. (3.7m) wide was estimated to cost \$2,250. Note that for the assumed dimensions, the cost of the full-width turn lane is double that of the taper. The benefits are difficult to estimate because the reduction in accidents, the conventional measure of benefits, is not significant. The reduction in traffic conflicts due to right-turning vehicles is not quantifiable in terms of dollars.

Several of the study sites did not have typical pavement markings. The uses of the dotted and solid lines are explained and illustrated in Figure 9.(9)

Superelevation may be employed to facilitate right-turning movements at slightly higher speeds. However, the use of superelevation may create drainage problems. Although superelevation is a concern, further consideration is beyond the scope of this research.

Table 10. Minimum Dimensions for Deceleration Lanes

Speed Limit	Type of Lane or Taper	Dimension
45 mph or higher	Right turn	200 ft.
Less than 45 mph	Right turn	100 ft.
45 mph or higher	Taper	200 ft.
Less than 45 mph	Taper	100 ft.

1 ft. = .305 m
1 mph = 1.6 km/hr

Source: Reference 7. "Minimum Standards of Entrances to State Highways", Virginia Department of Highways and Transportation.

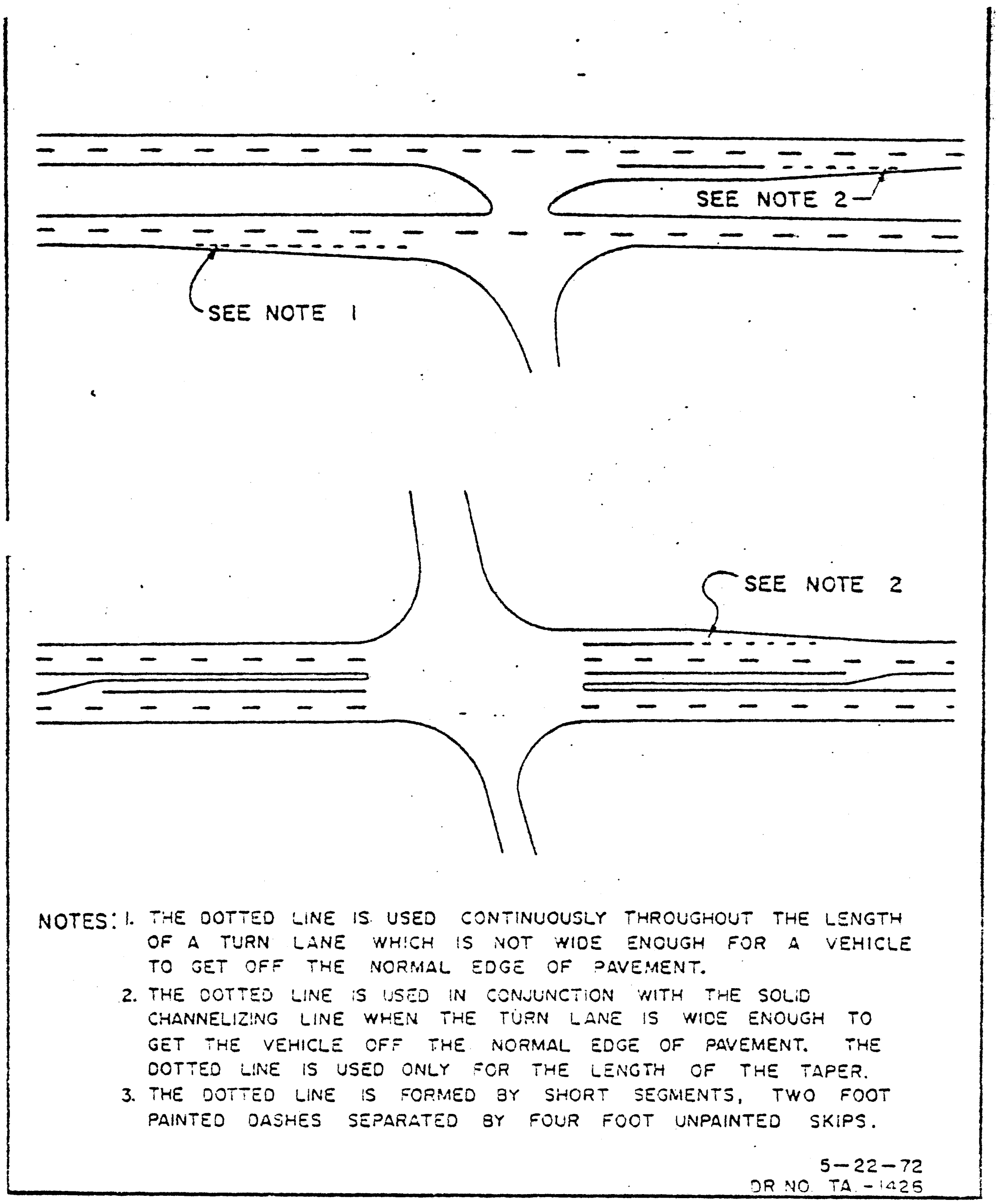


Figure 9. Typical pavement marking of turn lanes.
Source: Reference 9

CONCLUSIONS

Guidelines for the treatment of right turn movements at nonsignalized intersections in rural areas were developed in this study. Both 2-lane and 4-lane rural roads were considered. Although the original intent was to eliminate judgement in developing criteria for the guidelines, it was necessary to employ judgement where field data were lacking. Nevertheless, the synthesis approach employed placed emphasis on the field data and analysis.

The guidelines are to be employed as an aid in the selection of right turn treatments. It is anticipated that there will be cases where an intersection will deserve specialized attention because of its unique conditions. It is suggested that for these cases conventional methods that reflect the special concerns be used in lieu of the guidelines. It is important that this sort of flexibility be a part of the guidelines.

RECOMMENDATION

It is recommended that the guidelines developed in this study (see Appendix B) be adopted for use by the Virginia Department of Highways and Transportation as an aid in the selection of treatments for right turn movements on rural roads.

ACKNOWLEDGEMENTS

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REFERENCES

1. Location and Design Division, Virginia Department of Highways and Transportation, Road Designs and Standards, 1979

2. Glauz, William D., and Migletz, Donald J., "Application of Traffic Conflict Analysis at Intersections", NCHRP Report #219, Transportation Research Board, Washington, D.C., February 1980

3. Box, Paul C. and Oppenlander, Joseph C., Manual of Traffic Engineering Studies, 4th edition, Institute of Transportation Engineers, Arlington, Virginia, 1976

4. Nie, Norman H. et al. Statistical Package for the Social Sciences, 2nd,ed. McGraw-Hill, New York, New York, 1975

5. American Association of State Highway Officials, A Policy on Geometric Design of Rural Highways-1965, Washington, D.C., 1965

6. Transportation Studies Center, University of Maryland, "Critical Lane Analysis Workshop Notebook", College Park, Maryland, June 1979

7. Traffic and Safety Division, Virginia Department of Highways and Transportation "Minimum Standards of Entrances to State Highways", 1979

8 J. Bassett, Materials Division of Virginia Department of Highways and Transportation, telephone conversation, December 1980

9 Traffic and Safety Division, Virginia Department of Highways and Transportation "Memorandum — Typical Pavement Marking on Turn Lanes", No. TS-89, 1972

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APPENDIX A

CRITERIA FROM IDAHO AND IOWA

INTERSECTIONS (14-400)

CHANNELIZATION (14-420)

14-423.1 Right Turn Bays

Traffic conflicts may occur when cars on a two-lane highway slow down to turn right onto a minor road. If these conflicts could happen often enough, a right turn bay should be provided as shown in Figure 14-423.0. Table 14-423.1 relates the right-turning volume to the two-lane highway volume. For two-lane highway volumes less than those shown in the table, the right turn bay is not needed. For two-lane highway volumes greater than those shown in the table, a special design may be necessary.

TABLE 14-423.1
Vehicle Conflict Table

Rt. Turn DHV	2-Lane Highway DHV	
	Min.	Max.
5	200	400
10	175	350
15	150	300
20	125	250
25	100	200
Over 25	Special	Design

Taper Length

Design Speed	T
30	50
40	90
50	145
60	215
70	300

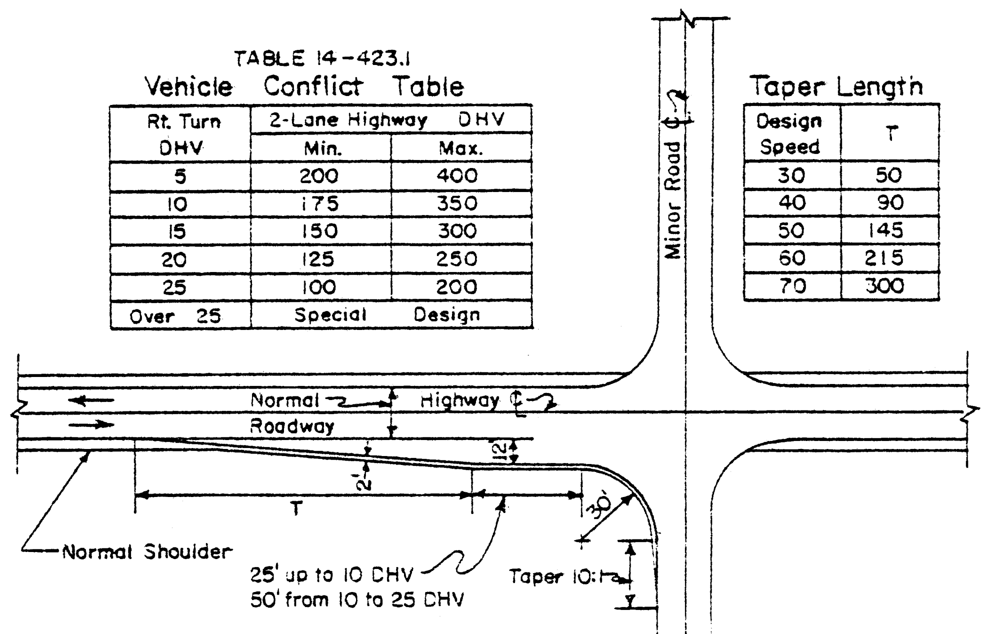


Figure A-1. Idaho DOT right turn treatment criteria.

1 ft. = 0.305 m
1 mph = 1.6 km/hr.

Two Lane

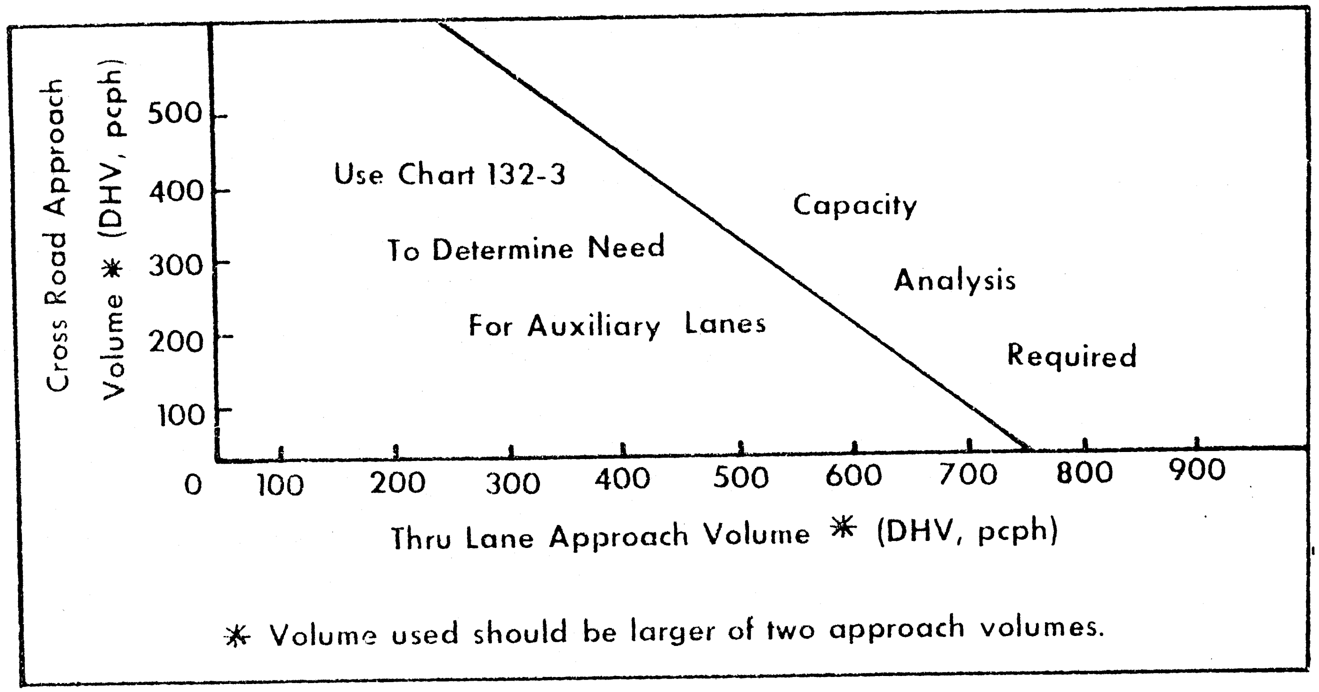


Chart 132-2

Figure A-2. Iowa DOT's first step in right turn warrants.

Iowa Two Lane

Sheet 5 of 15

01-132

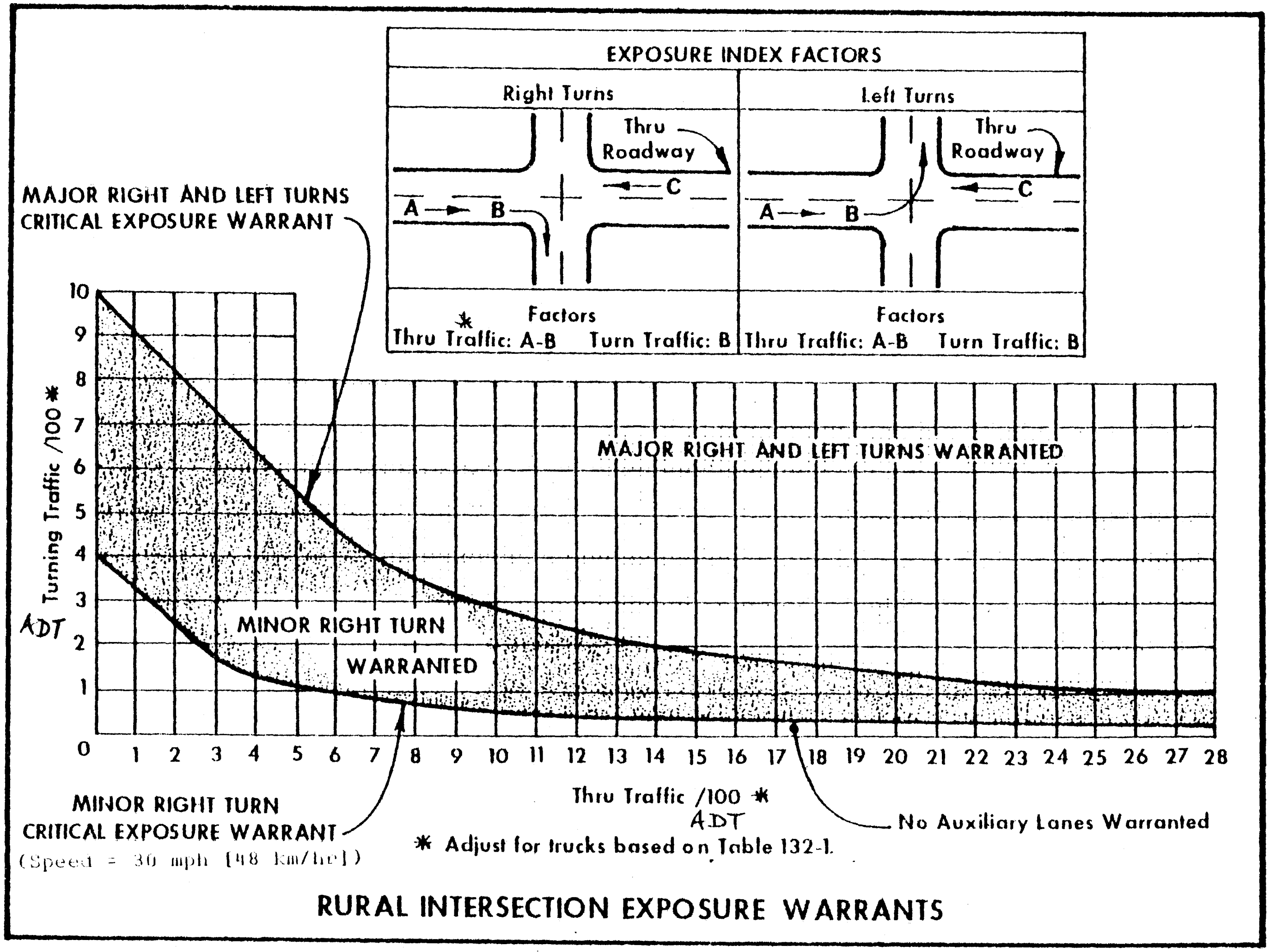


Chart 132-3

Revised 12-28-79

Exposure Index =
Thru Traffic x Turn Traffic

Figure A-3. Iowa DOT's rural intersection exposure warrants.

MINIMUM LENGTHS FOR RIGHT TURN DECELERATION LANES

Rural Highway Speed MPH(V)	Taper Length T	L=Deceleration Length-feet For Speed of Exit Curve-MPH(V)			
		15	20	25	30
30 *	120	185	160	140	—
40	180	295	265	235	185
50	180	405	385	355	315
60	180	500	490	460	430
70	180	590	570	550	510
Min. Radius of Curve (Feet)		50	90	150	230

Use Taper Type (shaded) | Use Parallel Type (blank) | Option-Parallel or Taper (grid)

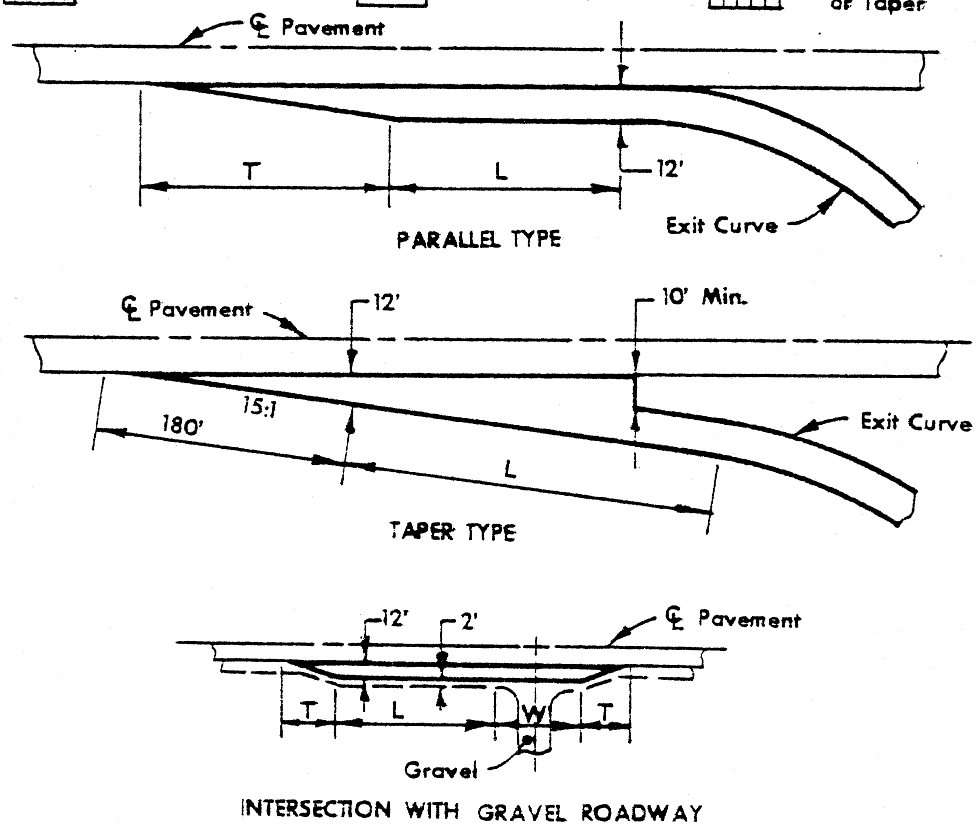


Table 132-2

Revised 12-28-79

*Minor right turn warrant has a speed of 30 mph

1 ft. = 0.305 m
1 mph = 1.62 KPH

Figure A-4. Iowa DOT's design dimension for right turn lanes.

APPENDIX B

GUIDELINES FOR THE TREATMENT OF RIGHT TURN MOVEMENTS ON RURAL ROADS

These guidelines are to be used as an aid in selecting the appropriate treatment for right turn movements on rural roads. Designs for right turn treatments are available in the Virginia Department of Highways and Transportation's Road Design and Standards, and "Minimum Standards of Entrances to State Highways".

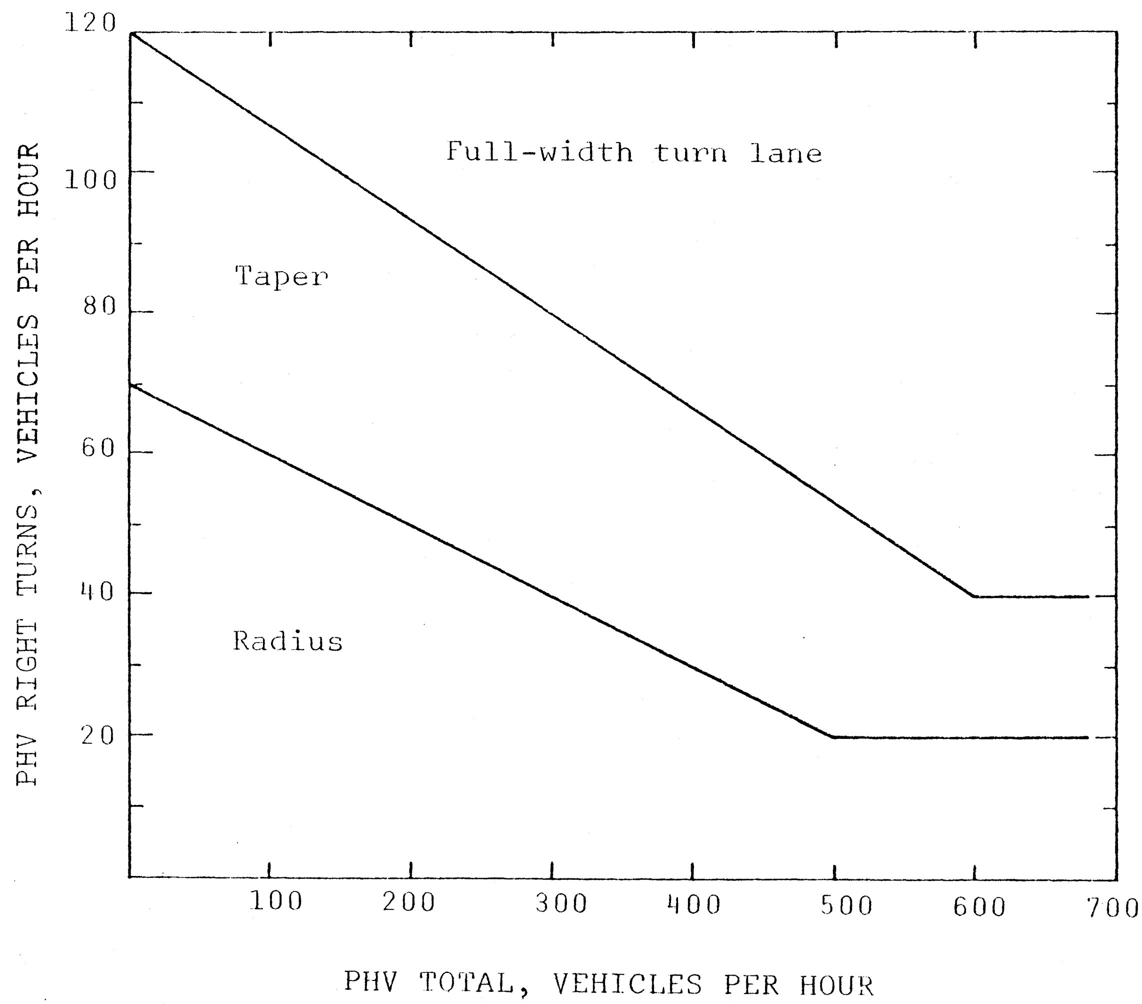
1. Guidelines are differentiated on the basis of the number of lanes on the major roadway. Refer to Figure B-1 for 2-lane roadways and Figure B-2 for 4-lane roadways. The minor roadway is a 2-lane road. Discussion on both figures is provided below. All volumes refer to the volumes on the approach under consideration for right turn treatments.

2. Figure B-1. Guidelines for 2-lane roadways. The predominant treatment for 2-lane roadways is the radius. Arterial roadways tend to carry higher volumes of traffic travelling at higher speeds as compared to local roadways. The traffic on local roadways tends to include a higher number and percentage of right-turning vehicles than that on arterials. An adjustment is needed to permit local roadways to handle more right turns (at lower speeds) compared to arterial roads. The following adjustment is made for posted speeds at or under 45 mph (72 km/hr):

   Adjusted Number of Right Turns = Number of Right Turns -20
   for number right turns > 40 and total volume < 300

   For example, let total volume = 200vph, right turn volume = 70vph and posted speed = 40 mph (64.4 km/hr). Then adjusted number of right turns = r = 70 - 20 = 50. Therefore, entering Figure B-1 with a total volume = 200 vph and r = 50vph, a radius is recommended as the right turn treatment.

   A taper is recommended for a primary route with a right turn, unless the volume conditions require a full-width turn lane or the percentage of right-turning vehicles make up less than 10% of the total traffic, in which case a radius is suggested.



<u>Legend</u>

PHV - Peak Hour Volume
(also Design Hourly
Volume equivalent)

SPEED ADJUSTMENT

For posted speeds at or under 45 mph (72 km/hr), PHV right turns > 40, and PHV Total < 300,

Adjusted PHV Right Turns = PHV Right Turns - 20

Figure B-1. Guidelines for right turn treatment: 2-lane highway.

3. Figure B-2. Guidelines for 4-lane roadways. Four-lane roadways tend to have a taper or full-width turn lane to facilitate right turn movements. Many of these roads are divided highways with a speed limit of 55 mph (88 km/hr).

4. Other factors that influence the selection of a treatment for right turn movements are sight distance, availability of right-of-way, grade, and angle of turn. Although these factors are not incorporated in the guidelines, they should be given consideration. The guidelines should be used unless the engineer determines that special treatment is necessary due to other factors.

5. Data collection procedures. In order to employ these guidelines, peak hour volume data must be collected. A two-stage procedure with a 48-hour mechanical count and 2 peak hour manual counts is recommended.

   a) 48-hour mechanical count. A 48-hour count with 15-minute recording intervals is made on the total approach volume and right turn volume. Traffic counters and road tubes are located as shown in Figure B-3. Whenever possible the traffic counters should be located near a signpost or guardrail for anchoring. Otherwise, a 3-foot section of a metal post may be used to secure the counters. With the exception of the total volume road tube on 4-lane roads, all tubes are positioned so that only tires on the right side of the vehicle traverse them. In this way, the potential for double counting is eliminated. Two technicians are needed for the installation of traffic counters; one installs the counter while the other controls traffic. It is recommended that traffic counters be installed during the anticipated off-peak period. A computer program is available to determine the peak hour based on total and right turn volumes. The use of print-punch traffic recorders facilitates the computer analysis. In most cases, the peak hour is the same for total and right turn volumes. If the peak hours are different, use the second highest peak hour or the right turn volume peak.

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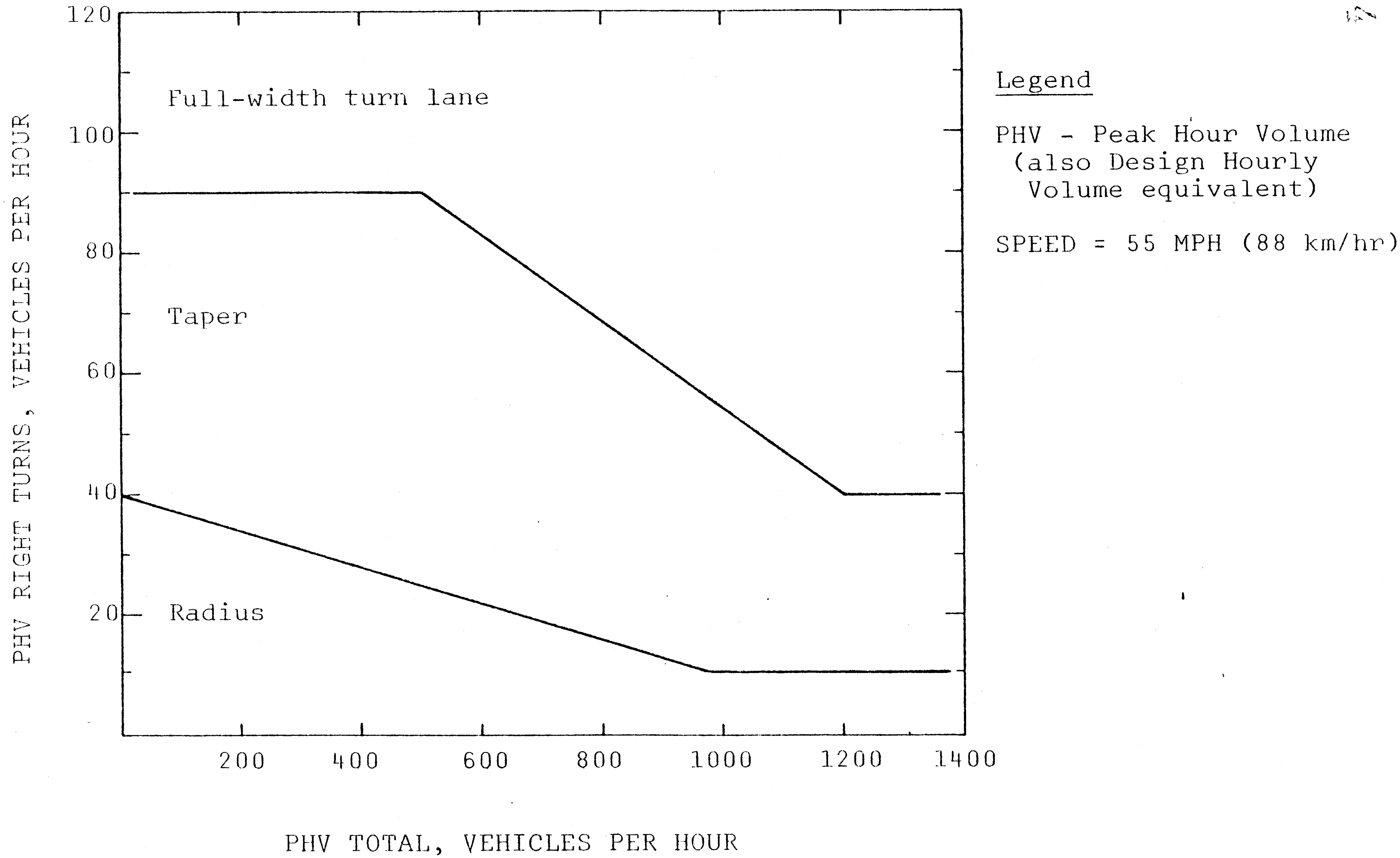

Figure B-2. Guidelines for right turn treatments: 4-lane highway.

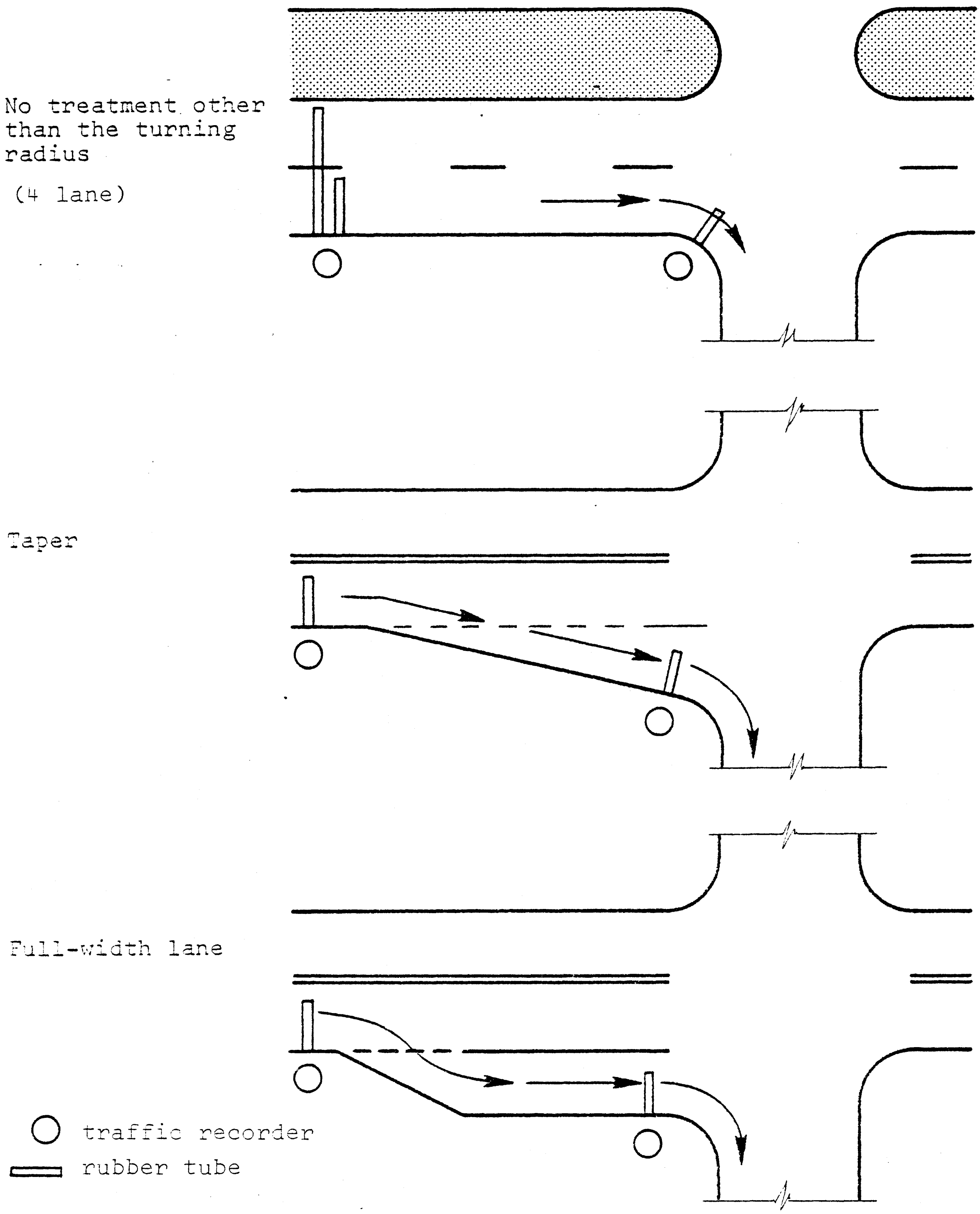

Figure B-3. Placement of traffic counters for the treatment of right-turning movements.

b) Peak hour manual count. Peak hour manual counts are made for two, preferably consecutive, days. Four days of the week, Monday (except the morning) through Thursday, are recommended for counting. The use of 15-minute recording intervals and a mechanical counting board are recommended. Only one technician is required for the manual counts. Although only one approach requires data collection, data may be collected for all directional movements on all approaches. The technician should be positioned so as to minimize distractions to the motorist. If desired, observations can be made from a Department truck parked on the shoulder of the road.