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RIGHT TURN ON RED

A Report To The Governor and General Assembly of Virginia

by

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

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IN REPLY PLEASE REFER TO

REPORT OF THE VIRGINIA DEPARTMENT OF HIGHWAYS AND TRANSPORTATION AND THE HIGHWAY SAFETY DIVISION OF VIRGINIA TO THE GOVERNOR AND GENERAL ASSEMBLY IN RESPONSE TO SENATE JOINT RESOLUTION #155

October 1, 1975

To:

The Honorable Mills E. Godwin, Jr., Governor of Virginia,
Secretary of Transportation and Public Safety,
and
Members of the General Assembly

On behalf of the Department of Highways and Transportation and the Highway Safety Division, we are pleased to transmit herewith, in accordance with Senate Joint Resolution #155, the results of our joint study of right turn on red at traffic signals. At our request, the study was conducted by the staff members of the Virginia Highway & Transportation Research Council, assisted by an Advisory Committee of the Virginia Association of Traffic Engineers. Additionally, comments on the subject study were obtained from a number of citizens.

The study concludes that Virginia should join her border states of North Carolina, West Virginia and Kentucky by implementing the general permissive rule for right turn on red. This rule allows a right turn on red unless a sign is posted to prohibit it. Suggested criteria for the designation of "no right turn on red" intersections are noted on page xvii of this report.

We can discern no significant hazard to motorists or pedestrians that will result from implementation of the general permissive rule. No significant increase in traffic crashes has been noted following the adoption of right turn on red in any state, including Virginia. Some accidents involving right turn on red vehicles can be anticipated, but these are likely to be infrequent and of minor severity. Moreover, the benefits to be received by the Commonwealth, in the form of energy savings, are expected to far outweigh the costs.

Respectfully submitted,

Douglas B. Fugate, Commissioner
Virginia Department of Highways and Transportation

John T. Hanna, Director
Highway Safety Division of Virginia

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ABSTRACT

The Commonwealth of Virginia implemented the sign permissive or "eastern" rule permitting right turns on red traffic signals where designated by sign in 1972. In 1975, as a result of the growing national trend toward employing the general permissive or "western" rule (right turn on red permitted except where prohibited by sign) and in the interests of motor fuel economy, the Virginia General Assembly directed the Department of Highways and Transportation and the Highway Safety Division to study right turn on red (RTOR) to determine whether Virginia's sign permissive law "should be retained, rescinded, or amended."

The scope of this study included a survey of the literature, a survey questionnaire of Virginia traffic engineers, a telephone survey of traffic engineers in other states, field studies of vehicle delay times and traffic conflicts at 20 selected intersections in Virginia and North Carolina, and an analysis of traffic crashes at 20 intersections in Virginia before and after RTOR was permitted.

The results of this study reveal that right turn on red signals can enable motorists to effect substantial savings in time and concomitant savings in gasoline by reducing the vehicle idling time at intersections. The average saving for right turning delayed vehicles was found to be 14 seconds. Since the general permissive rule for RTOR allows the maneuver at a greater percentage of approach legs than does the sign permissive rule, time and energy savings have been estimated to be greater statewide under the general permissive rule. Estimated savings in gasoline under the general permissive rule would be over three million gallons annually.

No significant increase in traffic crashes was found in Virginia and no increase would be expected with the general permissive rule, as none has been experienced in any other state with either the general permissive or the sign permissive rule. Moreover, study data reveal that traffic conflicts and thereby crash potential are actually reduced under RTOR, and that crashes which do occur because of RTOR are generally not severe.

When the total impact of RTOR was considered, the evidence was found to support the recommendation that Virginia implement the general permissive rule for right turn on red.

SUMMARY OF FINDINGS

(1) In Virginia, RTOR is permitted at 8.6% of the signalized intersection approaches. This figure is comparable to the level of implementation in other states with the sign permissive rule, but is much lower than the 80% to 90% implementation level found in states with the general permissive rule.

(2) Results of the questionnaire sent to Virginia traffic engineers revealed that 64% of the engineers favored retaining the sign permissive law while only 9% preferred the general permissive rule. These figures are similar to those found in other states before general permissive legislation was enacted.

(3) As of July 1975, the majority of states (27) were using the general permissive rule. This number included West Virginia, North Carolina, and Kentucky, three of the states bordering Virginia.

(4) In a study of 15 intersection approaches in Virginia, RTOR was found to save an average of 14 seconds for each delayed right turning vehicle.

(5) Contrary to the findings of other RTOR studies, fully- and semi-traffic actuated signals were found to yield greater time savings with RTOR than fixed time signals.

(6) Significant time savings were found at all types of RTOR approaches, including exclusive right turn lanes, combined through and right lanes, and single lane approaches.

(7) Only 2% of RTOR motorists did not come to a full stop during the study of the general permissive rule in North Carolina, while only 3% did not stop at locations studied in Virginia.

(8) There was a decrease in accident potential after RTOR signing as measured by traffic conflicts; however, the change was not statistically significant.

(9) A comparison of crash rates at 20 Virginia RTOR intersections revealed no statistically significant difference in either the frequency or severity of accidents after RTOR signing.

(10) In the year after the 20 Virginia intersections were signed to permit RTOR, ten accidents representing 3% of all crashes directly involved an RTOR vehicle, and another five crashes were possibly related to RTOR.

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CONCLUSIONS

Permitting motorists to turn right on red was found to save substantial time and energy without compromising highway safety. Because of the low 8.6% level of implementation of the current sign permissive rule, drivers in the Commonwealth are not realizing the full benefits of RTOR.

Implementation of the general permissive rule could save over three million gallons of fuel annually. Net benefits measured over five years, including time and energy savings for two alternative methods of implementation, are compared below:

Alternative	Net Benefit
Retain sign permissive RTOR and increase implementation to 50%	$25,811,800
Adopt general permissive RTOR (estimated implementation 80%)	$44,977,850

Comparison of the benefits of the two alternatives leads to the conclusion that the general permissive rule should be adopted in Virginia.

(e) The intersection approach has a history of RTOR accidents or a level of pedestrian and traffic conflicts incompatible with RTOR maneuvers.

3. On approaches where RTOR is prohibited, a sign corresponding with the requirements of the Manual on Uniform Traffic Control Devices should be used.

RECOMMENDATIONS

1. Legislation should be adopted in Virginia to permit right turns on red after stop at all traffic signals, except where prohibited by a sign. This change will require amendment of Section 46.1-184(a) of the Code of Virginia. A suggested revision of the amendment is included as Appendix A.

2. Guidelines for the prohibition of RTOR at specific approaches should be established. It is suggested that the guidelines include the provisions listed below.

   A. RTOR Should Be Prohibited Where:

      The sight distances at the cross streets onto which RTOR maneuvers are to be made are less than the following minimuns.

Speed Limit on Crossing Street (mph)	Minimum Sight Distance (feet)
25	275
30	325
35	400
40	475
45	550
50	600
55	650

Sight distance determinations apply to both horizontal and vertical alignments, and are to be based on a height of driver's eye of 3'9" and a height of object of 2'0" measured each way.

   B. RTOR May Be Prohibited Where:

      The result of a traffic and engineering study reveals that RTOR would be hazardous. Factors to be considered include:

      (a) Intersection geometrics which restrict the right turn maneuver or the driver's visibility of conflicting traffic.

      (b) Presence of an "all pedestrian" phase or a large steady volume of pedestrians crossing at the intersection.

      (c) Proximity of the intersection to school crossings where large numbers of children would be expected.

      (d) Dual (double) left turn lanes or other unusual movements that oppose the right turn maneuvers and would be unexpected by a RTOR driver.

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INTRODUCTION

The right turn on red traffic signal maneuver (RTOR) has now become a widely accepted feature of American driving patterns. Since 1937, when California became the first state to utilize RTOR, 46 states have adopted the practice in one form or another. Apparently, most of the states have decided that the advantages of right turn on red — driver convenience and energy conservation — outweigh the possible safety disadvantages. So widespread has RTOR become that the question has become more one of the manner of its implementation than whether to allow it. Until this year most of the states, including Virginia, had adopted the sign permissive rule (RTOR only where a sign is posted). During 1975, however, three states, Georgia, Ohio, and West Virginia, switched from the sign permissive to the general permissive rule (RTOR permitted unless a prohibitory sign is posted), and for the first time that rule has become the predominant one in the nation.

California introduced the general permissive rule in 1947, but for years its acceptance was limited primarily to the western states and, in fact, it came to be called the western rule. The majority of the states, especially those in the East, adopted the sign permissive rule and this was the rule accepted by the Uniform Vehicle Code (U.V.C.) in 1968 and the Manual on Uniform Traffic Control Devices (MUTCD) in 1971.[1,2] A nationwide trend toward use of the general permissive rule has been unmistakable and in July of this year § 11-202 * of the U.V.C. was amended to allow right turns on red unless prohibited by a sign. The vote by the U.V.C. to switch to the western rule was overwhelming (67 to 13), and perhaps reflects the majority status that rule has attained among the states. Recently, Senate Bill S 2049, shown in Appendix C, was introduced in Congress by Senator Dale Bumpers, D-Ark. to make RTOR mandatory nationwide.

As of this writing, 27 states allow RTOR unless there is a sign prohibiting it, while 19 allow it only where a permissive sign is posted, and only 4 prohibit it altogether. The states which follow the various rules are listed in Table 1. This list was current as of July 1975; however, the adoption of the general permissive rule by the U.V.C. will likely accelerate the trend toward acceptance of that rule and several other states may well switch by the end of this year.

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* A copy of the draft amendment to § 11-202 of the U.V.C. is included as Appendix B of this report. It should be noted that the U.V.C. also permits a left turn on red from a one-way street into a one-way street. This feature is discussed in the Purpose and Scope section of this report on page 3.

TABLE 1

STATUS OF THE STATES CONCERNING RTOR

General Permissive States

Alaska	Iowa	North Carolina
Arizona	Kansas	North Dakota
California	Kentucky	Ohio
Colorado	Minnesota	Oklahoma
Florida	Missouri	Oregon
Georgia	Montana	Texas
Hawaii	Nebraska	Utah
Illinois	Nevada[(a)]	Washington
Indiana	New Mexico[(a)]	West Virginia

Sign Permissive States

Alabama	Massachusetts	Pennsylvania
Arkansas	Michigan[(b)]	South Carolina
Delaware	Mississippi	South Dakota
Idaho	New Hampshire	Tennessee
Louisiana	New Jersey	Virginia
Maine	New York	Wyoming
Maryland		

Jurisdictions Prohibiting RTOR

Connecticut	Vermont	District of Columbia
Rhode Island	Wisconsin	

(a) Denotes states with a total permissive rule—i.e., there is no provision for a prohibitory sign.

(b) Michigan utilizes a red arrow on the traffic signal in lieu of a sign.

Virginia adopted the sign permissive rule in 1972. As in most sign permissive states, however, the number of intersections signed to permit RTOR has remained small. (Few states sign more than 10 percent of their approaches.) Therefore, in light of the energy conservation potential of RTOR, the Virginia General Assembly passed Senate Joint Resolution 155 in February 1975 to encourage the designation and signing of additional RTOR locations (see Appendix D). In that resolution the Assembly also directed the Department of Highways and Transportation and the Highway Safety Division to "conduct a joint study to determine if the present legislation should be retained, rescinded or amended." This report is the result of that joint study.

PURPOSE AND SCOPE

The purpose of this study was to determine whether Virginia's current sign permissive rule for right turn on red signals "should be retained, rescinded or amended." To satisfy that purpose research was directed at right turn on red in both sign permissive and general permissive forms, as well as the possibility of RTOR prohibition. A number of questions had to be answered by the research before an informed decision among the three options could be made. Does right turn on red save time and energy at signalized intersections? If so, are such savings greater under the sign permissive or the general permissive rule? Does right turn on red have a positive or negative effect on traffic flow? What effects does RTOR have on traffic safety? Will there be greater numbers of traffic crashes with right turn on red? If so, are they likely to be greater under the sign permissive or the general permissive rule? Is there likely to be a greater potential for traffic crashes as measured by traffic conflicts? Would traffic conflicts be more prevalent under either RTOR rule? Are there satisfactory criteria for distinguishing those intersection approach legs which are unsafe for RTOR? What are those criteria? Should we allow left turns on red signals from one-way streets onto one-way streets? Finally, what are the measurable benefits and costs to the Commonwealth under each of the available options?

Despite the broad nature of the problem addressed in this research, the study was necessarily limited in scope. The primary limitation was time. Research was started in March 1975 and was scheduled for completion by the end of August 1975. Hence, study design, data collection, data analysis, and report writing were to be completed in six months.

Because of the time limitations and necessary limitations of staff and budget, the scope of this study was addressed to the specific area of right turn on red. Eighteen of the states that have adopted the general permissive rule also permit a left turn on red (LTOR) from a one-way street onto a one-way street. As no studies were found on LTOR and this movement is not permitted in Virginia, it was not possible to collect empirical data needed to conduct a study of this condition. Therefore LTOR is not included in the scope of this report and no recommendations were drawn concerning this maneuver.

This study included a survey of the literature, a survey questionnaire of Virginia traffic engineers, a telephone survey of traffic engineers in other states, field studies of vehicle travel times and traffic conflicts at 20 selected intersections in Virginia and North Carolina, and an analysis of traffic crashes at 20 intersections in Virginia before and after RTOR was permitted.

METHOD

Literature Study

The RTOR study was initiated with a literature search facilitated by the Highway Research Information Service which identified two important references. An interim state of the art report for the National RTOR Study and a 1974 report from Purdue University had identified the most pertinent RTOR studies. (3, 4) Sponsoring agencies were then contacted to obtain complete copies of key RTOR reports. A list of the studies is given in the Bibliography, and the most important of them are discussed in the Analysis section of this report.

Determining Degree of Implementation of RTOR in Virginia

The method of determining the present degree of usage of right turn on red in Virginia was to obtain data through questionnaires mailed to all traffic engineers in Virginia. The purposes of the questionnaire were (1) to document current RTOR usage, (2) to determine the criteria being used to permit RTOR, (3) to tabulate costs for installing the RTOR signs, and (4) to survey opinions of the traffic engineers on RTOR (both sign permissive and general permissive schemes).

In May, questionnaires were mailed to the Virginia Highway and Transportation Department's district traffic engineers and to each town or city with a population of 3,500 and over. Sixty-four of the 73 questionnaires mailed (87.7%) were returned to the Research Council, and information contained on these was tabulated by computer. A blank copy of the questionnaire is in Appendix E of this report. The questionnaires were used to obtain an inventory of present traffic control signals in the state as well as to inventory the number of RTOR signs installed under the present sign permissive law. This information was compared to that of other states using the sign permissive regulation as well as to that of the states which have the general permissive rule.

The responses to several subjective questions asked of the traffic engineers were compiled to give a general picture of their opinion on RTOR.

Telephone Survey of Traffic Engineers

Because adoption of the general permissive rule is one option open to Virginia, a survey was made of several states which recently adopted that rule in hopes of identifying any problems which might accompany such a change. In each case the traffic engineering offices for the state and for one city within the state were called. Table 2 lists the states contacted, the city in each that was contacted, and the date on which each state switched to the general permissive rule.

TABLE 2

STATES AND CITIES CALLED IN THE TELEPHONE SURVEY OF TRAFFIC ENGINEERS

State	City	Effective Date of General Permissive Rule
North Carolina	Charlotte	July 1974
Florida	Jacksonville	1969
West Virginia	Charleston	May 1975
Illinois	Peoria	January 1974
Ohio	Columbus	July 1975
Kentucky	Louisville	June 1974
Georgia	Atlanta	July 1975
Colorado	Denver	1969

Notice in the table that most of the states have had recent experience with a changeover to a general permissive rule and thus are better able to give a comparative assessment of the general permissive rule than a state such as California which has had nothing else for over 28 years. Note also that most of the states chosen are east of the Mississippi and therefore perhaps more comparable to Virginia than most of the general permissive states, which are in the Far West. In addition, the cities contacted were not always the largest cities in the state but were selected as being of a size more comparable to those in Virginia. Time and economic considerations prevented the surveying of all 27 general permissive states.

A copy of the questionnaire used in the telephone survey is attached to this report as Appendix F. Because of the nature of a telephone interview, which provides no time for researching answers, the questions are of a general opinion type rather than technical. However, the literature survey showed that hard technical facts about RTOR are scarce, and perhaps engineering opinions based on working experience are the best evidence of the workability of the general permissive rule.

Field Studies

Study Approach

Research structured to collect empirical data which can be analyzed and statistically tested provides the most widely accepted method of deriving objective solutions to engineering problems. Therefore, the before and after empirical methodology was adopted for the conduct of the traffic conflict and travel delay field studies. The purpose was to determine: (1) Time and energy savings directly attributable to RTOR, (2) changes in accident potential created by RTOR signing, (3) driver acceptance of RTOR, (4) the degree of compliance with the law by stopping before turning right on red, and (5) special or unique problems not specifically included in the foregoing categories.

As the data collected in the field would be extrapolated to apply to the whole state, the authors felt the study should be conservatively designed, i.e., to minimize the benefits and accentuate the problems associated with RTOR. It was felt that since safety and energy conservation were the two conflicting interests in the RTOR controversy it would be better to err on the side of safety if any error were made.

Study Locations

To examine the impacts of Virginia's current sign permissive rule and the general permissive rule used by the majority of other states, field data were collected at 20 intersections during May, June, and July 1975. For the purposes of providing clarity in the discussions, the intersections were classified as shown in Table 3.

TABLE 3

FIELD STUDY INTERSECTIONS

Type	Number of Intersections	RTOR Status
Virginia before and after (new RTOR locations)	9	Sign permissive - 1 month after RTOR signing
Virginia comparison (old RTOR locations)	7	Sign permissive - 1 to 2 years after RTOR signing
North Carolina	4	General permissive - 1 year after adopting general permissive rule

The primary purpose of collecting before and after data at nine intersections in Virginia was to determine time and energy savings attributable to RTOR and to measure changes in accident potential. As these data were to represent total savings and accident problems in the entire state it was extremely important that the locations selected include a wide variety of intersection characteristics. The intersections, which were chosen at random throughout the state, have varying traffic and pedestrian demands, geometrical features, and environmental constraints. An inventory of the study locations is given in Appendix G. Due to time limitations only one month was allowed between the time the RTOR sign was erected and collection of the after data. No changes other than erection of the RTOR signs were made at any of the intersections.

Because the literature had indicated that the benefits and problems associated with RTOR are a function of time for comparison reasons, seven intersections in Virginia where RTOR signs had been in place from one to two years were chosen to specifically measure driver compliance and acceptance and accident potential.[4]

For convenience these are called "comparison" locations in this report. The selection of these intersections was not random. In keeping with the safety oriented conservative approach, sites were selected primarily in high volume areas where RTOR problems were expected. (See Appendix H.)

To compare findings of the sign permissive rule with those of the general permissive rule, four intersections in North Carolina were studied. Again the selection of the locations was not random. All are located in urban areas with high traffic volumes, and, in fact, two of the intersections had previously reported incidents of RTOR accidents. (See Appendix I.) This conservative approach toward safety was followed throughout the field studies.

Data Collection Process

Data collected at each intersection included: (1) Traffic volumes and turning movements, (2) delay for right turning delayed vehicles only, (3) driver acceptance of RTOR opportunities, (4) driver compliance with the law by stopping before making a right turn on red, (5) traffic conflicts, and (6) special or unique problems not specifically mentioned in items 1-5. All data were collected by a field team consisting of three members with the following assignments:

Observer	Task
1	Record traffic and pedestrian conflicts
2	Record turning movements and volumes and note special problems
3	Measure and record delay of right turning vehicles and compliance and acceptance of RTOR

To provide uniformity and consistency in the data, the same observers were used throughout the study.

Data were collected on an intersection approach for a 15 minute period, then 15 minutes was used to record the information and move to an adjacent approach where data were collected for another 15 minute period. In this manner, one 15 minute sample was obtained per hour on each approach. For example, the team would begin a typical day by collecting data from 7:00 a.m. to 7:15 a.m. on the west approach of a given intersection, take 15 minutes to record the data, and move to the north approach, where data would be collected from 7:30 a.m. to 7:45 a.m. At 8:00 a.m. the team would return to the west approach for another 15 minutes of data collection. Thus, by alternating approaches throughout the day, a representative sample of both morning and evening peak periods as well as off peak hours could be obtained. A 12-hour counting day was normally used, however, in a few areas where traffic volumes were heavy, data were collected for periods of less than 12 hours. Some data were taken at night to determine if darkness created any special problems with regard to RTOR. Most observations were made on Tuesdays, Wednesdays, and Thursdays, but because of scheduling problems and weather conditions, some data were taken on Friday mornings. Holidays were eliminated from the schedule and data were not taken during inclement weather. To reduce the effects the observers could have on motorists using the intersection, the team used an unmarked vehicle parked as inconspicuously as possible approximately 300 feet from the intersection.

Delay Data

One of the major objectives of this study was to determine the time and energy savings created by allowing motorists to turn right on red. A review of the literature suggested that time benefits derived from RTOR had been determined by the moving car technique in several previous studies.[4, 5] With this method, a vehicle is driven over a prescribed course both before and after RTOR implementation. A second technique that had been used was to instrument an approach so that delay data were recorded on a chart. In another study,[6] delay times were recorded from motion pictures taken of the approach. Although these methods should yield similar results, it was decided that measuring the delays of motorists under actual roadway conditions would give a more realistic result and would eliminate any bias introduced by the observer. This method proved especially useful because the 15 approaches studied in Virginia were in areas with noticeably different traffic characteristics.

After considering the time and budget limitations and other field data requirements for the study, a method of randomly selecting right turn delayed vehicles and measuring the delay with a stop watch was chosen. Preliminary tests indicated that the delay time of at least 75% of the right turning delayed vehicles could be recorded.

Time did not permit measuring the delays of all vehicles using a given approach; thus, for the purposes of this study, the term vehicle delay is defined as delay time of a right turning vehicle which is delayed by the red signal at an intersection. Specifically, the delay time of a right turning vehicle is that time the vehicle is actually stopped at the approach. It does not include deceleration time for the stop nor acceleration time required before making the right turn after stopping. To record delay time, the observer randomly selected, from the first six vehicles, a right turning vehicle which would encounter a delay because of the signal. When the wheels of the vehicle stopped, a stopwatch was started, and when the wheels again began moving the stopwatch was stopped. The elapsed time was the vehicle delay, and it was measured to the nearest second.

It should be noted that a conservative approach was used throughout the process of recording vehicle delay. Thus the delay data represent the minimum time that could be saved by RTOR. For example, to provide a representative sample of intersections, some locations had to be selected in urban areas with heavy traffic volumes. At peak periods in these areas, traffic is frequently delayed at distances much greater than 300 feet, the normal position of the observer. At these distances, it is often quite difficult to determine in advance which vehicles will turn right. To provide uniformity, delay was measured for only the single vehicle selected from the first six vehicles in a group. Thus, if more than six vehicles were delayed, their delay was not measured. Such vehicles were recorded as through-on-green-vehicles unless they did not get through on green and were delayed a second time.

Since the observer recording delay data also collected acceptance and compliance information, it was convenient to record these data on the same form (see Appendix J). Vehicles were classified under the major headings of "Right Turn on Green," "Captive," and "Delayed" in the collection of delay data. The term "captive" is defined as a right turning vehicle which is impeded from making a right turn on red by a through vehicle stopped in the same lane. Delay time for captive vehicles was not recorded since a captive driver cannot turn right on red even if the maneuver is authorized.

Delay data were further broken down into categories of drivers accepting and rejecting RTOR. The total delay time for all right turning vehicles is the sum of delay times for those vehicles accepting RTOR and those rejecting it.

Acceptance Data

The term "acceptance" is defined as an obvious attempt by a motorist to make a right turn on a red signal, whether successful or not. Data were collected on acceptance of RTOR as well as on the actual number of RTOR maneuvers. A motorist was classified as rejecting RTOR if he: (1) Was the lead vehicle, (2) had sufficient gaps in the cross street traffic (6 seconds of gap time or more), and (3) obviously made no attempt whatever to turn right on red.

Compliance Data

One major objection to RTOR is that motorists do not stop before turning right on red. To test the validity of that objection, data were collected on the number of motorists not stopping at each study intersection. For the purposes of these data, a stopped vehicle was defined as a vehicle whose wheels had stopped. This definition is rather rigorous as there are various degrees of slowing, rolling, jerking, etc. which are perhaps not unsafe, but in keeping with the conservative approach emphasized throughout the study, a total stop was required to satisfy the definition.

Traffic Conflict Data

The second major objective of this study was to determine the effects of RTOR on highway safety. Although a before and after accident study was conducted at selected intersections in Virginia, the results of previous reports indicated few incidences of RTOR accidents. To provide a different approach and to measure the accident potential of RTOR, a traffic conflict technique was used.

Based on the results of the literature survey, the only previous attempt to measure RTOR accident potential by a conflict method was made by May.[4] May, however, used Hayward's[7] definition of a traffic conflict, which is based on critical incidents. With the use of this definition the number of critical conflicts were so few that they were not of value in evaluating the RTOR maneuver. May concluded that the RTOR maneuver did not appear to cause any important changes in safety at the intersections he studied.

The traffic conflict technique used in this study was developed by Perkins.[8] This technique describes a traffic conflict as an evasive maneuver by a driver who either brakes (as indicated by a brake light signal) or changes lanes to avoid a collision. This method has been used by a number of states, including Virginia, to evaluate safety improvements at intersections. By using traffic conflicts in a before and after situation the relative effectiveness of an improvement can be determined immediately after the change without having to wait a year or two for accident data to develop.

To effectively employ the Perkins method of recording traffic conflicts for this study several modifications were necessary. First, emphasis was placed on observing all conflicts involving right turning vehicles. To accurately accomplish this at high volume intersections, several conflict counts (such as left turn traffic from the cross street, which rarely could involve a right turn vehicle), were eliminated from the collection process. Secondly, all conflicts involving a RTOR maneuver were specially marked.

Conflicts data were taken at the before and after locations to determine changes in accident potential created by RTOR. Data taken at the Virginia comparison locations (intersections signed for over a year) and in North Carolina were used to compare conflicts under the sign permissive rule and the general permissive rule.

The observer who collected the conflicts data in this study also collected similar data in 1970 when Virginia was participating in the nationwide study conducted by Baker.[9] Thus, his familiarity and experience with the technique provided the high degree of consistency needed for the before and after studies.

Although several studies have attempted to correlate traffic conflicts with accidents there was not time to conduct such a correlation in this study.[9,10,11,12] Thus, emphasis was placed on using conflicts to identify types of incidents which could result in RTOR traffic accidents and to determine their frequency.

Accident Data

To examine the possible effects of sign permissive RTOR maneuvers on highway safety, crash data taken for 20 Virginia intersections before and after RTOR was permitted were studied. A one year before and one year after study period was used.

The criteria used in selecting the 20 intersections are listed below:

(1) There must have been current records pertaining to traffic signs and signals available to the researchers.

(2) There must have been no changes in roadway speed limits at the intersection during the two-year study period.

(3) There must have been no highway construction at the intersection during the two-year period.

(4) There must have been no changes in the number or phasing of traffic signal lights at the intersection during the two-year study period.

In addition, intersections where the placement of RTOR signs occurred after June 1973 were excluded from the study for two reasons. First, at the time of the study the central accident report file was not current for crashes which occurred during the later months of 1974.(13) Second, choosing the earlier RTOR locations minimized the overlap between the RTOR intersection study periods and the national energy crisis. The latter reason was important because reductions in vehicle trips and speeds due to the energy crisis were especially influential upon accident trends between December 1973 and May 1974.(14)

It should be recognized that the available choice of RTOR intersections did introduce a potential source of bias into the accident data analysis. When the sign permissive rule was adopted in 1972, only a few carefully selected approaches were chosen by traffic engineers for RTOR, and these were ones where traffic patterns and roadway characteristics were relatively ideal for introducing RTOR without safety hazards. Typically, these locations had low volumes of right turning traffic, were at lightly traveled secondary roads, had low speed limits, had little pedestrian activity, and had minimal peak hour congestion. Thus, the 20 intersections studied were not a random sample of all possible Virginia RTOR sites.

Over 100 RTOR locations maintained by the Virginia Department of Highways and Transportation were screened, and 16 intersections were found which conformed to the four criteria listed above. In addition, the cities of Charlottesville and Newport News were each found to have two intersections satisfying the stated criteria. These four sites were included to give municipal representation, and made a total of 20 intersections in the study group.

For each intersection, copies of FR-300 accident reports of all crashes occurring during the two-year study period were obtained from the Traffic and Safety Division, Virginia Department of Highways and Transportation. In analyzing the crashes, all the evidence contained in the FR-300 form was considered, including the verbal description of the crash, the crash diagram, and any other pertinent data.

Data Classification

To ensure consistent analysis, a standard procedure was followed in screening the FR-300 report forms. Crashes reported as having occurred more than 150 feet from the intersection were excluded from the study. A preliminary examination of the FR-300's had indicated that reports of crashes at distances greater than 150 feet from the intersection generally could not be evaluated in terms of driving maneuvers or signal changes at the intersection itself. Landmarks shown on the accident report diagrams were compared with photographs of the intersections to verify reported intersection proximity.

To compare the effect of RTOR implementation, each crash was classified as "before" or "after" depending on whether it occurred during the year before or the year after placement of the RTOR signs.

Accident severity was indicated by having each crash categorized as either a "fatal crash," a "personal injury crash," or a "property damage crash." Fatal crashes were any in which a traffic death occurred and personal injury crashes were any with one or more persons injured; all other crashes were designated property damage crashes, even though a damage estimate may not have been reported.

RTOR accident involvement was specified by having each crash designated as a "definite RTOR crash," a "possible RTOR crash," or a "non-RTOR crash," depending on whether an RTOR maneuver was involved. The precise definitions used in this classification were as follows:

(1) Definite RTOR Crash: one for which all the evidence stated in the accident report FR-300 indicates that the crash occurred during or after a RTOR maneuver, and that the crash would not have occurred had the RTOR not been attempted. For the purpose of this definition, an RTOR maneuver is any attempt to turn right against a red light.

(2) Possible RTOR Crash: one for which all the evidence stated in the accident report FR-300 indicates that the crash may have occurred as a result of an RTOR maneuver.

(3) Non-RTOR Crash: one for which there is no evidence stated in the accident report FR-300 to indicate that the crash occurred as a result of an RTOR maneuver, or that an RTOR maneuver was in any way a contributing cause of the crash.

In order to compare crash totals in relation to volume levels, daily traffic counts were obtained from the Transportation Planning Division, Virginia Department of Highways and Transportation.

To facilitate the study of fully signed vs. partially signed RTOR intersections, crashes were further classified according to the intersection leg from which the vehicle at fault had approached the intersection. For the purpose of making this classification, "intersection leg" was defined as any distinct roadway by which vehicles could enter the intersection from a single direction, together with its adjacent, opposite direction lanes. Under this definition a T-intersection would have three legs while a cross intersection would have four.

To determine if RTOR changed the distribution of accidents each crash was classified as to the type of collision which occurred: Rear end, angle, sideswipe, fixed object, and other.

The crash characteristics described above — type of collision, severity of the crash, involvement of pedestrians, and involvement of RTOR — along with traffic volumes for each intersection, were the basis for the accident data analysis.

Cost-Benefit

In a statewide survey many of the traffic engineers in Virginia expressed concern that the general permissive law would be cost prohibitive. They believed that the majority of Virginia's intersections would have to be signed to prohibit right turn on red to maintain highway safety. Most approved of the present sign permissive law, which allows them considerable discretion in choosing the locations where the maneuver will be permitted and at the same time produces positive influences on traffic flow. Although the abolishment of RTOR was not advocated by many engineers, it was felt that an economic analysis would not be complete unless the cost or savings realized through such a move were studied.

The method of analysis chosen was to develop comparative five-year cash flow tables on the three alternatives — retention of the sign permissive rule, adoption of the general permissive rule, and abolishment of RTOR. The total yearly costs or savings produced were then present valued back to period zero at a nominal rate to give a reasonable estimate of the total dollar value of each alternative. Not all expense items could be assigned a dollar value. Possible legal expenses involved in changing city codes to allow the maneuver, or possible lawsuits involving RTOR are examples. One of the potential savings gained through RTOR is also non-measurable. This is the health and sanitary savings related to a reduction in automobile pollutants realized through shorter delay times for right turning vehicles. Also, an assumption was made that any additional administrative expenses incurred because of RTOR legislation would be minimal and could be handled by present traffic personnel. However, all other major and relevant expense items were included and are explained below as they apply to the three alternatives.

1. Retain present sign permissive law.

   (a) Sign Cost — More RTOR signs will be installed at the same average cost per sign experienced in the past.

   (b) Accident Cost — Accidents involving RTOR vehicles involve property damage and possibly personal injuries.

   (c) Sign Maintenance Cost — Repair and replacement of previously installed signs will be required. The cost can only be estimated.

   (d) Time Savings — Time savings of RTOR vehicles can be calculated and converted to a dollar savings at the minimum wage rate of $2.10/hour.

   (e) Fuel Savings — The fuel savings of reduced delay time at intersections for right turning vehicles can be computed by using savings figures available for present RTOR locations.

2. Adoption of a general permissive law.

   (a) RTOR Sign Removal Cost — Present "permissive" signs would no longer be needed and would be removed.

   (b) RTOR Prohibitive Sign Installation Cost — Intersection approaches where RTOR would be hazardous would have to be signed no turn on red (NTOR).

   (c) Accident Costs — Same as 1 (b) except that the degree of implementation would be greater under the general permissive rule.

   (d) Sign Maintenance Cost — Same as 1 (c).

   (e) Time Savings — Same as 1 (d).

   (f) Fuel Savings — Same as 1 (e).

3. Abolish RTOR (Rescind the sign permissive law.)

   (a) RTOR Sign Removal Cost

It was also felt that the major automobile insurance companies might have detected a change in the accident rates in states with general permissive or sign permissive laws and responded by requesting rate changes in those states. To determine if this was the case, several of the major insurance companies were contacted. The results of this survey are given in the Analysis section of this report.

To maintain the safety oriented posture of this study, a conservative approach was taken in computing the cost-benefit relationship; that is, the cost figures used in the analysis are the highest estimates reported, while the savings figures are the lowest estimates. This approach was considered necessary to preclude bias toward any choice because of inflated savings or underestimated costs.

Guidelines for Implementation of RTOR

Whether the sign permissive or general permissive RTOR rule is used in Virginia, guidelines for implementation of the law must be developed. To accomplish this, criteria of other states were reveiwed. In addition, comments and suggestions from Virginia traffic engineers were solicited.

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THE PROBLEMS WITH RTOR

In spite of the fact that it has now been adopted by 46 states, right turn on red remains controversial. Proponents contend that RTOR is not only a convenience and time saver for drivers, but that it conserves energy by reducing wasteful idling time at traffic signals. Opponents believe that the saving from RTOR is at the expense of safety, and many also contend that the savings are negligible in light of costs for enforcing RTOR laws and maintaining RTOR signs. They argue that societal costs of increased numbers of accidents, coupled with costs of implementing RTOR, outweigh the energy savings. In this report the authors have attempted to weigh these arguments and to strike a balance in their recommendations between the seemingly conflicting interests of fuel economy and safety. This section of the report introduces some of the more important arguments surrounding the question of RTOR. Some of these items are discussed more fully in the Analysis section of this report, and others could not be easily tested and are discussed only in this section.

Nonuniform Practices of the States

Most traffic engineers, and drivers as well, agree that uniformity in state traffic laws would be desirable. Though few empirical studies have been made of the subject, it seems obvious that variations among the states are potentially confusing and even dangerous for interstate travelers and new residents. Even the Code of Virginia reflects a concern for uniformity by requiring that the system of marking and signing of highways in the state "correlate with and so far as possible conform to the system adopted in other states." (Va. Code Ann. § 46.1-173.)[15]

Until very recently the goal of uniformity in RTOR would have been satisfied by acceptance of the sign permissive rule that Virginia has adopted. The majority of the states, especially in the East, have operated under that rule for the past several years, and that was the rule accepted by the U.V.C. and the MUTCD.[1,2] During the past year, however, enough states have switched to the general permissive rule to make it the predominant RTOR rule nationwide (27 states to 19 with the sign permissive rule). In addition, the general permissive rule states are no longer confined to the West. Three of Virginia's five border states* have now adopted the general permissive rule, two of them in the past year. The U.V.C. adopted the general permissive rule in July of this year and the MUTCD will likely follow suit. At least one more state, Arkansas, is expected to accept the general permissive rule this year. Obviously, there is no uniformity in RTOR laws among the states, but the trend at this time is apparently toward the general permissive rule.

* The states are North Carolina, Kentucky and West Virginia. The District of Columbia prohibits RTOR, while Maryland and Tennessee still use the sign permissive rule.

RTOR Dilutes the Meaning of the Red Light

One of the truly uniform traffic control devices is the steady red light to indicate a stop. The argument has been made that any alteration of the fundamental stopping requirement would undermine the effectiveness of the red light as a traffic signal. Once again, little empirical data are available on the psychological impact of a red light on a driver or the effect that RTOR would have on that impact. Proponents of RTOR argue that devices such as green arrows and separate right turn lanes with yield signs or stop signs have been used successfully for years without hurting the effectiveness of the red light, and that RTOR itself has now been adopted by 46 states and that none of these is considering rescinding the law to avoid dilution of the red light's meaning. Compliance data discussed in the Analysis section of this report indicate that 2% to 3% of the drivers in Virginia and North Carolina fail to stop before executing a RTOR maneuver. But none of these arguments is conclusive and there is probably no practical way of settling the question. No one knows whether RTOR dilutes the meaning of the red light.

RTOR is Not Suited to Urban Areas

Many opponents of the general permissive rule feel that urban areas, because of high pedestrian volumes, often congested traffic conditions, and narrow streets, are poor areas for RTOR. They argue that because RTOR must be prohibited at many intersections in cities it is cheaper to follow the sign permissive rule and erect signs at only the safe intersections or to prohibit RTOR altogether. However, the experiences of cities across the country do not support this argument. For example, the City of Los Angeles with over 2,900 signalized intersections has posted prohibitory RTOR signs at only 3 of those intersections. Atlanta has 30 intersections where RTOR is prohibited. Jacksonville, Florida, has signed less than 1% of its intersections. In fact, of the cities surveyed during this study only Charleston, West Virginia, has prohibited RTOR at more than 10 percent of its intersections, and it should be noted that prior to adopting the general permissive rule Charleston had signed 75% to 80% of its intersections to allow RTOR. Thus, even with 20% of its intersections signed there are fewer RTOR signs in Charleston now than under the sign permissive rule. In no case has any city studied signed more than 25% of its intersections to prohibit RTOR under the general permissive rule, and even at that rate the choice would be to sign 25% under the general permissive rule or 75% under the sign permissive rule to achieve the same fuel savings.

Charlotte, North Carolina, one of the few cities to sign as many as 25% of its intersections, has already removed over half of the prohibitions in the year since the general permissive rule was adopted. The fear that RTOR is not suited to urban areas simply is not justified by the experiences of these cities.
Perhaps New York or Chicago would have some difficulty with a general permissive rule, but cities such as Atlanta; Charlotte; Columbus, Ohio; Louisville; and Jacksonville are much more comparable to the cities in Virginia, and not one of them has signed more than 10% of its intersections to prohibit RTOR.

During the course of this study several intersections were studied in urban areas in both Virginia and North Carolina. Of special interest was the central business district (CBD) of Raleigh, North Carolina, where there are very few approaches signed to prohibit RTOR. Similar to most downtown areas, the Raleigh CBD has high pedestrian volumes and one-way street systems frequently carrying heavy peak hour volumes. In most cases "walk" phases are included in the signal cycle. On-site observations of the area during peak and off peak periods revealed that there were very few pedestrian-vehicle conflicts and RTOR did not appear to adversely affect pedestrian movement. The efficiency of traffic flow in the area appeared to be enhanced by RTOR. A further discussion of the data collected in the Raleigh area is in the Analysis section.

RTOR is Hazardous to Pedestrians

The pedestrian safety problem is probably the most serious objection to RTOR. It is one of the most often discussed but perhaps least documented aspects of the RTOR controversy. Few statistics, if any, are available. Of course any confrontation between a car and a pedestrian is likely to be one-sided (especially if the pedestrian is a child) but reports indicate that few pedestrian accidents are caused by RTOR. Rather the problem seems to be more one of delay and inconvenience for the pedestrian caused by failure of drivers to yield to them. The low rate of speed of a right turning vehicle, especially at a red light, apparently prevents accidents but does not stop a driver from ignoring a pedestrian's right-of-way.

All of the RTOR states, whether general permissive or sign permissive, require drivers to yield to pedestrians before turning. In addition, virtually all of the states use the volume of pedestrian traffic as one criterion for determining whether to allow RTOR at an intersection. Nevertheless, a right turning vehicle can present a threat to pedestrians in states such as Virginia where the concept of pedestrian right-of-way may not be as well established as in states such as California. It should be added, however, that a vehicle turning right on green poses at least as great a threat to pedestrians as a RTOR vehicle. This threat has been the impetus behind the use of "all pedestrian phases" at some busy intersections, and many RTOR states have banned RTOR where "all pedestrian phases" are in operation. General prohibitions against RTOR around school crossings and anywhere that pedestrian traffic is heavy are quite common in state RTOR criteria. Protection of the pedestrian is perhaps one of the most important reasons for establishing guidelines for statewide criteria for the implementation of RTOR under either the general permissive or the sign permissive rule.

While the pedestrian problem is not an easy one to deal with in discussing RTOR, perhaps the greatest problem is not with RTOR but with driver attitudes toward pedestrians in general. Given the present interest in conserving energy, perhaps this would be an excellent time to consider strengthening Virginia's laws on pedestrian right-of-way. After all, the energy savings of a driver turning right on red is negligible compared to that of a pedestrian who is walking in lieu of driving. Sections 46.1-230, 231, and 232 of the Code of Virginia, which constitute much of Virginia's pedestrian protection statutes, are included as Appendix K of this report. The California statutes (Appendix L) and the U.V.C. provisions (Appendix M) on a pedestrian's rights and responsibilities are also included for comparison purposes.

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It should be noted that Virginia's pedestrian laws compare favorably with those of many of her sister states; however, California has gained the reputation of being more protective of pedestrians than most states, including Virginia. There are subtle differences between the Code of Virginia and the California statutes that may help explain the difference in the two states' reputations. Some of these differences are discussed below.

(1) Va. Code Ann. § 46.1-230(a) "When crossing highways or streets, pedestrians shall not carelessly or maliciously interfere with the orderly passage of vehicles." This is the first sentence of Virginia's pedestrian statutes and as such tends to set the tone for the pedestrian section. Unfortunately, the tone seems unfriendly to pedestrians and seems to place the orderly passage of vehicles above the safety of pedestrians as the statutes' objective. No such provision is in either the California Code or the U.V.C., and it appears to have little function in the Virginia Code in light of § 46.1-231(b).

(2) Va. Code Ann. § 46.1-230(a) "They (pedestrians) shall cross wherever possible only at intersections, but where intersections of streets contain no marked crosswalks pedestrians shall not be guilty of negligence as a matter of law for failure to cross at said intersection." This is the only section of Virginia's code which deals with pedestrians crossing outside crosswalks and it does not define the consequences of not crossing at a crosswalk. Note that both the California code (§ 21954) and the U.V.C. (§ 11-503) spell out the rights and responsibilities of pedestrians outside crosswalks and the responsibilities of drivers encountering them.

(3) Va. Code Ann. § 46.1-231(b) "No pedestrian shall enter or cross an intersection in disregard of approaching traffic." This section is a limitation on the grant of pedestrian right-of-way in subsection (a). Both the California Code and the U.V.C. have such limitations but the wording is quite different from Virginia's. California Code § 21950(b) states that: "The provisions of this section shall not relieve a pedestrian from the duty of using due care for his safety. No pedestrian shall suddenly leave a curb or other place of safety and walk or run into the path of a vehicle which is so close as to constitute an immediate hazard." The difference is subtle but can be extremely important in a court of law. An injured pedestrian in California need only prove that he did not "suddenly" "walk or run" into the path of a vehicle that posed an "immediate hazard." The same pedestrian in Virginia must show that he did not "disregard" "approaching traffic," in spite of the fact that the traffic should yield to him if there is time. Under the Virginia law a pedestrian is well advised to stay on the corner until there is no traffic in sight.

(4) § 11-504 (U.V.C.) "Notwithstanding other provisions of this chapter on the provisions of any local ordinance, every driver of a vehicle shall exercise due care to avoid colliding with any pedestrian and shall give warning by sounding the horn when necessary and shall exercise proper precaution upon observing any child or any obviously confused, incapacitated or intoxicated person." This section on the responsibility

of drivers to exercise due care toward pedestrians, and a similar, though less comprehensive one in the California Code, has no counterpart in the Virginia Code. Such a section would seem highly desirable in the promotion of pedestrian safety.

(5) § 21951 (California Code): "Whenever any vehicle has stopped at a marked crosswalk or at any unmarked crosswalk at an intersection to permit a pedestrian to cross the roadway the driver of any other vehicle approaching from the rear shall not overtake and pass the stopped vehicle." This section of the California Code also has no counterpart in the Virginia Code.

As the foregoing brief analysis reveals, Virginia's pedestrian protection laws might well benefit from revision. Though a revision might take many forms, it is the belief of the authors that to promote pedestrian safety it should include at least the changes listed below.

(1) Reorganization of the statutes to distinguish the rights and privileges of pedestrians within a crosswalk, or at an intersection, from those crossing a roadway outside a crosswalk or intersection.

(2) Modification of the limitation on pedestrian right-of-way at crosswalks which now reads "No pedestrian shall enter or cross an intersection in disregard of approaching traffic" to a form which forbids only sudden movements into the path of vehicles so close as to create an imminent hazard.

(3) Inclusion of a section to require drivers to exercise due care toward pedestrians at all times.

The California Code and U.V.C. provisions could be used as models if desired though they are by no means perfect nor necessarily appropriate for Virginia. Whatever form is used, however, the pedestrian protection laws should be modified.

Implementation is Not Standardized

Because most states, including Virginia, leave RTOR signing to the discretion of local traffic engineers, the percentage of intersections where RTOR is allowed varies by locality. In Virginia RTOR is allowed far more frequently in urban areas than in rural areas and small towns, and it is more widespread in northern Virginia than in the southern part of the state. Some jurisdictions, such as Roanoke, do not allow RTOR at all. Even more significant than variations within the state, however, is the difference in utilization of RTOR between general permissive and sign permissive states. Virtually all states tend to be slow in erecting RTOR signs. This may be from a desire to save money, to avoid a confusing mass of signs, or to avoid controversy, but whatever the reason the result is quite different depending on whether the general permissive or sign permissive rule is in effect. This is the reason that in most general permissive states RTOR is allowed at 80% to 90% of the intersections while in most sign permissive states it is permitted at less than 10%. Thus it is true that implementation of RTOR is not standardized within Virginia or among the states, though generally implementation is more widespread in those states using the general permissive rule.

Benefits From RTOR Depend on Signal Timing

An argument has been made that because Virginia has a large percentage of actuated traffic signals (signals which are triggered by the approach of a vehicle) it would not benefit as much from RTOR as states using fixed time signals (signals which change only at preset time intervals). In a sense this is true. The purpose of an activated signal is to reduce the waiting time for vehicles at an intersection, the same as that of RTOR. Because there is a limited amount of time that can be saved, however, the two tend to cancel or reduce the effects of each other rather than reinforce each other. Thus a large number of actuated signals in a state would theoretically reduce the potential benefit of RTOR. Reality does not always support theory, however. According to the results of the field studies conducted this year, the time and energy savings are apparently greater at actuated signals than at fixed time signals, at least in Virginia. The analysis of this study and an explanation of its conclusions can be found under the discussions on Delay and Cost/Benefit in the Analysis section of the report. In addition, it should be noted that fixed time and fully actuated signals each account for 40% of the total number of signals in Virginia (the other 20% are actuated in one direction only and are called semi-actuated). Thus, regardless of which type signal creates the greater saving, Virginia would benefit significantly from any increase in the implementation of RTOR.

A related aspect of the actuated signal problem is the belief that a vehicle might trigger an actuated signal, and then execute a right turn on red, leaving the signal to turn green for an empty street. The fear is that requiring the cross street traffic to stop for a car which has already left (assuming no other vehicles are present) will cause a net loss of time and fuel (rather than a saving) from the RTOR maneuver. Based on the results of the field studies, apparently this fear is more illusory than real. At an actuated signal the light would change whether the vehicle made the turn on red or on green. Since the cross street traffic would have to stop whether the turn were made on green or on red, the energy consumption would be exactly the same for all except the RTOR vehicle, which would save. Stopping for a car which has already gone might infuriate drivers but it would cost them no more than if the turn were made on green. Of course, in a few cases the use of presence detector type actuators would result in a more efficient intersection, but greater implementation of RTOR would not require that the detectors of every signalized intersection be changed. Observations made during the data collection process indicate that the situation simply does not occur very often because there are usually other vehicles present to make use of the actuated green signal.

Accident Data are Not Significant or Meaningful

Published studies by state and municipal governments have all concluded that there is no significant problem associated with RTOR that would justify prohibiting the maneuver. Opponents of RTOR have questioned the results of these studies on two main grounds. First, the adequacy of these studies in distinguishing changes in accident severity and frequency attributable to RTOR is in doubt. Sampling deficiencies are apparent in most of these studies and the accident reports relied on did not always permit a determination of whether RTOR was involved in the accident (this is especially true where a RTOR vehicle caused an accident but was not actually involved in the collision). Second, even if the conclusions of these studies are accepted there remains a question of their applicability to Virginia. Differences in vehicle laws, enforcement emphasis, and other aspects of highway safety might produce different results in Virginia.

These objections are not without merit. Though the very consensus of these studies is impressive, their faults cannot be ignored. To satisfy the need for more meaningful accident data an accident study was conducted at 20 intersections in Virginia during the past year. The results, which in many ways substantiate those of the earlier studies, are given in the Accident Data Analysis section of this report.

Legal Aspects — Liability of Drivers, Traffic Engineers, and the State

In most states where RTOR is allowed the driver is required to stop and to yield to pedestrians and to traffic in the intersection (which would include left turning vehicles as well as cross street traffic). This is true under Virginia's present statute and it would also be true under the U.V.C. provision for RTOR shown in Appendix B. For that reason the onus is on the right turning driver to safely negotiate a right turn on red, and any accident which might result would likely be considered his fault. There are situations which might occur, however, in which the traffic engineer or even the state might be sued for a RTOR related accident. For example, in a sign permissive state, if a RTOR sign were posted at an approach where RTOR should not be allowed (because of limited sight distance or unusual design of the intersection), the traffic engineer or state might be considered negligent. Conversely, in a general permissive state, if a prohibiting sign were not erected (or if it were knocked down and not replaced properly) at a dangerous intersection, the traffic engineer or state might be sued.

The state of Virginia (as well as her counties) would likely be protected from such suits by the doctrine of sovereign immunity. Though criticized often and abandoned in several states, sovereign immunity remains a valid defense in Virginia. However, the immunity of the state apparently does not extend to municipalities,[16] and definitely does not protect officials of the state in certain cases. Virginia's law on sovereign immunity is best stated in Sayars v. Bullar 180 Va. 222 (1942):

> A state cannot be sued except by permission, and even if the suit, in form, be against the officers and agents of the State, if, in effect, it be against the State, it is not maintainable. The state acts only through its agents and as long as these agents act legally and within the scope of their employment, they act for the State, but if they act wrongfully their conduct is chargeable to them alone. In a tort action against an employee of the State, allegation and proof of some act done by the employee outside the scope of his authority or of some act within the scope of his authority but performed so negligently that it can be said that its negligent performance takes him who did it outside the protection of his employment are required.

Thus a traffic engineer could be successfully sued only if he were acting outside the scope of his authority or if he were acting with gross negligence. For example, if an engineer were to totally ignore the criteria established for RTOR signing, then he might well be considered as acting outside the scope of his authority. Also, if a sign prohibiting RTOR were knocked down and the engineer failed to replace it within a reasonable length of time he might be considered negligent.

However, so long as the engineer reasonably adheres to the RTOR signing criteria and makes efforts to discover and replace missing signs he will likely be shielded from tort liability. Even if immunity does not protect the engineer, he cannot be held liable unless the litigant can prove that the engineer's actions caused the accident. In a situation where the RTOR driver must stop and yield it is difficult to imagine situations in which the absence of a prohibitory sign (or presence of a permissive one) could be considered the proximate cause of an accident.

In general, the liability of the state and its engineers for RTOR accidents would probably be the same as for any other accident involving a traffic control device. An engineer can be held liable if a stop sign is knocked down and after notice (actual or constructive) he does not replace it. He can also be held liable if the sign is not erected in conformance with state regulations. In any case, however, the negligence of the engineer would have to be the proximate cause of the accident before liability would ensue. There is no apparent reason why the law should apply differently to RTOR than to other traffic signs.

Acceptance of RTOR

In general RTOR is accepted quite well by the motoring public. In most states there is a transition period immediately following the adoption of RTOR during which acceptance is somewhat low. After a few months, however, drivers apparently become accustomed to the rule and acceptance is much higher. Data collected in Virginia and North Carolina and discussed in the Analysis section indicate that the more common RTOR intersections are in an area, the more quickly drivers become accustomed to RTOR and accept it. For example, data indicate that in areas such as Richmond where RTOR is allowed at numerous intersections, acceptance is high. By contrast, in Newport News, where only a few intersections have been signed for RTOR, acceptance is much lower. Apparently familiarity with RTOR leads to acceptance. In North Carolina, where the general permissive rule is used, acceptance is generally high. This may well be because RTOR is allowed at over 80% of the intersections in North Carolina.

Compliance with RTOR

Bound up in the controversy over the safety of RTOR is the question of whether drivers will comply with RTOR laws. If drivers do not comply with the requirement to stop and to yield to pedestrians and to other vehicles, or if they ignore prohibitory signs, then RTOR can certainly become a hazard. There is no indication, however, that RTOR has become a hazard in any state, including Virginia. Compliance is apparently quite good and seems to improve as familiarity with RTOR laws increases. For this reason several states indicated that a widespread publicity campaign on the privilege of RTOR and its limitations is quite desirable after the adoption of RTOR. Such a campaign might well be considered by Virginia if the present law is changed in any way.

ANALYSIS

Determining Degree of Implementation of RTOR in Virginia

The "Questionnaire for Virginia Traffic Engineers" mailed in May was the chief source for information on the implementation of RTOR in Virginia. The responses to this questionnaire provided valuable information on the type and number of traffic signal controlled intersections in the state, and included an inventory of present RTOR signing conditions and attitudes concerning right turn on red after stop.

Seventy-three questionnaires were mailed and 64 were returned, for an 87.6% response rate, which is unusually high for this type of survey. In addition, several of the engineers (or town managers in some areas) who failed to respond by mail were contacted by telephone and some of the more critical information was obtained in this manner. The jurisdictions from which no responses were received are the less populated towns of Virginia (less than 10,000 census population). Some (or perhaps even most of these) have no signalized intersections. For these reasons, the responses were very satisfactory and useful. A copy of the questionnaire is attached as Appendix E.

The information obtained revealed that Virginia has 2,955 signalized intersections, of which 2,243 (or 76%) have four traffic approaches and 606 (20.5%) have three (T intersections). One hundred and six were classified as being "other", meaning that there are more than four approaches to the signal. This information and some additional data are given in Table 4. A complete inventory listed by jurisdiction is given in Appendix N. This information was used to verify that intersections studied in the time delay segment of the field work were representative of the state.

TABLE 4

VIRGINIA INTERSECTION AND APPROACH DATA

Total Signalized Intersections

Type of Intersection				Type of Signal		
4-Leg	3-Leg	Other	Total	Fixed Time	Semi-Actuated	Fully Actuated
2,243	606	106	**2,955**	1,156	575	1,224

Traffic Approach Information

Total Approaches	No. Where RTOR is Not Possible	No. of Possible RTOR Approaches	Approaches with RTOR	Total Studied
11,361	1,621	9,740	839	3,722

The total number of approaches, 11,361, minus those approaches at which right turn on red is not possible (because of one-way streets, railroad crossings, etc,) yields 9,740 possible right turn on red locations in Virginia. With 839 signs presently installed, Virginia has implemented RTOR at only 8.6% of the possible locations. Of the 64 jurisdictions responding to the questionnaire, 28, or 44%, have not installed any RTOR signs at traffic signals.

When the traffic engineers were asked the number of additional signal approaches where they might consider RTOR, they listed 3,631 approaches. If these locations were to be signed, right turn on red would then be allowed at 46% of the 9,740 possible locations. For that reason, and because a 50% level would be a break-even point for the cost of installing RTOR signs as opposed to No Right Turn On Red signs, a 50% level of sign implementation was used in comparing the sign permissive rule to the general permissive rule in the Benefit/Cost section of this report.

One section of the questionnaire was designed to determine existing criteria for posting RTOR signs in Virginia. The most frequently mentioned criteria included (1) a minimum sight distance varying according to speed limits posted (frequency = 6), (2) absence of heavy pedestrian traffic (frequency = 6), and (3) presence of separate right turn lanes (frequency = 6). Other questions were included to gain information for use in developing criteria for signing right turn on red locations. Those conditions under which less than 15% of the respondents felt they would allow RTOR are listed in Table 5. (Positive response here refers to an answer of "ALWAYS" or "USUALLY" when asked whether RTOR would be permitted under a particular isolated condition.)

TABLE 5

CONDITIONS UNDER WHICH RTOR MIGHT BE PERMITTED

Condition	Percentage of Virginia Engineers Who Would Permit RTOR
Traffic volume 25,000 ADT	14.0
Pedestrian traffic 100/hr.	11.0
Speed Limit = 55 mph	10.0
Double left turn opposing the right turn	9.5
Bad intersection accident history	6.0
Pedestrian traffic 300/hr.	3.0
Unusual intersection geometrics	1.5

One question to be resolved by the questionnaire was whether traffic engineers in the larger cities (over 50,000 population) would differ from their rural counterparts in the criteria used for allowing RTOR. The answers to questions 12 through 46 were used for this determination. The results showed that an average of 58% of the city engineers would allow RTOR under the conditions described in each of these questions as compared to 41% for all respondents. The district traffic engineers were exactly in line with total respondents at a 41% average positive response to allow RTOR under the various conditions. Experience with RTOR signing within the various jurisdictions was also thought to be an important factor in how the questions were answered. With the jurisdictions which have no RTOR experience to date excluded, the average positive response to questions 12-46 increases to 51%. Those jurisdictions without RTOR gave only a 26.9% favorable rating. This low figure indicates the conservative attitude of the traffic engineers. Without experience with the rule, they are conservative toward its use. With RTOR experience, they are much more favorable toward its use. (See Appendix O.)

As mentioned earlier, RTOR implementation has been slow in Virginia. Although the larger cities express greater approval for RTOR than other areas in the state, their rate of implementation is low: only 8.1% as compared to almost 15% in the eight districts. Roanoke, which presently has no RTOR approaches, is partly responsible for the low percentage in the cities, however.

Comments on RTOR

The traffic engineers were asked to list any problems which, in their opinions, are associated with RTOR. Comments on possible noncompliance with the law as well as physical problems with the signs and problems with implementation were to be noted. The comments offered and the number of times each was noted are given in Table 6.

TABLE 6

TRAFFIC ENGINEER COMMENTS ON RTOR

Comment	Number of Times Noted (Total Respondents = 64)[a]
(1) Drivers do not completely stop before turning	11
(2) Drivers do not see the sign	7
(3) Drivers do not yield to pedestrians	2
(4) Shoulder use is increased by RTOR	2
(5) RTOR vehicles lure through vehicles into the intersection	2
(6) Presence detector type signals are needed for maximum efficiency	1
(7) Motorists stop on green signal	1
(8) Commercial entrances near RTOR approaches present a danger	1
(9) Overhead RTOR signs cut the signal support wire	1

[a] Some of the respondents had had no experience with RTOR; however, their comments were included in the tabulation because their reasons for not installing signs were considered as important as the comments made by other engineers on the basis of actual experience with RTOR.

The small number of problems cited possibly means that only a few intersections presented problems and that RTOR should be prohibited at those locations. Increased enforcement of stopping for the red signal would lower the occurrence of the most frequently noted problem. Some of the other problems seem to result from the motorists' lack of familiarity with RTOR, and these should decrease with time.

Sufficient sight distance is a very important criteria for allowing RTOR. One means of improving sight distance at intersections where there are two or more approach lanes is to move the STOP bar forward (toward the intersection) for the RTOR vehicle, to allow the driver clear visibility of the cross traffic movement. The traffic engineers were asked if they favored relocation of the stop bar where possible and 92% answered yes. They were also asked if they favored left turn on red for vehicles turning from a one-way street to a one-way street, and only 42% favored allowing this maneuver.

Finally, the engineers were asked whether they favored retaining the present legislation controlling the RTOR maneuvers, believed it should be rescinded, or wanted it amended to allow RTOR at all signalized intersections unless prohibited by sign (the general permissive rule). Sixty-four percent favored retaining the present law and 9% favored the general permissive rule. The remainder of the engineers, 27%, did not comment on this question.

In summary, although few problems have been noted with RTOR, Virginia traffic engineers are conservative toward the maneuver. Only 8.6% of the possible approaches have been signed to permit RTOR in the two years since it has been lawful. The general tone of the comments was favorable toward the maneuver, but only 9% of the engineers favored adopting the general permissive rule.

Telephone Survey of Traffic Engineers

Few of the states contacted in the telephone survey had done any detailed research before adopting the general permissive rule. Georgia, Kentucky, and Colorado indicated that not only were no studies made, but that the legislature adopted the measure contrary to the highway department's recommendation. Most of the states indicated that they had looked at available studies from other states or from the Institute of Traffic Engineers, and had contacted states using the general permissive rule. Only Florida had gone further than this; it had operated a two-year test in the City of Tampa before adopting the rule statewide. Apparently the more recent converts to the general permissive rule have been willing to accept the experiences of other states as a basis for acting.

Of course most of the states had had some experience with the sign permissive rule, and thus with RTOR in general, before adopting the general permissive rule. Only Colorado went directly from an outright prohibition to the general permissive rule (Florida and North Carolina had had a statewide prohibition but had had cities which allowed RTOR). In the other five states, the percentage of approaches that had been signed to permit RTOR was very consistent — about 5% in every case, or about the same percentage as in Virginia at the beginning of this study. (There had been considerable variation among the cities, however. For example, Charleston, West Virginia, had signed 75% of its approaches while Atlanta, Georgia, had put up only three signs in the entire city.)

The extent to which the states contacted prohibit RTOR under the general permissive rule is much more variable than the extent to which they allowed RTOR under the sign permissive rule. For example, West Virginia has no prohibitory signs at state controlled intersections (although the City of Charleston has signed 15% to 20%) while Ohio has signed 25% of its intersections. Ohio has only recently adopted the general permissive rule, however, and may be using an ultra conservative approach. North Carolina used such an approach, signing 25% of its approaches initially and then gradually reducing the percentage to 10% to 15%. The decrease in Charlotte was quite dramatic — from 500 approaches to 250 in less than one year. On the other hand, Georgia appears to be using the opposite tack. Like Ohio, Georgia adopted the general permissive rule in July 1975, but has signed less than 1% of the eligible approaches to prohibit RTOR. Apparently Georgia plans to erect signs as they prove necessary rather than removing them as they prove unnecessary. In most of the other states and cities contacted the percentage of approaches with prohibitory signs was between 5% and 10%, probably a more reasonable figure than the extremes represented by Georgia and Ohio, and very close to the percentage of approaches signed to permit RTOR under the sign permissive rule.

None of the states contacted indicated that there had been any problems with implementing the general permissive rule. Several engineers mentioned the importance of prohibitory signs where needed, especially around pedestrian crossings and school zones, but all indicated that problems have been minor and that many anticipated problems had never materialized. (Some of the states had operated under the general permissive rule for only a few weeks and could not give an unqualified reply.)

All of the states agreed that there had been no noticeable increase in accident rates following the adoption of the general permissive rule. It is important to note, however, that none of the states surveyed have standardized procedures for reporting RTOR involvement in accidents. Only Colorado and North Carolina appear to be collecting data specifically on RTOR accidents; but even in those states the accident report form is not coded to indicate RTOR involvement, and therefore the statistics obtained seem suspect. Nevertheless, it is interesting that the Denver traffic engineer felt that the general permissive rule might have even reduced accidents. He cited several intersections with heavy right turn volumes where congestion had been greatly reduced by RTOR. He said that there were several such intersections which were close to school zones and which would never have been signed to permit RTOR, but which had actually become safer because of reduced traffic buildup after RTOR was allowed. Denver also cited a cost saving from RTOR in reducing the warrants for right turn bypasses in the city.

Most of the states do not utilize specific criteria for determining where to prohibit RTOR. In most cases the signing is left to the discretion of the local traffic engineer. Most of the cities and some of the states do have an informal list of factors to be considered, but only Illinois and Ohio have established formal statewide criteria. (Both of these states had adopted the criteria as part of a rule making power granted to the director of transportation. A discussion of the criteria used by these and other states is included in the section entitled "Criteria for RTOR Implementation.") It is interesting to note, however, that Colorado and Florida have begun modifying some of their signs to read "No Turns on Red When Children Present" at school crossings, rather than prohibiting RTOR altogether at such approaches.

The opinions of the traffic engineers contacted are perhaps the most interesting part of the survey. Only one of the 16 indicated that he was actually against the general permissive rule, and he was in Georgia where it had been in operation for only two weeks. Of the remaining 15, 11 gave it strong support while 4 were somewhat lukewarm. Five of the respondents, or nearly one-third of those questioned, volunteered the fact that the general permissive rule had won them over in actual operation after they had opposed its adoption. Given a human reluctance to admit error, such a large percentage seems very significant. No question was specifically asked about opinions before and after, and yet 5 of the engineers admitted that the problems which they had anticipated had not materialized, and that they had switched from opposition to support of the general permissive rule.

Field Studies

The field studies constituted the data collection portion of the RTOR study in Virginia. Data were collected on four subjects: (1) delay savings associated with RTOR, (2) driver acceptance of RTOR, (3) driver compliance with RTOR laws, and (4) traffic conflicts associated with RTOR. This section is an analysis of the data collected in the field studies.

Delay Data

Much of the literature suggests that the most important benefit of RTOR is the savings in time and energy it allows. The purpose of collecting traffic delay data was to determine if RTOR significantly saves time and energy at intersections in Virginia and to determine the impact of these savings on a statewide basis.

As discussed in the Methodology, time savings attributed to RTOR were empirically derived by measuring right turn vehicle delay at nine intersections in Virginia (shown in Table 3) using the before and after technique. Of the 18 approaches studied, one had a continuous green arrow, another had previously been signed to permit RTOR, and still another was not signed in the after period. Thus, only 15 approaches could be used to determine time and energy savings. The mean time saved per RTOR approach was then multiplied by the total number of approaches to examine the statewide savings under both the sign permissive and general permissive laws.

Before reliability can be placed in the results obtained from the before and after technique three conditions must be satisfied. First, the sample must be representative of the signalized intersections in Virginia. Secondly, the sample must be large enough that the results will be statistically significant. Thirdly the sample must be drawn from the same population so that all variables — traffic volumes, turning movements, signal timing, and number of lanes — are similar in the before and after periods.

Thus, the first task in the analysis procedure was to determine if the 15 study approaches would provide delay data that were statistically meaningful to describe the average or mean delay of the population of delayed right turning vehicles in the state.

To determine this, all delay data from the before phase of the study were used as a sample in an estimation of the mean. These data are shown in Appendix Tables P-1 and P-3. The mean delay at the 15 approaches was 25.85 seconds and the standard deviation was 10.63. Using these values with a confidence level of 90% and an error in the estimate of 20%, the number of approaches needed to ascertain the mean delay of the population was calculated as follows:*

Error in Estimate, d = 20% = 25.85 x 0.20 = 5.17 sec.

$\alpha = 0.10$

$t_{0.95}$ for 14 degrees of freedom = 1.761

$$\text{thus, } n = \text{number of approaches needed} = \frac{(1.761)^2(10.63)^2}{5.17^2} = 13$$

Therefore, it can be concluded with 90% confidence that for a sample size of 13 approaches, the mean delay of the population can be expected to fall between 20.68 and 31.02 seconds. As 15 approaches were studied, the minimum requirement for statistical significance was satisfied. Further significance is given to these results by reviewing the findings of other studies. For example, the Minnesota Highway Department conducted a right turn vehicle delay study at 10 approaches in Minnesota and obtained a mean delay before RTOR signing of 24.51 seconds, which is comparible to the 25.85 seconds obtained in this study and well within the interval described above.[18] Benke and Ries again repeated the experiment at 12 sites in 1972 in Minnesota and obtained a mean delay (peak and off peak) of 27.30 seconds, which is again well within the estimated population interval.[19] Although several other studies of vehicle delay have been published, a review of this literature indicated the results could not be directly compared due to differences in study techniques.

Once the adequacy of the sample size is determined, the next test of reliability in utilizing the before and after technique is to assure that both sets of data were drawn from the same population. For this purpose, if it is shown that the traffic volume, the number of right turns, the number of captives, and the number of delayed right turns are not significantly different in the before and after studies, then the data were drawn from the same population, and, therefore, any statistical difference in vehicle delay times must be attributed to RTOR. (It should be noted that care was taken to ensure that other variables, such as signal timing and number of lanes, remained the same in both study periods.) Using the paired t test to examine the difference in means at a confidence level of 99%, it was found that there were no significant differences in any of the variables except delay times, which were significantly lower in the after study, as can be seen by the summary of the results of these tests shown in Table 7. Thus, since delay was the only parameter to change significantly, it was concluded that RTOR significantly reduces delay for right turning vehicles.

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* This procedure is outlined in most statistic texts. For example see reference (17).

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TABLE 7

SIGNIFICANCE OF DELAY TIME
($t_{0.99}$ for 14 degrees of freedom = 2.624)

Parameter	t	Significance
Approach Volume	1.70	No
Number of right turns	0.50	No
Number of captives	-2.40	No
Delayed right turns	0.29	No
Delay time	5.30	Yes

In the after period, delay was recorded for 786 vehicles, of which 308, or 39%, made a RTOR with little or no measurable delay. In fact, the average time for a RTOR maneuver when the intersection was clear was between 1 and 2 seconds. In keeping with a conservative approach to minimize delay, 2 seconds was recorded as the delay for the 308 motorists who made the RTOR maneuver immediately after arriving at the intersection. The stopwatch technique proved quite effective for recording vehicle delays as 717 of 1,045 delayed vehicles (or 69%) were measured in the before period and 786 of 1,035 (or 76%) were measured in the after period.

During the period before RTOR signing, delays of 717 vehicles were measured at 18,555 seconds for a mean delay per delayed right turning vehicle of 25.9 seconds. In the after period, the 786 vehicles measured had a total delay time of 9,264 seconds and a mean delay of 11.8 seconds. Thus, the average delay saved per right turning vehicle was 14.1 seconds a savings of 54%. This saving is somewhat greater than that found in previous studies; however, the difference may be caused by the fact that previous studies did not utilize the wide cross section of variables that were included in this study, and that different data collection processes and methods were used. For purposes of comparison, a summary of time savings from other studies is shown in Table 8.

The Minnesota studies utilized approximately the same procedure used in this study to determine time savings per delayed vehicle; however, their data were collected at urban intersections where traffic volumes were heavier and delay times greater than in the Virginia sample, which included rural and suburban approaches as well as urban approaches. In fact, as shown in Table 9, the mean savings in urban areas in Virginia was only 9.69 seconds, a result very similar to the Minnesota findings. The data in Table 9 indicated that RTOR is not only applicable to urban areas, but is effective in reducing delay in suburban and rural areas, where traffic volumes are normally lower.

TABLE 8

SUMMARY OF AVERAGE TIME SAVED PER DELAYED RIGHT TURN VEHICLE

Author and study location	Year	Type of traffic environment and signal control	RTOR signing rule	Mean time saved per right turn vehicle (seconds)
Ray;(5) Berkeley, California	1956	Central business district, fixed time traffic signals	General permissive	7.8 peak traffic flow period 9.6 off peak traffic flow period
Minnesota(18) Department of Highways	1965	Urban; both fixed and traffic actuated signals	Sign permissive	12.0 peak period 10.4 off peak period
Minnesota(19) Department of Highways	1972	Urban; both fixed and traffic actuated signals	General permissive	7.0 peak period 10.7 off peak period
May;(4) Lafayette, Indiana	1974	Central business district	General permissive	0.15 (6.4) peak and off peak periods

TABLE 9

TIME SAVINGS BY LOCATION TYPE
VIRGINIA BEFORE AND AFTER DATA

Location	No. Approaches	Time saved per delayed right turn vehicle (seconds)
Urban	7	9.69
Suburban	2	14.23
Rural	6	21.59

The next step in the analysis was to convert the time savings per delayed right turn vehicle into total savings per approach, per day. The calculations and results of this process are shown in Appendix Tables P-5 and P-6. The procedure used to compute time savings per RTOR approach per day was to multiply the 1974 approach average daily traffic (ADT) by the percentage of vehicles making right turns, then by the percentage of all right turning vehicles which were delayed and by the average time saved per delayed vehicle. (All values except the 1974 approach ADT were derived from empirical field data.) The result was applied to the number of approaches in the state to yield total time and energy savings on a statewide basis for the sign permissive and general permissive rules. These savings are discussed further in the Benefit-Cost section of the Analysis.

Several interesting relationships were noted in the delay data. Table 10 shows a comparison of the delay of right turning vehicles as a function of the type of signal (i.e., fixed, semi actuated, and fully actuated). According to these figures, both semi and fully actuated signals produce lower mean delay times than does the fixed time type signal. Furthermore, the fully actuated signals showed a greater difference in means between the before and after periods, and thus a greater savings in delay times at these locations. This is especially significant in Virginia where the inventory of traffic signals had indicated that some 1,224 signals, or 40% of the total number, were fully actuated. Benke and Ries also found that actuated signals had greater time savings than fixed time signals in their study of Minnesota intersections.(19) Some states, including Kansas, had previously not allowed RTOR at fully actuated signals. Apparently it was felt that traffic actuated signals provided such efficient flow at intersections that RTOR would be of little value. As suggested by Table 10, RTOR does save time at fixed signals but savings are greater at fully actuated signals due to longer signal cycles and short green time on minor approaches.

Another important relationship was shown by a comparison of the right turn approaches by type (i.e., right turn lane only, combined right and through lane, or combined right, through, and left turn lane), as shown in Table 11. Although the exclusive right turn lane approaches had a lower mean delay time in the after period, the greatest differences in the means was found with the combined right and through lane. It should be noted, however, that time was saved even where a single lane approach existed. Thus, it was concluded that time savings can be realized regardless of the number of approach lanes.

Although it was not possible to collect before and after delay data at the comparison approaches in Virginia, or in North Carolina, delay times were recorded (see Appendix tables Q-1 and Q-2) for these approaches and are compared in Table 12. Although the mean delay was lower in both Virginia cases, it should be emphasized that this result may be due to the sampling of only problem, high traffic volume approaches in North Carolina.

As a further observation, a comparison was made of the Virginia delay savings as a function of the length of the red phase of the signal cycle. A similar graph was developed by Ray in California(5). Using a least squares fit for a linear function, the correlation coefficient was only 0.49 for the Virginia sample. The low correlation indicates that there is not a definite relationship between delay saving and the length of the red phase in the Virginia study. This finding is probably attributed to the many variables, such as type of signal, traffic volume, and traffic composition, included in the Virginia sample.

TABLE 10

MEAN DELAY PER RIGHT TURN DELAYED VEHICLE BY TYPE OF SIGNAL

Type of Signal	Number of Approaches Studied	Before RTOR			After RTOR			Difference in Means (Seconds)
		No. Vehicles Delayed	Delay (Seconds)	Mean Delay (Seconds)	No. Vehicles Delayed	Delay (Seconds)	Mean Delay (Seconds)	
Fixed	2	117	2,846	24.3	133	2,025	15.2	9.1
Semi-Actuated	6	263	5,639	21.4	249	3,244	13.0	8.4
Fully Actuated	7	337	10,070	29.8	404	3,995	9.8	20.0

TABLE 11

MEAN DELAY PER RIGHT TURN DELAYED VEHICLE BY TYPE OF RIGHT TURN LANE

Type of Approach	Number of Approaches	Before RTOR			After RTOR			Difference In Means (Seconds)
		No. Vehicles Delayed	Delay (Seconds)	Mean Delay (Seconds)	No. Vehicles Delayed	Delay (Seconds)	Mean Delay (Seconds)	
Right Lane Only	6	364	8,393	23.0	364	3,693	10.1	12.9
Right Lane & Thru	7	193	6,262	32.4	273	2,842	10.4	22.0
Right Lane, Thru and Lert Turn	2	160	3,900	24.3	149	2,729	18.3	6.0

TABLE 12

MEAN DELAY PER RIGHT TURN DELAYED VEHICLE
SIGN PERMISSIVE VS. GENERAL PERMISSIVE

Location	Time RTOR Permitted	No. Vehicles Studied	Measured Delay (Sec.)	Mean Delay (Sec.)
Va. "After"	1 Month	786	9,264	11.79
Va. "Comp."	1 to 2 years	686	4,716	6.87
N. C.	1 Year	313	5,864	18.73

As only the delay of right turning vehicles was measured in this study, it was not possible to measure the effects of RTOR on the total volume of traffic using the intersections or on intersections' capacities. Based on observations of the data collectors, however, RTOR did have a noticeable effect on the level of service at intersections which were not operating at capacity. For example, in the before period it was frequently noted that traffic would back up beyond the length of most right turn lanes during peak hours. In the after period, however, there was not a single case of right turning traffic backing up beyond the length of the turn lane. No change was noted at intersections operating at capacity and there were very few RTOR maneuvers at these approaches during peak periods. Thus, as reported by Van Gelder, RTOR may improve the level of service but does not increase the capacity of an intersection[20]. It was also noted that RTOR was used more frequently during the off peak period than during peak hours because of the limited gaps in the cross street traffic.

Based on a before and after vehicle delay study of 15 approaches in Virginia the findings were:

(1) Statistically significant savings in right turning vehicle delay time were found attributable to RTOR.

(2) An average savings of 14 seconds per delayed right turning vehicle was found.

(3) A mean time savings of 5,647 seconds per RTOR approach per day was found.

(4) Traffic actuated signals were found to yield greater time savings with RTOR than did fixed time signals.

(5) Time savings were found on single lane approaches, combined through and right turn approaches, and exclusive right turn lane approaches.

Acceptance Data

Data derived from the field studies in Virginia and North Carolina on driver acceptance and rejection of RTOR are shown in Appendix Tables Q-1 and Q-2. A summary of the data is shown in Table 13. As expected, in the one month after period in Virginia there was little acceptance of RTOR, probably because drivers were not aware of the signs. Generally acceptance was low in the Newport News and Bristol areas where RTOR is not frequently used. It is interesting to note that there was a significant difference in the proportion of Virginia motorists who rejected RTOR at the comparison locations as compared to the North Carolina motorists at the general permissive locations in that state. Greater acceptance of RTOR was found under the sign permissive rule than under the general permissive rule. One possible explanation for this result is that signing acts as a reminder which prompts increased utilization. Another possibility is that because the general permissive rule had been in effect in North Carolina for only one year, and because it had not been generally publicized, many motorists may not have been aware of the regulation.

TABLE 13

SUMMARY OF ACCEPTANCE DATA

Location	Time RTOR Permitted	Number Rejecting RTOR	Number RTOR Maneuvers	Percentage Accepting RTOR
Va. "After"	1 Month	165	593	78.23
Va. "Comp."	1 to 2 Years	46	611	93.00
North Carolina	1 Year	61	304	83.29

Compliance Data

One of the major arguments offered by opponents of RTOR is that the maneuver dilutes the meaning of the traffic signal because motorists turn right without stopping. Compliance data were accumulated during the field studies to test this argument. By definition, compliance requires that a motorist come to a complete stop before making a RTOR maneuver. The data tabulated in Appendix Tables R-1 through R-3 and summarized in Table 14 indicate that in Virginia 3%, and in North Carolina only 2%, of the motorists did not stop before turning right on red. However, at the Virginia comparison approaches over 9% of the motorists did not comply with the stopping requirement. The reason for this larger figure is not clear. Examination of the data in Appendix Table R-2 reveals that the majority of these violations occurred on four approaches at just three intersections. The intersections are near urban areas and serve major traffic generators. All three are located well within the state, and are not near interstate routes, which reduces the possibility that foreign traffic is involved. Why these three approaches should experience poor compliance is not known. It is possible that the RTOR law is not strictly enforced at these locations, but that is only speculation.

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TABLE 14

SUMMARY OF COMPLIANCE DATA

Location	Time RTOR Permitted	Motorists Stopping Before RTOR	Motorists Not Stopping Before RTOR	
			Number	%
Va. "Before and After"	1 Month	575	18	3.04
Va. "Comparison"	1 to 2 Years	554	57	9.33
North Carolina	1 Year	298	6	1.97

The observation drawn from these data is that, generally, permitting RTOR does not apparently result in motorists turning right on red without stopping.

Another important area of concern regarding driver compliance with the RTOR law is that motorists may turn right on red where RTOR is prohibited. As illustrated in Appendix Table R-1 before RTOR was permitted at 15 approaches in Virginia, 10 out of 657 motorists (1.5%) made an illegal RTOR maneuver. All but one of these incidents occurred in Northern Virginia where RTOR is permitted more frequently than in most other sections of the state. In North Carolina only one non-RTOR approach was studied and out of 28 opportunities to turn, one motorist (3.6%) made an illegal RTOR. While this sample is too small to be of statistical significance, motorists do not seem to disregard "NO TURN ON RED" signs used under the general permissive law.

Traffic Conflict Data

As described in the Method section, the traffic conflict technique developed by Perkins[8] was used to measure the accident potential of RTOR. By using the conflicts technique to record the number of evasive maneuvers taken by drivers to avoid a collision, the type and frequency of conflicts caused by RTOR motorists could be determined. In addition, by recording conflicts at an intersection before and after RTOR signing, any changes in accident potential created by RTOR could be determined.

To determine the accident potential of RTOR for the sign permissive and general permissive rules, conflicts were taken at the 20 intersections in North Carolina and Virginia shown in Table 3. During the study, movements of over 55,000 vehicles were observed and 594 conflicts were recorded. These data are shown in Appendices T and U and are summarized in Table 15.

TABLE 15

SUMMARY OF TRAFFIC CONFLICT DATA

Location	Total Conflicts	RTOR Conflicts	% RTOR Conflicts
Virginia Before and After (new RTOR locations)	148	17	11.49
Virginia Comparison (old RTOR locations)	192	7	3.65
North Carolina (General Permissive Rule)	254	28	11.02
TOTAL	594	52	8.75

Type and Frequency of RTOR Conflicts

As illustrated in Table 15, out of 594 traffic conflicts observed, 52 involved an RTOR maneuver. Of the 52 RTOR conflicts, 14 were opposing left turn conflicts, 22 were cross traffic, 12 were rear end, and 4 involved pedestrians. The type and frequency of RTOR traffic conflicts are given in Table 16. For the purpose of clarity, the definitions of these conflicts are illustrated in Figures 1 through 6.

TABLE 16

TYPE AND FREQUENCY OF RTOR CONFLICTS

RTOR Conflict Type	Location			Total
	Virginia		North Carolina	
	Before & After (New Locations)	Comparison (Old Locations)		
Opposing left turn	1	2	11	14
Through cross traffic left to right		1	2	3
Left turn cross traffic from left		1	1	2
Right turn cross traffic	8	3	6	17
Rear end	7		5	12
Pedestrian	1		3	4
TOTAL	17	7	28	52

Although several studies have indicated that there is some correlation between conflicts and accidents, no study was found that provided correlation between RTOR conflicts and accidents. Whether a conflict results in an accident is dependent on the reactions of the drivers of the vehicles involved; however, based on the field studies it is the opinion of the observers that the relationship of RTOR conflicts and accident types would probably be similar to that shown in Table 17.

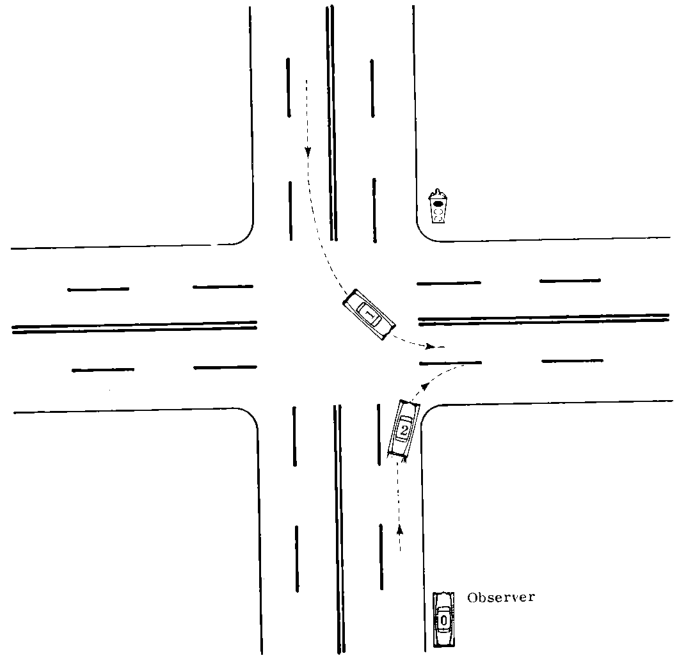

Figure 1. Opposing left turn RTOR conflict. The RTOR vehicle (No. 2) attempts to turn right on red and must brake to avoid hitting vehicle No. 1 making a left turn on a green signal.

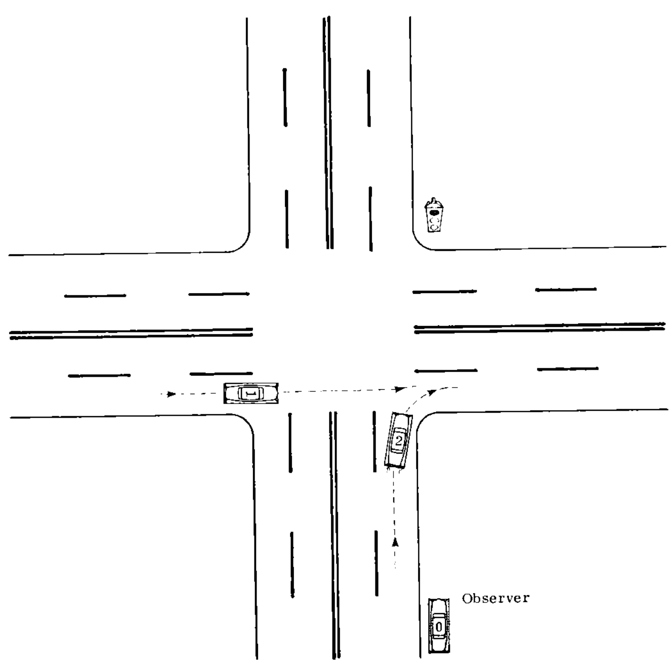

Figure 2. Through (left to right) cross traffic RTOR conflict. The RTOR vehicle (No. 2) attempts an RTOR maneuver and must brake to avoid hitting vehicle No. 1 travelling through on a green signal.

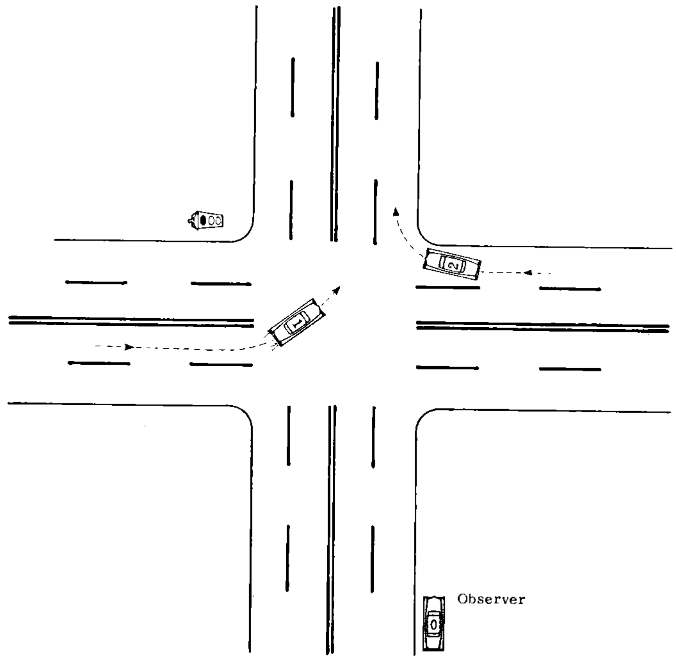

Figure 3. Left turn cross traffic (from left) RTOR conflict. Vehicle No. 1 making a left turn on a green signal must brake to avoid a collision with vehicle No. 2 attempting to turn right on a red signal.

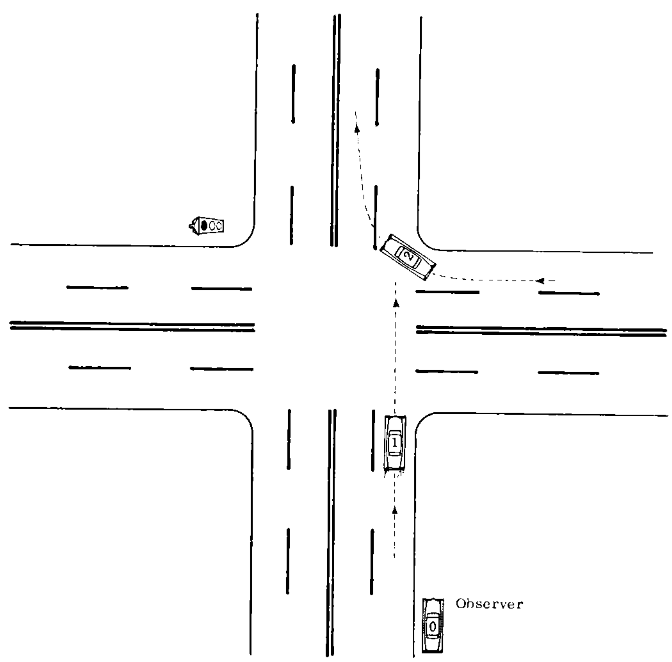

Figure 4. Right turn cross traffic RTOR conflict. Vehicle No. 1 travelling through the intersection on a green light must brake to avoid a collision with vehicle No. 2 making a right turn on a red signal.

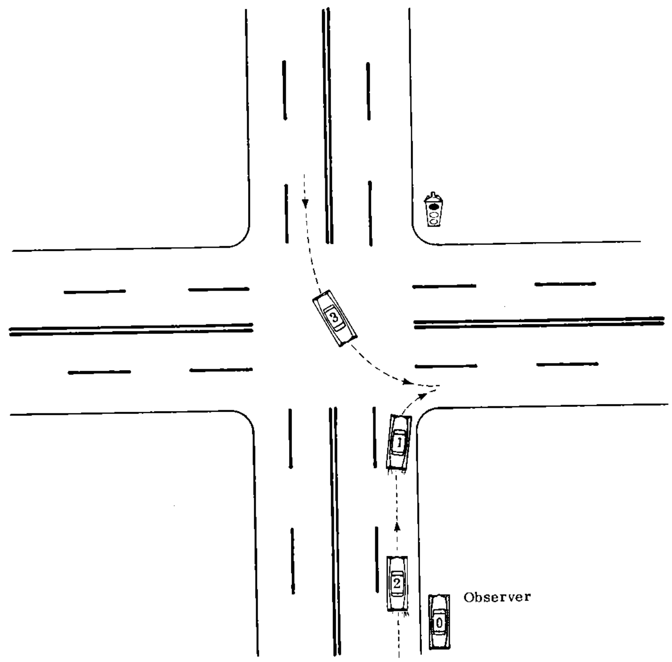

Figure 5. Rear end RTOR conflict. Vehicle No. 1 begins to make an RTOR maneuver but stops due to traffic in the intersection (vehicle No. 3). Vehicle No. 2 anticipates vehicle No. 1 will complete the turn and begins to move to the head of the queue but must apply brakes to avoid a collision with No. 1 when No. 1 stops.

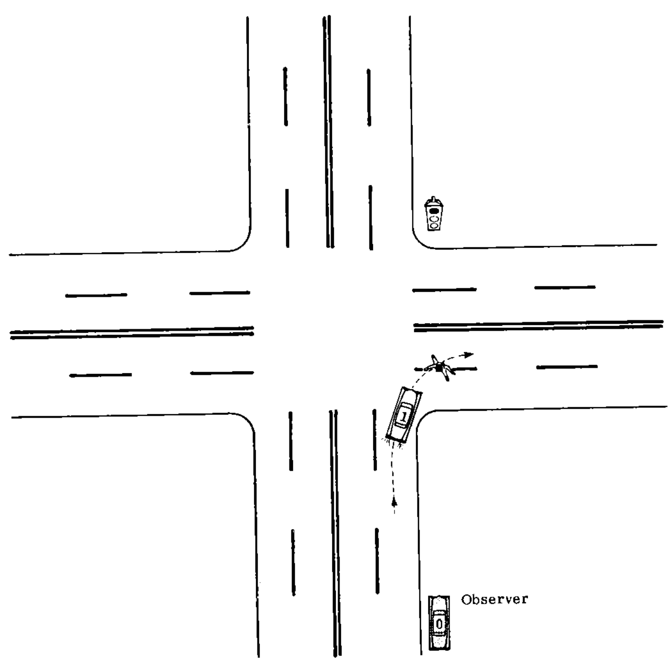

Figure 6. Pedestrian RTOR conflict. The RTOR vehicle (No. 1) attempting to turn right on a red signal must brake to avoid hitting a pedestrian.

TABLE 17

SUGGESTED RELATIONSHIP OF TYPE OF RTOR CONFLICT AND TYPE OF RTOR ACCIDENT

Conflict Type	Suggested Accident Type
Opposing left turn	Angle
Through cross traffic left to right	Angle
Left turn cross traffic from left	Angle
Right turn cross traffic	Rear End and Angle
Rear end	Rear End
Pedestrian	Pedestrian or Rear End

If the relationship suggested in Table 17 is valid, then the majority of RTOR accidents should be rear end and angle type collisions. However, to determine if the relationship proposed in Table 17 has an empirical basis, an analysis of the RTOR accidents was made at the accident locations studied in Virginia. (Due to time constraints it was not possible to collect before and after accident data at the same intersections at which the conflict data were collected.) It is interesting to note that of the 10 RTOR accidents reported at 20 intersections, there were 5 angle collisions, 4 rear end crashes and 1 sideswipe accident. All 10 RTOR accidents involved minor property damage with no fatalities or injuries. Thus, the accident data seem to suggest that there is reason to believe that the conflict technique was accurate in identifying the accident potential of RTOR.

It should be noted that of the 52 RTOR conflicts observed only a few were of the near miss type. This finding suggests that RTOR should not create a serious accident problem. Although the RTOR conflict data do suggest that angle collisions are possible, it should be noted that in most cases the vehicle speeds are low and only minor damage would be expected. As noted above, the Virginia RTOR accident data consisted of only minor property damage accidents.

Another interesting relationship found in RTOR conflict data was that in both the Virginia and North Carolina locations RTOR conflicts occurred at only a few approaches. For example, in the before and after conflict study in Virginia only 5 approaches out of 17 had RTOR conflicts. An attempt was made to determine if similar factors (i.e., speed limits, number of lanes, etc.) existed at intersections with RTOR conflicts, however, there does not seem to be a common variable. One observation was that the numbers of RTOR conflicts were greater at intersections with heavy traffic volumes.

During the early phase of this study the question of whether there were more RTOR conflicts under the sign permissive or general permissive rule was raised. As shown in Table 15, the percentage of RTOR conflicts at the North Carolina approaches (general permissive rule) is not different from that at Virginia locations. Therefore, the accident potential of RTOR appears to be the same, regardless of which RTOR law is used.

Changes in Accident Potential Created by RTOR

An evaluation of the changes in accident potential at intersections as measured by traffic conflicts was made at 17 approaches in Virginia using the before and after technique. A summary of the before and after data is given Appendix Tables T-1 and V-1.

As noted in Table T-1, there were 171 conflicts in the before period and 148 after RTOR signing, a decrease of 13.5%. Traffic volumes at these locations decreased 2.5%, which indicates that RTOR may decrease accident potential at intersections. The means of before and after traffic volumes and conflicts were statistically tested (paired t-test) and the differences were found to be not significant.

As there appeared to be a trend of decreasing RTOR accident potential at intersections, the data were further analyzed to determine what type of conflict changed due to RTOR. A summary of the before and after distribution of traffic conflicts by type is given in Table 18. The most noticeable change was that rear end conflicts decreased in the after period and right turn cross traffic conflicts increased. However, none of the changes were statistically significant.

TABLE 18

DISTRIBUTION OF TRAFFIC CONFLICTS
(VIRGINIA BEFORE AND AFTER APPROACHES)

Conflict Type	Before Total Conflicts		Before RTOR Conflicts	After Total Conflicts		After RTOR Conflicts	Z Statistic
	No.	%		No.	%		
Weave	11	6.43		8	5.41		0.38
Right turn from wrong lane	1	0.58		6	4.05		2.11
Opposing left turn	20	11.71	1	19	12.84	1	0.31
Right turn cross traffic	3	1.75	3	9	6.08	8	2.03
Rear end	129	75.44		103	69.59	7	1.17
Pedestrian	7	4.09		3	2.03	1	1.05
TOTAL	171	100.00	4	148	100.00	17	

Although the difference is not significant, an important observation is that the number of rear end conflicts decreased after RTOR signing. This decrease appears reasonable, as reduced vehicle delay created by RTOR would be expected to decrease the opportunity for a rear end collision. A further discussion of accidents as related to traffic conflicts is presented in the Accident Analysis section of this report.

The traffic conflict study also revealed the following items concerning driver behavior.

(1) RTOR is prohibited in a number of states where a separate signal phase permits left turns or pedestrian movements. Based on the before and after study of conflicts at 6 approaches where a separate left turn phase could create a conflict with RTOR vehicles, only 1 conflict of this type was observed in the before period and 2 were noted in the after study. Thus, permitting RTOR at approaches where left turning vehicles oppose the RTOR maneuver does not appear to create a potential accident problem. Also, it was noted that RTOR vehicles did not delay left turning vehicles.

RTOR is not usually found in Virginia in areas with heavy pedestrian and vehicle traffic volumes. Therefore, the Virginia data are not representative of pedestrian-vehicle conflict situations found in large urban areas. Several intersection approaches with separate pedestrian signals were studied in Raleigh, North Carolina, and no problems were observed. There is, therefore, no evidence to suggest RTOR should be prohibited at all locations with exclusive pedestrian phases.

(2) One problem of RTOR offered by the Virginia traffic engineers was that RTOR influenced some motorists to stop on green as well as on the red signal. During the studies in North Carolina and Virginia, movements of over 55,600 vehicles were recorded and only 1 incident of a motorist stopping on green was noted.

(3) Another intuitively expected effect of RTOR was that the RTOR vehicle would lure the following vehicle through the intersection. During the study, only 1 incident of this nature was noted.

Summary and Conclusions

1. Approximately 11% of all conflicts observed at intersections involved an RTOR maneuver. The proportion of conflicts was the same under the general permissive and sign permissive rules.

2. Based on an analysis of RTOR conflicts in Virginia and North Carolina, the majority of collisions involving an RTOR vehicle are expected to be rear end and angle type accidents. Virginia accident data were found to support this theory.

3. RTOR conflicts occurred at only a few approaches. A common variable to identify the characteristic(s) which create RTOR conflicts was not found.

4. There was a 13.5% decrease in traffic conflicts in a before and after study of 17 approaches in Virginia, but this reduction was not statistically significant.

5. There was a decrease in rear end conflicts and an increase in cross traffic conflicts after RTOR was permitted but these changes were not statistically significant.

It can be concluded that RTOR does not adversely affect accident potential at intersections. In fact, there is an indication that RTOR may actually decrease the accident potential.

Accident Data

The analysis of accidents under RTOR will be divided into two parts. First, literature concerning both the general permissive and the sign permissive rules will be briefly reviewed. Second, Virginia's study of the effects of RTOR signing will be outlined and the findings disclosed.

Review of the Literature

There are several methodological requirements for studies attempting to isolate and assess the effects of RTOR on accident experience at particular locations, and the findings of the studies reviewed here should be interpreted in light of the adequacy of their methodologies. The two basic requirements for studies attempting to assess RTOR are discussed below.

(1) Design — First, it is necessary to compare the accident experience of a particular location under RTOR with what would have occurred had RTOR not been instituted at that location. There are two methods for making such a comparison. Under the first method, two study locations could be selected so that they are alike in every characteristic related to RTOR and to accidents. One is then signed for RTOR while the other is not. The numbers and types of accidents occurring at each are compared. This method is difficult to implement: first, because it is difficult to find intersections so carefully matched, and second because even if matches are available, the pertinent variables for matching are not always known. Because of these difficulties, another method is more often used. This is a longitudinal design comparing accident experience for the same site at two different periods of time. In the case of RTOR, one period would be before and one after RTOR was permitted at the intersection to be studied. While this method eliminates the differences in locations, it does not rule out differences at the same location across time. Therefore, conditions such as traffic volumes, which change with time, should be taken into account. Also, to avoid cyclical variations, the before and after study periods should be chosen so that they are equal in length and cover the same months of the year.

(2) Sample Selection — Ideally, sites should be randomly selected so that they adequately represent the population from which they are drawn. However, this is rarely possible in the case of RTOR because of such problems as inadequate record keeping. If selection is made on a nonrandom basis, the criteria for selection should be explicit and should not be expected to affect the variables to be measured and compared across time — in this case, accidents.

Because only one of the seven RTOR studies available met both of these criteria, it would appear that most of the studies cannot be considered conclusive. However, it should be noted that all but one of the studies reached similar conclusions. This uniformity of results makes the studies, taken as a group, of more value as evidence than each would individually be. The consensus of the studies, in spite of individual deficiencies, provides evidence that is at least suggestive of the impact of RTOR on accidents.

Accident Studies Under the General Permissive Rule

There are three major studies of RTOR under the general permissive rule, none of which present before/after comparison data. In California, the state which was the major proponent of the general rule, RTOR was initially studied in 1956[5]. The accident experience of 75 nonrandomly chosen intersections was monitored for three years while under the general permissive rule. It was found that 0.3% of all crashes and 0.8% of all injury crashes were RTOR related. Ray's interpretation of this finding was that, "this appears to be a negligible amount of the total accident experience at the intersections studied." While this interpretation seems intuitively valid, without historical data to confirm the extent of past accident experience for these intersections, the significance of these figures cannot be determined. The California study did find that RTOR accidents were underrepresented in terms of right turning volume. However, Ray's conclusion that "right turn on red does not add to accident hazard at signalized intersections" has not been proven by his study. Both Colorado and North Carolina[21,22] employed a similar, post RTOR design, and both had similar findings. However, since none of these studies included a basis for comparison, it is impossible to quantify the effect of the general permissive RTOR rule on accidents from their results.

Accident Studies Under the Sign Permissive Rule

Several studies comparing before and after periods have been conducted on the sign permissive rule. Two studies were conducted in Indiana by May[4] on a total of 54 intersections and covering five years. In the first study, covering the period one year before and one year after RTOR, May found that there were more personal injury accidents but fewer property damage accidents and fewer total accidents after RTOR. Almost identical results were obtained in the second study, which covered the period two years before to two years after RTOR signing. In no case was the change in accidents statistically significant, though the reduction in total accidents in the second study approached significance (p .07). Thus the report concluded that there was no signficant change in accident frequency after RTOR. However, there were two flaws in these studies. First, only high accident locations were studied because of the availability of records, and second, the accident figures were not adjusted for traffic volume changes during the before and after periods.

An Oklahoma study reached much the same conclusion as the Indiana study.[23] Seventy-nine intersections where all four approach legs were signed for RTOR were studied for a period of one year before and one year after RTOR. The accident rate, which was adjusted for changes in traffic volume, decreased by 4.7% after RTOR. A similar study in Minnesota[18] showed no change in the accident experience before and after RTOR signing. However, the Minnesota findings are not conclusive because some data are missing.

Only one study reviewed reported an increase in accidents. May studied the accident experiences at four nonrandomly selected intersections in Fort Lauderdale, Florida, and found total accidents increased 21% while rear end accidents decreased 31%.(24) These figures, which are in opposition to all previously reviewed materials, may be invalid due to the small number of intersections studied (since an increase from 5 accidents to 6 constitutes a 20% increase) or due to selection procedures. However, this study does suggest that the distribution of types of accidents may be affected by RTOR.

Overall, all but one of the studies agree in their findings that RTOR has not had a significant adverse impact upon accident experience at signed intersections.

Virginia RTOR Accident Analysis

The review of the literature concerning RTOR revealed that while no studies were completely successful in isolating and quantifying the highway safety impact of RTOR signing, taken together they suggest that RTOR (as it has been used in the past) does not significantly increase accidents at signed intersections. To determine if this were true in Virginia, the accident experience of 20 RTOR signed intersections was examined. These intersections were chosen based on various criteria, (see page 11) including availability of data, construction or other site changes during the study period, and time of RTOR signing (so as not to overlap with the energy crisis). While these sites were not randomly chosen, the authors believe that they were chosen based on criteria which would not affect accident experience, and which would avoid confounding. It should be noted, however, that since very few Virginia intersections are signed for RTOR, those that are should be classified as relatively safe for RTOR as determined by local traffic engineers. Overall, the accident experience of these intersections is relatively limited. Thus, any generalizations made should apply only to intersections which are similar to those chosen for this study. An inventory of those sites, including such information as number of RTOR signed legs, type of traffic signal employed, traffic volumes, and speed limits, appears in Appendix W. The accident experience for each of these 20 intersections was monitored for one year before the RTOR signing date and one year after, using FR300 accident report forms as source documents.

Findings

Traffic crashes occurring at the selected intersections during the study period were classified according to whether they involved fatalities, personal injuries or property damage, and whether they occurred during the before or after period. These findings appear in Table 19. There were no traffic fatalities during the study period. Accidents resulting in personal injury increased from 43 before RTOR to 60 after, while the number of persons injured increased from 69 to 72. Property damage crashes (including all those not listed as involving a fatality or personal injury) increased from 265 before to 277 after signing, while actual property damage increased from $161,245 to $170,807. Total crashes increased by 29, from 308 before to 337 after RTOR.

TABLE 19

CRASH TYPE BY STUDY PERIOD, BEFORE AND AFTER RTOR

Category	Before RTOR Signing	After RTOR Signing
Fatal Crashes	0	0
Personal Injury Crashes	43	60
Persons Injured	69	72
Property Damage Crashes	265	277
Amount of Property Damage	$161,243	$170,807
Total Crashes	308	337

Crashes occurring in the after period were then analyzed as to their RTOR involvement and categorized as a definite RTOR crash, a possible RTOR crash, or a non-RTOR crash (all crashes in the before period were considered non-RTOR even though illegal RTOR maneuvers were possible). The results of this analysis are shown in Table 20. There were a total of 10 crashes that definitely involved RTOR; all were property damage crashes. Another 5 accidents, 3 involving property damage and 2 involving single injuries, were classified as possible RTOR crashes. RTOR property damage, including both definite and possible categories, totalled $4,844.

As mentioned previously, in order to accurately assess the effects of RTOR on accident experience, conditions in the before and after period should be similar in all aspects except RTOR signing, so that any changes detected can be attributed to the maneuver. While attempts were made to screen out intersections where changes occurred during the study period, one factor obviously changes across time — traffic volume. To control for this variable, accident rates, rather than absolute numbers of accidents, were compared for each intersection (see Table 21).

TABLE 20

RTOR TOTAL CRASH INVOLVEMENT

Categories	"Definite" RTOR Crashes		"Possible" RTOR Crashes		Non-RTOR Crashes	
	Before RTOR Signing	After RTOR Signing	Before RTOR Signing	After RTOR Signing	Before RTOR Signing	After RTOR Signing
Fatal Crashes	0	0	0	0	0	0
Personal Injury Crashes	0	0	0	2	43	58
Property Damage Crashes	0	10	0	3	265	264
Total Crashes	0	10	1	5	308	322
Amount of Property Damage	$0	$2,419	$0	$2,425	$140,615	$161,461
Persons Injured (Includes 3 non-RTOR pedestrian Crashes)	0	0	0	2	69	70

TABLE 21

INTERSECTION TOTAL CRASH RATES
(YEARLY CRASHES PER MILLION INTERSECTION TRIPS)

Intersection Number	Intersection Crashes		Intersection Crash Rate	
	Before RTOR Signing	After RTOR Signing	Before RTOR Signing	After RTOR Signing
1	14	19	1.54	1.96
2	21	23	1.47	1.53
3	9	16	0.90	1.70
4	4	2	1.34	0.64
5	14	10	1.78	1.24
6	64	60	3.49	3.15
7	16	14	1.61	1.30
8	9	12	1.36	1.64
9	9	5	1.17	0.65
10	11	20	1.74	2.94
11	6	11	0.90	1.59
12	12	8	2.13	1.30
13	6	6	2.09	1.94
14	37	34	3.05	2.79
15	15	26	1.69	2.71
16	4	5	0.49	0.53
17	18	18	1.76	1.66
18	23	28	2.01	2.30
19	8	10	1.25	1.50
20	8	10	1.36	1.55
TOTAL	308	337	1.79	1.86

The before and after crash rates were statistically tested and found not to be significantly different. Thus, while the total number of intersection crashes increased under RTOR, this increase was not significant. In addition, when accidents were tested by type (personal injury and property damage) no significant differences were found between the before and after accident rates for any type of accident. From these findings it was concluded that for the Virginia intersections studied RTOR signing did not result in an increased accident experience.

Several variables were then examined to determine if they had any effect upon accidents under RTOR. First the relationship between speed on both the RTOR and cross leg of the intersection and its accident experience were examined (see Appendix X). Speed situations were classified into three groups: (1) intersections where RTOR vehicles travel from a roadway signed for a lower speed limit to one signed for a higher limit, (2) intersections where RTOR vehicles travel from a roadway signed for a higher speed limit to one signed for a lower speed limit, and (3) intersections where both the RTOR and cross legs are signed for the same speed limit. Secondly, approaches were categorized as to whether they were adjacent to other RTOR legs, and as to whether they were opposite an approach with a protected left turn maneuver. These factors were tested using analysis of variance and none were found to significantly affect crash rates before or after RTOR signing.

All of the 10 definite RTOR crashes occurred at 4 intersections, with from 1 to 4 crashes occurring at each site. Thus, 100% of the definite RTOR crashes occurred at only 9% of the studied intersections. It would seem unlikely that RTOR crashes would recur at these specific sites unless there was some characteristic of these locations that makes them inherently dangerous for RTOR maneuvers. If such characteristics exist, this fact would be important in determining criteria for prohibiting RTOR signing. Table 22 summarizes information concerning these 4 approach legs. While no overall pattern is discernible, some observations can be made concerning these RTOR involved intersections. While 100% of the RTOR accident intersections employed a fully actuated traffic signal, only 75% of the total number of studied intersections used this type of signal. About 75% of these intersections recorded a relatively high right turn volume while only about 50% of the total intersections reported a similar finding. Also, while 3 of the RTOR accident intersections had volumes of 15,000 vehicles per day, only 50% of the total intersections had volumes that high. In terms of speeds, 10% of all intersection legs were signed for 25 mph on the RTOR signed leg and 35 mph on the cross leg; 50% of the RTOR accident involved legs were similarly signed. Unfortunately, no definite conclusions can be drawn from these data.

The 10 to 15 RTOR accidents that occurred during the study period constituted 3% to 4% of all the accidents that occurred during that period. From that fact it might be assumed that adoption of RTOR would increase accidents statewide by 3% to 4%. However, there is evidence that this is not the case. Data collected in Virginia as well as in other states have shown no evidence of a significant change in total accidents. Apparently a shift rather than an increase in accidents occurs as a result of RTOR. To test this possibility a compilation was made of accident data, as well as conflict data, broken down by type,and is presented in Table 23.

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TABLE 22

SELECTED CHARACTERISTICS OF APPROACH LEGS
INVOLVED IN DEFINITE RTOR ACCIDENTS

Characteristic	1-Route 636-WB	15-Route 1270-WB	18-Route 1-SB	20-Route 620-WB
Number of Definite RTOR Crashes	3	4	2	1
Area	Suburban	Suburban	Suburban	Rural
Intersection Type	T	Cross	Cross	Cross
Signal Type	Fully Actuated	Fully Actuated	Fully Actuated	Fully Actuated
Speed Limits (mph)				
1) RTOR Leg	25	25	35	40
2) Cross Leg	35	35	25	45
Number Approaching Traffic Lanes	2[a]	2[a]	3	2[a]
Right Turns are Made on One Traffic Lane	No	No	No	Yes
Opposing Left Turn Arrow	No	No	Yes	No
Percent Right Turn Traffic (App.)	50%	30%	20%	30%
Traffic Volume on Intersection Street (App.)	15,000 VPD[b]	15,000 VPD	15,000 VPD	12,000 VPD
Restrictive Geometrics	Yes	No	No	No
Sight Distance[c]	Good	Good	Good	Poor

a One plus right turn lane

b VPD — vehicles per day

c Sight distance — adequacy was determined by standards subsequently recommended in this study

TABLE 23

ACCIDENT AND CONFLICT DATA BY TYPE

Accident Data					
Type	Before RTOR		After RTOR		Z Statistic
	Number	Percent	Number	Percent	
Rear End	83	46%	79	39%	1.37
Angle	69	38	86	42	.80
Sideswipe	14	8	22	11	1.00
Fixed Object	5	3	7	4	.56
Other	9	5	9	4	.47
TOTAL	180	100%	203	100%	

Conflict Data					
Type	Before RTOR		After RTOR		Z Statistic
	Number	Percent	Number	Percent	
Rear End	129	75%	103	70%	1.17
Opposing Left Turn and Cross Traffic	23	14	28	19	1.34
Weave and Right Turn from Wrong Lane	12	7	14	9	0.79
Other	7	4	3	2	1.05
TOTAL	171	100%	148	100%	

As can be seen from Table 23, rear end conflicts decreased during the after period, and the same is true of rear end accidents. However, left turn and cross street conflicts increased and this increase is reflected in an increase in angle accidents, the type most likely to result from these conflicts. In addition, weaving and right turn from the wrong lane conflicts increased as did sideswipe accidents — the type accident with which these conflicts are associated. It is important to note that none of the changes shown in the table were statistically significant. Nevertheless, a trend is visible which lends some credence to the belief that RTOR causes a shift in accident type rather than an increase in accident frequency.

Summary

To isolate the effects of RTOR signing in Virginia, the accident experiences of 20 selected intersections were studied for one year before RTOR signing and for one year after. While this sample is biased somewhat toward the selection of safer intersections (those which would best accommodate RTOR) this bias applies for both the before and after periods and is therefore adequately controlled. The reader is cautioned to remember that generalizations from these results should be applied only to intersections similar to those in the study group.

The following findings are noted.

(1) While the absolute numbers of crashes increased between the before and after periods, the difference was not significant.

(2) Controlling for increases in traffic volume across time, numbers of crashes were converted into accident rates, and there were no significant differences between the before and after crash rates.

(3) Speeds on both RTOR and cross legs of signed intersections did not significantly affect before and after crash rates, nor did categorizing approaches as adjacent or non-adjacent to RTOR, or as being opposite an approach allowing a protected left turn maneuver.

It can be concluded from these findings that RTOR, as established thus far in Virginia, has had no significant adverse effect upon accident experience.

Cost-Benefit

Most of the information included in the cost-benefit analysis was obtained by actual observation (field studies of average time delays) and from a questionnaire sent to traffic engineers across the state. However, a few of the items are estimates using the best available data. A brief explanation is given for how each item in the analysis was determined. The results of the analysis give the economic value of each of the three alternatives.

The cost of installation of each new right turn on red sign was determined from the cost information supplied by the traffic engineers, town managers, and traffic sign supervisors who responded to the questionnaire. In most cases the questionnaire was completed by a traffic engineer, though in smaller towns the information was often supplied by the town manager. An average cost per existing RTOR sign was computed from the data collected, and the result (including study cost of the intersection traffic patterns) was the following:

Average labor	$ 9.42
Material (sign face, metal, and post or hanger)	21.55
Study of intersection	18.33
Total Cost	$49.30≈$50.00/sign

This figure is probably a little high since early studies of intersections are generally more expensive than later ones. However, in keeping with a conservative approach, this figure was used in all computations. Reported labor costs varied somewhat because of different logistical methods used in installing the signs. Some areas install the signs only when a minimum number of signs have been approved and thus reduce the cost per sign. Other jurisdictions install signs immediately upon approval and thereby maximize the cost. For the purposes of this study, the cost for installing a "NO RIGHT TURN ON RED" sign is assumed to equal the cost of installing permissive RTOR signs.

The answers to the questionnaire also supplied data on the number of traffic approaches to be considered in determining total cost figures for the state. The total number of traffic approaches in Virginia, 11,361, minus those approaches at which RTOR is not possible because of one-way streets or other physical factors, 1,621, yields a figure of 9,740 approaches at which RTOR is feasible. Of these, 839 were signed to allow RTOR as of June 20, 1975. If RTOR were abolished, these 839 signs would have to be removed. A cost of approximately $20 per sign was believed to be a reasonable removal expense considering the labor involved and the expense of reworking the sign face, Alternatively, if the general permissive rule were adopted, the permissive RTOR signs would have to be removed and a probable maximum of 20% of the 9,740 possible approaches would have to be signed to prohibit RTOR. (The 20% value is derived from evaluating the experience of other states that recently passed general permissive laws and that prohibit RTOR at approximately 20% of the possible approaches.)

Sign maintenance expense must also be considered under either the sign permissive or general permissive rule. A figure of $3 per sign was estimated to be reasonable for right turn on red signs (sign permissive). This average figure would include signs which would need no maintenance as well as those requiring total replacement. Since under the general permissive rule, the "NO RIGHT TURN ON RED" signs would be important for highway safety, increased maintenance funds would have to be budgeted. An average figure of $10 per sign would not appear unreasonable in that case.

An important consideration in this cost analysis was possible expenses incurred as a result of RTOR accidents (those which definitely involve RTOR vehicles). As was shown in the accident analysis, only 10 definite RTOR accidents were found in the study of 20 RTOR intersections during a period of one year both before and after RTOR signing. There were no fatal or injury accidents and property damage amounted to a total of $2,419 (average damage per accident = $242). The 20 intersections studied included a total of 43 approaches at which right turn on red is allowed. To determine a figure for potential accident costs over the entire state at a level of RTOR implementation of 50% (the maximum economical percentage using the sign permissive rule — see Methodology section), the total accident damage figure for these 43 approaches was multiplied by a factor of 113 (number of RTOR approaches under the 50% approximation, 4,870,divided by the number of approaches studied, 43, yields 113). Statewide property damage was then computed to be approximately $273,300 per year.

If the general permissive rule were adopted, RTOR would likely be permitted at approximately 80%, or 7,792, of the eligible approaches in the state. The total potential cost of accidents involving RTOR vehicles would then be $437,800 per year. (Total accident damage figure for 43 approaches, $2,419, multiplied by a factor of 181 arrived at by dividing the 7,792 approaches where RTOR would be permitted by the 43 approaches studied.) Though this figure is much higher than that reported by other states with general permissive laws, it was used in the study in order to maintain a safety oriented, conservative approach. These figures do not mean that the state would incur an additional $437,800 a year in accident costs under the general permissive rule. The accident analysis did not reveal a statistical difference between total accident costs (including all accidents of every type) during the before period as compared to the period after RTOR signing. However, the right turn on red maneuver now is a part of the total accident profile and a cost is assigned to it. There is evidence of some shift in accident types at the study intersections between the two periods (a slight decrease in rear end accidents and an increase in angle accidents was noted, however, neither was statistically significant) as well as a slight decrease in the average accident cost after RTOR signing. (The reason for the decrease in costs per accident is uncertain; however, it could mean that drivers are more cautious and alert at RTOR intersections. This factor was not studied here.) Also, it is important to note that with RTOR allowed at 839 approaches in Virginia already, total right turn on red accident costs probably exceed $47,000 now (839/43 = factor of 19.5 to be multiplied by $2,419).

A change in the automobile insurance premium rates by the major companies operating in Virginia (caused by any assumptions regarding accident potential in states which allow RTOR) would also have to be considered as a possible cost or savings to Virginia motorists resulting from RTOR legislation. To determine the effect on premium rates, representatives of several major companies, such as State Farm and Hartford, were contacted. No increases have been requested in any state where the sign permissive or general permissive rules are used. None of the representatives contacted knew of any concern by the companies regarding this maneuver. For this reason, no increase or decrease in insurance costs were included in this analysis.

On the positive side, allowing right turn on red saves a considerable amount of traffic delay time. This delay time could be used for more productive purposes whether at home or at work, and should be computed at some dollar value to Virginia motorists. To get as accurate an estimate as possible of delay saved, 15 approaches were studied across the state both before and after RTOR signing. These intersections included both 4-leg and 3-leg groups with both fixed time and actuated signals. It was the opinion of the research engineers that this sample was representative of Virginia's intersections, and that time delay savings found here could be extrapolated over the entire state to get a reasonable estimate of total time saved statewide. The field data revealed that a total of 84,710 seconds per day were saved at the 15 approaches after RTOR signing. This yields an average time saved per day per approach of 5,647 sec. At $2.10 an hour (minimum wage rate) and 365 days a year these figures give a yearly savings of $1,202 per approach per year due to RTOR. If Virginia were to reach 50% implementation of RTOR (4,870 approaches allowing RTOR), the statewide time/dollar saving would be $5,853,700 per year. At the 80% level of implementation which could be expected if the general permissive rule were enacted, total yearly statewide time savings would be valued at approximately $9,366,000. At the present 8.6% level of implementation Virginia's total annual time savings is slightly over $1 million.

Also to be considered (and possibly more important), are the fuel savings to be expected with RTOR vehicles experiencing shorter delay times at intersections. To calculate this fuel savings, a reasonably accurate fuel consumption figure for an average idling vehicle engine was needed. Since it was hard to determine what an average idling vehicle was, this figure was hard to pinpoint. Automobiles vary widely in how they are maintained and built, but in general most vehicle engines operate inefficiently at the idling condition since carburetors are adjusted for driving economy and not for idling.

Several sources listed values for fuel consumption while idling, but none seemed both comprehensive enough and recent enough to yield a figure of the desired accuracy. Robley Winfrey, in his Economic Analysis for Highways, arrived at an average rate (with the transmission in drive) of approximately .5 gal./hr.[25] This figure was for a composite group of pre-air-pollution control vehicles (pre-1970), which unfortunately means it is too low for today's vehicles. The same is true for the rate given in the National Cooperative Highway Research Program Report #111 (Running Costs of Motor Vehicles as Affected by Road Design and Traffic).[26] In Report #111, a composite vehicle was developed to find fuel and other costs, but the latest car model tested was a 1968 vehicle. However, the value given in that report (.63 gal./hour) is often quoted, and was used in the press releases from the office of Arkansas Senator Dale Bumpers when he introduced his national right turn on red legislation.

In July, the Research and Development Department of the Ethyl Corporation tested seven vehicles in their laboratory. The results showed an idling fuel consumption range of .25 gal./hr. for a 122 cu. in., 4-cylinder engine to 1.09 gal./hr. for a 351 cu. in., 8-cylinder engine. Another study, made by Arthur D. Little, Incorporated, showed a rate of consumption of 1.08 gal./hr. for a 400 cu. in. engine. Finally, the Ford Motor Company Emission Research Laboratory in Detroit tested two 1975 vehicles in July and found the 2.3 liter Pinto to use .5 gal./hr. at idle and the 400 cu. in. 1975 engine to use .9 gal./hr., yielding a median value of .7 gal./hr. Because of the varied results of all these tests and because the mean values fell within the range of .6 - .8 gal./hr., the authors decided a figure of .7 gal./hr. was both reasonable and sufficiently accurate to use in calculating fuel savings due to RTOR.

Using the .7 gal./hr. value and the field time delay savings value of 5,647 sec. per RTOR approach per day, the authors found that an implementation rate of 50% would yield a fuel savings of 1.95 million gallons a year compared to .33 million gallon being saved with the present 8.6% implementation level. Using the assumption of 80% implementation under the general permissive rule, over 3.12 million gallons of fuel could be saved annually due to RTOR. At an average value of 55¢/gallon for fuel, the fuel savings in dollars after general permissive legislation would be $1,717,570 yearly. At the possible 50% sign permissive level, savings of $1,073,500 yearly could be realized. (Approximately $180,000 are being saved at the present 8.6% level.)

Summary

Significant fuel and time savings are possible under both the sign permissive and general permissive rules for RTOR. The passage of general permissive legislation in Virginia would result in a saving of 3.1 million gallons of fuel a year. Net benefits to the citizens of the Commonwealth for the three alternatives measured over a five-year period are given in Table 24. (Cash flow tables used to arrive at these figures are in Appendix Y.)

TABLE 24

SUMMARY OF ECONOMIC ANALYSIS

Savings	Enact General Permissive RTOR (80% RTOR Implementation)	Retain Sign Permissive RTOR (Max. 50% Implementation)	Prohibit RTOR
Dollar Savings/5 year	$44,977,855	$25,811,800	($16,780)
Gallons of fuel saved/yearly	3,122,860	1,951,780	—

Guidelines for Implementation of RTOR

According to an interim report from the national RTOR study, 25 states have individualized RTOR guidelines "ranging in sophistication from engineering judgement to a formal list of numerical warrants."[3] The study revealed that "the existing guidelines prohibiting or permitting RTOR vary considerably between the states" and "there is no agreement as to which factors should be considered in selecting RTOR locations." However, the report went on to list 15 factors which are considered by general permissive states in prohibiting RTOR and an additional 7 which are used by the sign permissive states for the same purpose. These factors, combined into a single list, are given in Table 25 with the number of states which include each factor in its criteria.

TABLE 25

SUMMARY OF FACTORS CONSIDERED IN PROHIBITING RTOR

Criteria	No. of States Using Criteria
1. Significant Pedestrian Volumes	12
2. Restrictive Geometrics	9
3. Five or More Approaches	8
4. Inadequate Sight Distance	6
5. Speeds Through Intersection	5
6. RTOR Conflicts with Other Vehicle Movements, e.g., Left Turn Phase	4
7. Exclusive Pedestrian Phase (All-Red)	3
8. Vehicle Conflict is Serious	3
9. Signals Under School Crossing Warrant	3
10. History of Accidents Related to RTOR (5 or more)	2
11. Complex Signal Phasing	2
12. Pedestrian Signal Locations	2
13. No Appreciable Right Turns	1
14. Short Red Interval	1
15. Fully Actuated Signals	1
16. High Cross Street Volumes	1

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It seems apparent from the table that while there is no real consensus on the criteria to be considered in prohibiting RTOR, there is some agreement on the most important criteria — high pedestrian volumes, restrictive geometrics, five or more approach intersections, inadequate sight distances and high speeds through the intersection — being considered. Other factors are, of course, considered important by some states. As an example of the criteria used by general permissive states, the guidelines and warrants of three recent converts to the general permissive rule — Illinois, Ohio, and Indiana — are included in Appendix Z.

Utilizing the information from the national RTOR study and the examples of criteria from other states, as well as data and opinions gathered during this study, the authors devised a list of guidelines which should be considered if Virginia is to adopt the general permissive rule for RTOR. The list is included as part of the recommendations of this report on page xvii.

SECONDARY FINDINGS AND RECOMMENDATIONS

During the course of the analysis and field observations for this report, many factors became evident which, though not a part of the original study, were worthy of comment. This section lists some of these findings as well as some recommendations pertaining to the implementation of RTOR in Virginia.

Size and Illumination of Signs

The size and illumination of RTOR (or prohibitory RTOR) signs can be critical at night or anytime that visibility is poor. A particular visibility problem was noted with overhead signs (those mounted beside the traffic signal). Also, the smaller signs (several sizes are recognized by the Uniform Vehicle Code and the Virginia[27] MUTCD) were clearly more difficult to see than the larger signs, especially when mounted overhead. At one time the Manual on Uniform Traffic Control Devices required that RTOR signs be placed beside the traffic signal. Since July 1975, however, post mounted signs have been permitted by the MUTCD.

Therefore, in light of the visibility problem, the authors recommend (1) that only the large signs be used for RTOR, (2) that the signs be mounted overhead where adequate illumination is available to make them visible at night, and (3) that post mounted and overhead signs be used at locations which are not well illuminated by street lights.

Placement of Signs

There appears to be considerable disagreement among traffic engineers concerning the location of the RTOR sign, i.e., whether the signs should be overhead mounted or post mounted. As a result, some areas of the state have used only signal mounted signs, whereas others have used only post mounted signs. Both sign placement procedures were studied as part of this research. From the data collected at intersections, it appears that the location of the sign is not an important factor influencing the effectiveness of the sign. Presumably, at most intersections the majority of the traffic is composed of the persons who travel the same route from home to work and back everyday. They become familiar with specific traffic regulations in their area, including RTOR, and once they do, the placement of the sign is not important. This presumption is substantiated by observations at an intersection near Charlottesville at which a post mounted permissive RTOR sign had been taken down due to construction of a sidewalk. After several weeks motorists frequently made RTOR maneuvers even though the sign was missing. Of course, of vital importance, especially with the general permissive rule, is informing foreign drivers of the RTOR regulation. During this study several intersections were observed where the signal mounted sign was more effective than a post mounted one because of the clutter of other messages on the approach. In other cases, due to intersection design, signal head location, etc., a post mounted sign appeared to be the better choice. As both signing schemes are used throughout the nation, there does not appear to be a reason why one method should be selected over another. However, it is important that the sign be placed in the position of maximum effectiveness.

Therefore, it is recommended that a review of the conditions at each intersection, including illumination requirements, be made and the sign be placed at the point(s) of maximum effectiveness.

Pedestrian Protection Laws

Because violation of pedestrian right-of-way is one of the dangers of RTOR, and because Virginia's pedestrian protection laws do not afford pedestrians the same degree of protection to be found in some other jurisdictions, the authors recommend that the Code of Virginia be amended to incorporate the changes discussed on page 21 of this report.

Offset Stop Bars

Field observations have indicated that visibility for the RTOR vehicle at multi-lane approaches is often obstructed by cars stopped on the inner traffic lanes. It is, therefore, recommended (and a majority of Virginia's traffic engineers agree) that the pavement stop bars on the lanes adjacent to a right turn lane be offset where necessary to allow a clear view of traffic approaching the intersection.

Traffic Actuated Detectors

During this study it was noted that a majority of traffic signals in Virginia are traffic actuated. A possible problem with most of these actuated signals is that once an RTOR vehicle actuates the detector the signal changes, delaying main line traffic, giving green time to an empty approach. Such incidents could cause several motorists to believe signals are malfunctioning, and thus generate an increased number of studies by the signal engineer. This problem was given special attention during the field studies, but there were only a few special cases (usually T intersections) where the incident was observed. Due to the infrequent nature of this situation, there does not appear to be a widespread need to replace a majority of traffic actuators in Virginia with presence type detectors.

Therefore, to increase the efficiency of traffic flow at intersections, it is recommended that (1) presence detectors be used when replacing old or designing new signal systems, and (2) presence detectors be installed be installed at any existing intersection that is found to be frequently operating inefficiently due to RTOR maneuvers.

Left Turn on Red

The Uniform Vehicle Code provision for RTOR recommends that left turns on red from a one-way street to a one-way street (LTOR) be allowed as well as RTOR. No study of LTOR was made for this report and none has ever been done so far as could be ascertained. Therefore, no recommendation is made concerning LTOR in Virginia.

RTOR Coding on Accident Report Forms

The present Virginia accident report form (FR-300) is not designed to identify accidents involving RTOR vehicles. Therefore, to facilitate future study of the safety of RTOR in Virginia, it is recommended that the pending revision of the accident report include an item to designate whether any vehicle involved was making a RTOR maneuver.

Publicity for RTOR

Because the level of acceptance of RTOR is often quite low during the first months after adoption of the general permissive rule, it is recommended that any change to the general permissive rule in Virginia be accompanied by a vigorous publicity campaign to make the public aware of its availability.

"Fine Tuning" of Traffic Signals

One observation of the field studies team was that many vehicles, not only right turning vehicles but through and left turning vehicles, were often needlessly delayed because of improperly timed traffic signals. In light of the potential for time and fuel savings inherent in eliminating unnecessary traffic delays, it is recommended that a program of "fine tuning" the timing of traffic signals be initiated on a statewide basis.

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APPENDIX A

SUGGESTED AMENDMENT TO CODE OF VIRGINIA

§ 46.1-184(a) of the Code of Virginia currently permits right turn on red after stop when a sign is posted as shown below.

> § 46.1-184. Signals by lights or semaphores. — Signals by lights or semaphores shall be as follows:
>
> (a) Red indicates that traffic then moving shall stop and remain stopped as long as the red signal is shown, except in the direction indicated by a lighted green arrow; provided, however, that the governing body of any county or town having jurisdiction of its streets and roads, and any city, or the State Highway Commissioner for roads under his jurisdiction, may provide for a legal right turn on a red signal after coming to a full stop, provided that a sign indicating that such right turn is permissible is placed at the intersection. Such turning traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic using the intersection. Green indicates the traffic shall then move in the direction of the signal and remain in motion as long as the green signal is given, except that such traffic shall yield to other vehicles and pedestrians lawfully within the intersection.

It is suggested that § 46.1-184(a) of the Code of Virginia be amended to permit right turn on red after stop at all intersections except where a sign prohibits the maneuver as noted below.

> § 46.1-184. Signals by lights or semaphores. — Signals by lights or semaphores shall be as follows:
>
> (a) Red indicates that traffic then moving should stop and remain stopped as long as the red signal is shown, except in the direction indicated by a lighted green arrow; provided, however, that except when a sign is in place prohibiting a turn on red, vehicular traffic facing a steady red signal may cautiously enter the intersection to make a right turn after coming to a full stop. Such right turning traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection. Green indicates the traffic shall then move in the direction of the signal and remain in motion as long as the green signal is given, except that such traffic shall yield to other vehicles and pedestrians lawfully within the intersection.

APPENDIX B

AMENDMENT TO UNIFORM VEHICLE CODE

This is the draft copy of the amendment to the Uniform Vehicle Code adopted in July 1975. Note that it not only allows right turn on red unless there is a prohibitory sign, it also allows a left turn on red from a one-way street to a one-way street unless a sign is posted.

Draft: The Uniform Vehicle Code would be amended as follows:

§ 11-202 — Traffic control signal legend

(c) Steady red indication

1. Vehicular traffic facing a steady red signal alone shall stop at a clearly marked stop line, but if none, before entering the crosswalk on the near side of the intersection, or if none, then before entering the intersection and shall remain standing until an indication to proceed is shown except as provided in subsection (c) 2.

2. Except when a sign is in place prohibiting (permitting) a turn, vehicular traffic facing a steady red signal may cautiously enter the intersection to turn right, or to turn left from a one-way roadway onto a one-way roadway (make the turn indicated by such sign) after stopping as required by subsection (c) 1. Such vehicular traffic shall yield the right of way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.

3. Unless otherwise directed by a pedestrian-control signal as provided in § 11-203, pedestrians facing a steady red signal alone shall not enter the roadway.

APPENDIX C

U. S. SENATOR DALE BUMPERS'S RTOR BILL

94th Congress
1st Session

S. 2049

IN THE SENATE OF THE UNITED STATES

Mr. Bumpers ______________________________

introduced the following bill; which was read twice and referred to the Committee on ______________________________

A BILL

To amend Title 23 of the United States Code in order to conserve vital fuel and energy resources.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

Sec. 1. Chapter 1 of Title 23 of the United States Code is amended by inserting at the end thereof a new section as follows:

"SEC. 156. TRAFFIC SIGNALS.

"(a) The Secretary of Transportation shall not approve any project under section 106 in any State after June 30, 1976, which does not have a State law or laws (1) permitting drivers of motor vehicles on the public highways, roads, or streets of such State to turn right at steady red light traffic signals, after such vehicles first come to a complete stop and yield to pedestrian and vehicular traffic, and (2) authorizing municipal, county, and other local governments to permit motor vehicles on the public highways, roads or streets of such state to turn right at steady red light traffic signals, after such vehicles first come to a complete stop and yield to pedestrian and vehicular traffic; provided that such state law or laws shall require that the appropriate State Transportation Agency shall adopt regulations and guidelines to assure the safety of pedestrian and vehicular traffic in such state which are at least as effective as regulations and guidelines promulgated by the Secretary and referred to in subsection (b) hereinbelow.

"(b) The Secretary is hereby directed to adopt such guidelines and regulations as may be necessary to assure the safety of pedestrian and vehicular traffic on public highways, roads and streets in such states which authorize right turns at steady red light traffic signals.

"(c) For the purposes of this section, "steady red light traffic signals" shall mean circular red light traffic signals other than flashing signals, which hold the red light signal for five seconds or longer. Other terms used in this section shall have the same meaning as in Section 101 of Title 23, United States Code."

"(d) Notwithstanding the provisions of Section 120 of Title 23, United States Code, sums apportioned to any state under Section 104 of Title 23, United States Code, shall be available to pay the entire cost of any modification of the signing of the Federal-Aid highways, roads or streets directly attributable to the requirements of this section."

Sec. 2. The table of contents of chapter 1 of Title 23 of the United States Code is amended by inserting at the end thereof the following:
"156. Traffic signals."

APPENDIX D

VIRGINIA SENATE JOINT RESOLUTION NO. 155

SENATE JOINT RESOLUTION NO. 155

(Proposed by the Senate Committee on Transportation)

Encouraging right-turn-on-red studies and directing the Department of Highways and Transportation and the Highway Safety Division to study existing legislation on right-turns-on-red signals.

WHEREAS, the right-turn-on-red signal legislation has been in effect since July one, nineteen seventy-two; and

WHEREAS, there appears to be no increase in the number of highway crashes due to the statute change; and

WHEREAS, it is in the interest of Virginia to conserve energy in all ways possible; now, therefore, be it

RESOLVED by the Senate, the House of Delegates concurring, That the governing body of each county and town having jurisdiction of its streets and roads, each city having this jurisdiction, and the State Highways and Transportation Commissioner for roads under his jurisdiction be encouraged to conduct engineering and traffic studies for the purpose of designating additional locations where right-turns-on-red should be allowed and signs erected accordingly; and be it

RESOLVED FURTHER, That the Virginia Department of Highways and Transportation and the Virginia Highway Safety Division are hereby directed to conduct a joint study to determine if the present legislation should be retained, rescinded or amended. The study should include but not be limited to cost, enhancement of highway safety, and energy conservation. The study shall be concluded and findings reported to the Governor and the General Assembly not later than October one, nineteen hundred seventy-five.

Official Use by Clerks

Agreed to By The Senate	**Agreed to By The House of Delegates**
with / without amendment	with / without amendment
Date:	Date: ....
.... Clerk of the Senate	.... Clerk of the House of Delegates

APPENDIX E

QUESTIONNAIRE FOR VIRGINIA TRAFFIC ENGINEERS
Right-Turn-On-Red (RTOR) Signing

(1) Jurisdiction ______________________

(2) Date ______________________

Section A — Implementation of the current Virginia law authorizing Right-Turn-On-Red after stop.

For the following types of intersections and traffic signal controls, please indicate the number of such intersections in your jurisdiction:

	Intersections			
Intersection Characteristics	(a) Four-leg intersection	(b) Three-leg intersection	(c) All others	(d) Total
(3) Total number of traffic signal controlled intersections, excluding those with "flashing beacons" only.				
(4) Total number of fixed time signals.				
(5) Total number of semi-actuated signals.				
(6) Total number of fully-actuated signals.				
(7) Total number of signal approaches (intersection legs) signed to permit RTOR.				
(8) Total number of approaches where RTOR is not possible, i.e., because of one-way streets or channelized right turn lanes with yield signs.				
(9) Total number of signal approaches studied for RTOR.				
(10) Total number of additional signal approaches where RTOR might be feasible.				
(11) Total number of signal approaches where you would never permit RTOR.				

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Section B — Criteria for the Implementation of Right-Turn-On-Red after stop.

Decisions to permit or prohibit right-turn-on-red at signalized intersections must be based upon traffic engineering studies utilizing a number of criteria specific to the intersection under study. In the following section, please check, or X, ALWAYS, USUALLY, RARELY or NEVER in corresponding columns to indicate your decision as to whether you would permit right-turn-on-red based upon the criterion listed below. Please assume that the criterion under consideration would be the final decisive one. Assume also that other factors are not critical to the decision.

Traffic Volume Considerations	Always	Usually	Rarely	Never
(12) If the two-way traffic on the intersecting street has an ADT of 25,000, I would _______ permit RTOR.	______	______	______	______
(13) If the two-way traffic on the intersecting street has an ADT of 15,000, I would ______ permit RTOR.	______	______	______	______
(14) If the traffic on the intersecting street has an ADT of 5,000, I would ______ permit RTOR.	______	______	______	______
(15) If traffic on the intersecting street has an ADT of 2,000 I would ______ permit RTOR.	______	______	______	______
(16) If the percentage of right turn traffic is 30% or greater, I would ______ permit RTOR.	______	______	______	______
(17) If the percentage of right turn traffic is 20%, I would ______ permit RTOR.	______	______	______	______
(18) If the percentage of right turn traffic is 10% or less, I would ______ permit RTOR.	______	______	______	______
Speed Considerations				
(19) If speed on the intersecting street is 55 mph, I would ______ permit RTOR.	______	______	______	______
(20) If speed on the intersecting street is 40 mph, I would ______ permit RTOR.	______	______	______	______
(21) If speed on the intersecting street is 25 mph, I would ______ permit RTOR.	______	______	______	______
Pedestrian Considerations				
(22) If pedestrian traffic in the path of the RTOR vehicle is 300 persons per hour, I would ______ permit RTOR.	______	______	______	______
(23) If pedestrian traffic in the path of the RTOR vehicle is 100 persons per hour, I would ______ permit RTOR.	______	______	______	______
(24) If pedestrian traffic in the path of the RTOR vehicle is 50 persons per hour, I would ______ permit RTOR.	______	______	______	______
(25) If the intersection provides a "WALK" phase for pedestrians, I would ______ permit RTOR.	______	______	______	______

	Always	Usually	Rarely	Never
Sight Distance Considerations				
(26) If the intersecting street speed is 25 mph and the RTOR driver's lateral sight distance is 250 feet, I would ______ permit RTOR.				
(27) If traffic speed is 25 mph and the sight distance is 300 feet, I would ______ permit RTOR.				
(28) If traffic speed is 25 mph and the sight distance is 350 feet, I would ______ permit RTOR.				
(29) If traffic speed is 40 mph and the sight distance is 350 feet, I would ______ permit RTOR.				
(30) If traffic speed is 40 mph and the sight distance is 400 feet, I would ______ permit RTOR.				
(31) If traffic speed is 40 mph and the sight distance is 450 feet, I would ______ permit RTOR.				
(32) If traffic speed is 55 mph and the sight distance is 600 feet, I would ______ permit RTOR.				
Number of Approach Lanes Considerations				
(33) If there is one traffic lane, I would ______ permit RTOR.				
(34) If there are two traffic lanes including an exclusive right turn lane, I would ______ permit RTOR.				
(35) If there are two traffic lanes without an exclusive right turn lane, I would ______ permit RTOR.				
(36) If there are three or more approach lanes to the intersection I would ______ permit RTOR.				
School Zone Considerations				
(37) If the intersection is at a school crossing or within a school zone, I would ______ permit RTOR.				
Number of Departure Lanes Considerations				
(38) If there is one departure lane, I would ______ permit RTOR.				
(39) If there are two departure lanes, I would ______ permit RTOR.				

Left Turn Considerations	Always	Usually	Rarely	Never
(40) If the intersection traffic signals provide for a left turn arrow opposing the right turn, I would ______ permit RTOR.	______	______	______	______
(41) If dual (double) left turns opposing the right turn are permitted, I would ______ permit RTOR.	______	______	______	______
Other Considerations				
(42) If the intersection is characterized by restrictive geometrics (5 or more intersection legs, parallel collector-distributor roads, small curb radius, an adjacent RR crossing, jogged intersection, etc.), I would ______ permit RTOR.	______	______	______	______
(43) If the intersection has a bad accident history or frequent traffic conflicts, I would ______ permit RTOR.	______	______	______	______
(44) If the RTOR traffic approach has a "red" interval of 20 seconds or less, I would ______ permit RTOR.	______	______	______	______
(45) If the signal cycle is variable, i.e., if semi or fully traffic actuated detectors are used, I would ______ permit RTOR.	______	______	______	______
(46) If there is a separate signal indication (green arrow) for right turns, I would ______ permit RTOR.	______	______	______	______

(47) Please provide any specific comments or supportive data you might have about the above questions, or any criteria you recommend for implementing right-turn-on-red. (Use additional pages if necessary.)

(48) Please mention any particular problems with the current RTOR legislation — e.g., public reaction, drivers not coming to full stop, drivers not observing signal heads and lured into intersection by RTOR vehicle, changes in accident rates.

Section C — Cost Considerations

(49) How much has it cost your department to study and sign each intersection approach now designated RTOR. (Answers will be applied to the total column of question 7, Section A, to develop total cost.)

(a) Study Costs $ ________

(b) Signing Costs (1 + 2) $ ________

1. Material $ ______

2. Labor $ ______

TOTAL $ ________

Section D — General Comments

(50) How many intersection approaches were studied and found unsuitable for RTOR? ________ What was the average cost of each study? ________

(51) If Virginia switched from its current "sign permissive law" to a "general permissive" law which would allow RTOR everywhere except where prohibited by sign, approximately what percentage of your eligible approaches would require RTOR prohibition? __________

(52) Where there are two or more approach lanes should the stop bar for RTOR vehicles be relocated to permit adequate sight distance for RTOR motorists to stop and check cross traffic? ____________________

(53) Would you favor legislation authorizing left-turn-on-red for vehicles turning from and onto one-way streets? ____________________

(54) Should the existing legislation controlling the RTOR maneuver at signalized intersections be retained, rescinded or amended? Please provide appropriate justification for your answer.

(55) Comments

Name ______________________________

Title ______________________________

Mailing Address ______________________________

____

____

Phone Number ______________________________

0875

APPENDIX F

TELEPHONE SURVEY OF GENERAL PERMISSIVE STATES ON RTOR

Name of City/State ______________________

Name of Individual ______________________

Title ______________________

1. How long has your jurisdiction had a general permissive RTOR rule ?

   ____

2. Were any studies or surveys done prior to the change to the general permissive rule ? ______________________

   ____

3. Approximately what percentage of the eligible signalized approach lanes were signed for RTOR before the law was changed to general permissive ?

   ____

4. After the change to general permissive what percentage of the signalized approach lanes were signed to prohibit RTOR ? ______________________

   Has this percentage changed since the initial changeover ?

   ____

   ____

5. Have there been problems in implementation ? ______________________

   ____

   ____

   ____

   ____

6. Has there been any noticeable change in accident rates since the change to general permissive rule ? ______________________

   ____

   Can any change be attributed to RTOR ? ______________________

   ____

   ____

7. Are there established criteria for prohibiting RTOR at specific intersections?

____

____

Were these established by the legislature or by your department?

____

____

8. What is your professional opinion of the general permissive RTOR rule? Is it good, bad, indifferent? ______________________

____

APPENDIX G

INTERSECTION CHARACTERISTICS
VIRGINIA BEFORE AND AFTER
(NEW RTOR LOCATIONS)

INTERSECTION	JURISDICTION	AREA	INT. TYPE	NO. RTOR LEGS	DATE SIGNED	SIGNAL DESCRIPTION	APPROACH STUDIED	RTOR APPROACH	LANES NO.	LANES TYPE	1974 APPROACH ADT	SPEED LIMIT	PEDESTRIANS PER DAY
Rte 58 A & Rte 63 at St. Paul	Bristol Highway District	Urban	T	1	6/26/75	Full Act. 2 phase	Rte 58 A WB	No	1 1	LT & Thru RTL	3565	25	0-25
							Rte 63 SB	yes	1 1	LTL RTL	1875	25	0-25
Rte 21 & 58 at Independence	Bristol Highway District	Urban	+	4	6/26/75	Full Act. 3 phase	Rte 58 WB	yes	1 1	LTL RT & Thru	1725	25	0-25
							Rte 21 SB	yes	1 1	LT & Thru RTL	1298	25	25-50
Rte 360 & 643 at Lee Davis High School	Richmond Highway District	Rural	+	2	6/30/75	Full Act. 3 phase with minor movements	Rte 360 EB	yes	1 2 1	LTL Thru RT Taper	4203	55/45	0-25
							Rte 360 WB	yes	1 2 1	LTL Thru RT Taper	4203	55/45	0-25
Rte 1 & Willis Rd. (Rte 613) near Bellwood	Richmond Highway District	Suburban	+	2	6/2/75	Semi Act. 2 phase	Rte 1 NB	yes	1 1 1	LT & Thru Thru RTL	8648	45	0-25
					6/30/75		Willis Rd. WB	yes	1	LT, Thru & RT	2653	35	0-25
Warwick Blvd. & Maxwell Lane	City of Newport News	Rural	T	2	6/5/75	Semi Act. 2 phase	Warwick Blvd. SB	yes	1 1	Thru RT & Thru	7541	45	0-25
					8/31/73		Maxwell Lane EB	yes	1 1	LTL RTL	1842	25	0-25
Jefferson Ave. & 48th Street	City of Newport News	Urban	T	2	6/5/75	Semi Act. 3 phase	Jefferson Ave. NB	yes	1 1 1	LT & Thru Thru RT & Thru	8737	45	25-50
							48th Street WB	yes	1	LT, Thru & RT	931	25	25-50
Jefferson Ave. & Denbigh Blvd.	City of Newport News	Rural	+	2	6/5/75	Semi Act. 3 phase	Jefferson Ave. NB	yes	1 1 1	LT & Thru Thru RTL	8028	55/45	0-25
							Denbigh Blvd. EB	No	1 1 1	LTL Thru RTL	7988	35	0-25
Rte 123 & 677 near Vienna	Culpeper Highway District	Rural	+	3	6/11/75	Full Act. 3 phase with minor movements	Rte 123 NB	yes	1 2 1	LTL Thru RT Taper	14878	45	0-25
					6/11/75 (12/3/74 Rte 123 SB)		Rte 677 WB	yes	1 1	LTL Rt & Thru	3367	35	0-25
Rte 244 & 120	Culpeper Highway District	Urban	+	3	6/11/75	Fixed time 2 phases	Rte 244 WB	yes	2 1	Thru RTL (No LT permitted)	12358	30	75-100
							Rte 120 SB	yes	2 1	Thru RTL (No LT permitted)	12675	35	75-100

APPENDIX H

INTERSECTION CHARACTERISTICS

VIRGINIA COMPARISON LOCATIONS
(OLD RTOR APPROACHES)

INTERSECTION	JURISDICTION	AREA	INT. TYPE	NO. RTOR LEGS	DATE SIGNED	SIGNAL DESCRIPTION	APPROACH STUDIED	RTOR APPROACH	LANES NO.	LANES TYPE	1974 APPROACH ADT	SPEED LIMIT	PEDESTRIANS PER DAY
Rte. 301 & Wilkerson Road	Richmond Highway District	Suburban	+	2	3-27-74	Full Act. 3 phase with minor movements	Rte. 301 NB	Yes	1 2 1	LTL Thru RT taper	4790	45	0-25
							Rte. 301 SB	Yes	1 2 1	LTL Thru RT taper	4770	45	0-25
Grove & Malvern Avenue	City of Richmond	Urban	+	4	12-74	Fixed time 2 phase	Grove Ave. EB	Yes	1 1	Thru & LT Thru & RT	8300	35	75-100
							Malvern Ave. NB	Yes	1 1	Thru & LT Thru & RT	7400	35	75-100
Rte. 7 & Glen Carlyn Dr. (Rte. 1078)	Culpeper Highway District	Urban	+	3	5-30-74	Full Act. 3 phase	Rte. 7 EB	Yes	1 2 1	LTL Thru RTL	15475	40	75-100
							Glen Carlyn Dr. NB	Yes	1	LT, Thru & RT	3400	25	75-100
Rte. 123 & Glyndon	City of Vienna	Urban	+	4	12-74	Fixed time 2 phase	Rte. 123 NB	Yes	1 1 1	LTL Thru Thru & RT	14900	25	0-25
							Glyndon WB	Yes	1 1	LTL Thru & RT	1300	25	50-75
Rte. 460 & 622	Lynchburg Highway District	Suburban	+	2	12-3-73	Full Act. 3 phase with minor movements	Rte. 460 WB	Yes	1 1 1	LTL Thru Thru & RT	10865	55	0-25
							Rte. 622 NB	No	1	LT, Thru & RT	933	45	0-25
Rte. 1 & 1279	Culpeper Highway District	Suburban	+	4	12-26-72	Full Act. 3 phase	Rte. 1 SB	Yes	1 2 1	LTL Thru RTL	10785	35	100-125
							Rte. 1279 WB	Yes	1 1	LTL Thru & RT	4122	25	50-75
Rte. 1 & Russell Rd. (Rte. 3111)	Culpeper Highway District	Suburban	+	4	5-30-74	Full Act. 2 phase	Rte. 1 SB	Yes	1 1 1	LT & Thru Thru RTL	17140	45	75-100
							Russell Rd. EB	Yes	1 1	LTL Thru & RT	3028	25	50-75

APPENDIX I

INTERSECTION CHARACTERISTICS
NORTH CAROLINA LOCATIONS
(GENERAL PERMISSIVE RULE)

INTERSECTION	JURISDICTION	AREA	INT. TYPE	NO. RTOR LEGS	SIGNAL DESCRIPTION	APPROACH STUDIED	RTOR APPROACH	LANES		ESTIMATED APPROACH ADT	SPEED LIMIT MPH	PEDESTRIANS PER DAY
								NO.	TYPE			
Saunders & South St.	City of Raleigh, N.C.	Urban	+	3	Fixed 3 phase	Saunders St. SB	Yes	1 1	LT & Thru Thru & RT	2690	25	225
						South St. EB	Yes	1 1	LT & Thru RTL	4070	25	50
Old Wake Forest & Six Forks Rd.	City of Raleigh, N.C.	Urban	+	3	Full Act. 3 phase	Old Wake Forest Rd. SB	No	1 1 1	LTL Thru Thru & RT	10210	35	10
						Six Forks Rd. EB	Yes	1 1 1	LTL Thru RTL	6500	45	10
Hillsborough & McDowell Street	City of Raleigh, N.C.	Urban	+	2	Fixed 2 phase with pedestrian phase	Hillsborough St. EB	Yes	1 1	Thru Thru & RT	1000	25	320
						McDowell St. SB	Yes	1 2 1	LT & Thru Thru Thru & LT	13500	25	360
Chatham & Academy Street	City of Cary, N.C.	Urban	+	4	Fixed 2 phase	Chatham St. EB	Yes	1 1	LTL Thru & RT	2740	25	25
						Academy St. NB	Yes	1 1	LTL Thru & RT	2000	25	50

APPENDIX J

INTERSECTION DELAY, ACCEPTANCE AND COMPLIANCE DATA FORM

APPROACH Rte. 63 SB COUNTY ~~OR CITY~~ Wise DISTRICT Bristol

DATE 6-18-75 Wednesday STATUS Before RTOR Signing SIGNAL TYPE Full Act. 2 Phase

Red = 33 sec. Cycle = 72 sec.

TIME		NUMBER OF RIGHT TURNS	RIGHT TURN ON GREEN	NUMBER OF CAPTIVES	DELAY AND ACCEPTANCE													COMPLIANCE		MISCELLANEOUS
					REJECTED RTOR				ACCEPTED RTOR					TOTAL MEASURED DELAY		TOTAL DELAY NOT MEASURED			
					MEASURED DELAY		DELAY NOT MEAS.	TOTAL NO. REJ.	RTOR NO. DELAY	MEASURED DELAY		DELAY NOT MEAS.	TOTAL NO. RTOR				NUMBER OF MOTORISTS DID NOT STOP	NUMBER OF MOTORISTS USING SHOULDER	
FROM	TO				NO.	DELAY				NO.	DELAY			NO.	DELAY				
8:00 AM	8:15 AM	23	7		11	235	5	12						11	235	5			
9:00 AM	9:15 AM	37	13		8	184	6	8						8	184	6			
10:00 AM	10:15 AM	41	15		16	371	10	10						16	371	10			
11:00 AM	11:15 AM	34	14		16	399	4	11						16	399	4			
1:00 PM	1:15 PM	37	16		17	453	4	12						17	453	4			
2:00 PM	2:15 PM	40	24		15	340	1	11						15	340	1			
3:00 PM	3:15 PM	44	21		15	386	8	10						15	386	8			
4:00 PM	4:15 PM	32	12		14	341	5	9	1	1	2	0	1	15	343	5			
5:00 PM	5:15 PM	48	24		17	540	7	9						17	540	7			
6:00 PM	6:15 PM	29	12		16	414	1	11						16	414	1			
7:00 PM	7:15 PM	25	16		9	148	0	7						9	148	0			
TOTAL		380	174		154	3811	51	110	1	1	2	0	1	155	3813	51			

% RTOR 0.90% (VIOLATION)

% REJECTING RTOR 99.10%

MEAN DELAY PER RIGHT TURNING VEHICLE 24.60 sec.

APPENDIX K

VIRGINIA PEDESTRIAN STATUTES

Article 5

Protection of Pedestrians.

§ 46.1-230. How and where pedestrians to cross; crossing intersections diagonally. — (a) When crossing highways or streets, pedestrians shall not carelessly or maliciously interfere with the orderly passage of vehicles. They shall cross wherever possible only at intersections, but where intersections of streets contain no marked crosswalks pedestrians shall not be guilty of negligence as a matter of law for failure to cross at said intersection. They shall cross only at right angles.

(b) The governing body of an incorporated town or city or the governing body of a county authorized by law to regulate traffic may by ordinance permit pedestrians to cross an intersection diagonally when all traffic entering the intersection has been halted by lights, semaphores, or signals by a peace or police officer. (Code 1950, § 46-243; 1958, c. 541; 1966, c. 706.)

§ 46.1-231. Right-of-way of pedestrians. — (a) The driver of any vehicle upon a highway shall yield the right-of-way to a pedestrian crossing such highway within any clearly marked crosswalk whether at mid-block or at the end of any block, or any regular pedestrian crossing included in the prolongation of the lateral boundary lines of the adjacent sidewalk at the end of a block, except at intersections where the movement of traffic is being regulated by traffic officers or traffic direction devices.

(b) No pedestrian shall enter or cross an intersection in disregard of approaching traffic.

(c) The drivers of vehicles entering, crossing or turning at intersections shall change their course, slow down or come to a complete stop if necessary to permit pedestrians to cross such intersections safely and expeditiously.

(d) Pedestrians crossing highways or streets at intersections shall at all times have the right-of-way over vehicles making turns into the highways or streets being crossed by the pedestrians. (Code 1950, §§ 46-243, 46-244; 1958, c. 541; 1962, c. 471; 1968, c. 165; 1972, c. 576.)

§ 46.1-231.1. Pedestrian control signals. — Whenever special pedestrian control signals exhibiting the words "Walk" or "Don't Walk" are in place such signals shall indicate as follows:

(a) Walk. — Pedestrians facing such signal may proceed across the highway in the direction of the signal and shall be given the right-of-way by the drivers of all vehicles.

(b) Don't Walk. — No pedestrian shall start to cross the highway in the direction of such signal, but any pedestrian who has partially completed his crossing on the Walk signal shall proceed to a sidewalk or safety island while the Don't Walk signal is showing. (1974, c. 347.)

§ 46.1-232. Pedestrians stepping into street where they cannot be seen. — Pedestrians shall not step into that portion of a highway or street open to moving vehicular traffic at any point between intersections where their presence would be obscured from the vision of drivers of approaching vehicles by a vehicle or other obstruction at the curb or side, except to board a passenger bus or to enter a safety zone, in which event they shall cross the highway or street only at right angles. (Code 1950, § 46-245; 1958, c. 541.)

APPENDIX L

CALIFORNIA PEDESTRIAN STATUTES

§ 21950. Right-of-way at crosswalks

(a) The driver of a vehicle shall yield the right-of-way to a pedestrian crossing the roadway within any marked crosswalk or within any unmarked crosswalk at an intersection, except as otherwise provided in this chapter.

(b) The provisions of this section shall not relieve a pedestrian from the duty of using due care for his safety. No pedestrian shall suddenly leave a curb or other place of safety and walk or run into the path of a vehicle which is so close as to constitute an immediate hazard.

(c) The provisions of subdivision (b) shall not relieve a driver of a vehicle from the duty of exercising due care for the safety of any pedestrian within any marked crosswalk or within any unmarked crosswalk at an intersection.

(Stats. 1959, c. 3, p. 1687, § 21950. Amended by Stats. 1965, c. 1265, p. 3140, § 1; Stats. 1970, c. 1001, p. 1799, § 1.)

§ 21951. Vehicles stopped for pedestrians

Whenever any vehicle has stopped at a marked crosswalk or at any unmarked crosswalk at an intersection to permit a pedestrian to cross the roadway the driver of any other vehicle approaching from the rear shall not overtake and pass the stopped vehicle.

(Stats. 1959, c. 3, p. 1687, § 21951.)

§ 21953. Tunnel or overhead crossing

Whenever any pedestrian crosses a roadway other than by means of a pedestrian tunnel or overhead pedestrian crossing, if a pedestrian tunnel or overhead crossing serves the place where the pedestrian is crossing the roadway, such pedestrian shall yield the right-of-way to all vehicles on the highway.

(Stats. 1959, c. 3, p. 1687, § 21953.)

§ 21954. Pedestrians outside crosswalks

(a) Every pedestrian upon a roadway at any point other than within a marked crosswalk or within an unmarked crosswalk at an intersection shall yield the right-of-way to all vehicles upon the roadway.

(b) The provisions of this section shall not relieve the driver of a vehicle from the duty to exercise due care for the safety of any pedestrian upon a roadway.

(Stats. 1959, c. 3, p. 1687, § 21954. Amended by Stats. 1961, c. 1304, p. 3088, § 1.)

§ 21955. Crossing between controlled intersections

Between adjacent intersections controlled by traffic control signal devices or by police officers, pedestrians shall not cross the roadway at any place except in a crosswalk.

(Stats. 1959, c. 3, p. 1688, § 21955.)

3889

APPENDIX M

UNIFORM VEHICLE CODE PEDESTRIAN STATUTES

Article V — Pedestrians' Rights and Duties

§ 11-501—Pedestrian obedience to traffic-control devices and traffic regulations

(a) A pedestrian shall obey the instructions of any official traffic-control device specifically applicable to him, unless otherwise directed by a police officer. (New, 1968)

(b) Pedestrians shall be subject to traffic and pedestrian-control signals as provided in §§ 11-202 and 11-203. (Revised, 1968.)

(c) At all other places, pedestrians shall be accorded the privileges and shall be subject to the restrictions stated in this chapter.

§ 11-502—Pedestrians' right of way in crosswalks

(a) When traffic-control signals are not in place or not in operation the driver of a vehicle shall yield the right of way, slowing down or stopping if need be to so yield, to a pedestrian crossing the roadway within a crosswalk when the pedestrian is upon the half of the roadway upon which the vehicle is traveling, or when the pedestrian is approaching so closely from the opposite half of the roadway as to be in danger.

(b) No pedestrian shall suddenly leave a curb or other place of safety and walk or run into the path of a vehicle which is so close as to constitute an immediate hazard. (Revised, 1971.)

(c) Paragraph (a) shall not apply under the conditions stated in § 11-503(b).

(d) Whenever any vehicle is stopped at a marked crosswalk or at any unmarked crosswalk at an intersection to permit a pedestrian to cross the roadway, the driver of any other vehicle approaching from the rear shall not overtake and pass such stopped vehicle.

§ 11-503—Crossing at other than crosswalks

(a) Every pedestrian crossing a roadway at any point other than within a marked crosswalk or within an unmarked crosswalk at an intersection shall yield the right of way to all vehicles upon the roadway.

(b) Any pedestrian crossing a roadway at a point where a pedestrian tunnel or overhead pedestrian crossing has been provided shall yield the right of way to all vehicles upon the roadway.

(c) Between adjacent intersections at which traffic-control signals are in operation pedestrians shall not cross at any place except in a marked crosswalk.

(d) No pedestrian shall cross a roadway intersection diagonally unless authorized by official traffic-control devices; and, when authorized to cross diagonally, pedestrians shall cross only in accordance with the official traffic-control devices pertaining to such crossing movements. (New, 1962.)

§ 11-504—Drivers to exercise due care

Notwithstanding other provisions of this chapter or the provisions of any local ordinance, every driver of a vehicle shall exercise due care to avoid colliding with any pedestrian and shall give warning by sounding the horn when necessary and shall exercise proper precaution upon observing any child or any obviously confused, incapacitated or intoxicated person. (Revised, 1971.)

APPENDIX N

INVENTORY OF VIRGINIA INTERSECTIONS

QUESTIONNAIRE FOR VIRGINIA TRAFFIC ENGINEERS

HIGHWAY JURISDICTION	SIGNALIZED INTERSECTIONS							TRAFFIC APPROACH INFORMATION				
	TYPE OF INTERSECTION				TYPE OF SIGNAL			TOTAL APPROACHES	NO. WHERE RTOR IS NOT POSSIBLE	NO. OF POSSIBLE RTOR APPROACHES	APPROACHES WITH RTOR	TOTAL STUDIED
	4-LEG	3-LEG	OTHER	TOTAL	FIXED TIME	SEMI-ACTUATED	FULLY ACTUATED					
Bristol District	9	6	0	15	0	6	9	54	6	48	4	54
Salem District	23	14	2	39	2	5	32	144	11	133	5	141
Lynchburg District	15	8	2	25	1	5	19	94	4	90	11	91
Richmond District	69	17	0	86	0	13	73	327	16	311	38	323
Suffolk District	22	12	2	36	0	7	29	134	30	104	32	46
Fredericksburg District	18	1	0	19	0	2	17	75	11	64	0	75
Culpeper District	210	68	29	307	2	15	290	1189	165	1024	183	210
Staunton District	23	2	0	25	0	2	23	98	14	84	2	84
Alexandria	197	11	1	209	192	9	8	826	170	656	39	49
Chesapeake	17	5	5	27	3	9	15	108	34	74	20	70
Hampton	81	25	4	110	35	45	30	419	8	411	73	--
Lynchburg	41	19	4	64	25	10	29	241	54	187	21	168
Newport News	52	110	1	163	88	72	3	543	85	458	12	49
Norfolk	215	25	2	242	96	60	86	945	24	921	46	965
Portsmouth	111	10	2	123	17	19	87	444	25	419	30	64
Richmond	382	45	1	428	236	50	142	1721	350 (est.)	1371	58	63
Roanoke	74	29	9	112	44	33	35	425	36	389	0	425
Va. Beach	77	15	3	95	8	12	75	368	35	333	124	257

QUESTIONNAIRE FOR VIRGINIA TRAFFIC ENGINEERS

HIGHWAY JURISDICTION	SIGNALIZED INTERSECTIONS							TRAFFIC APPROACH INFORMATION				
	TYPE OF INTERSECTION				TYPE OF SIGNAL			TOTAL APPROACHES	NO. WHERE RTOR IS NOT POSSIBLE	NO. OF POSSIBLE RTOR APPROACHES	APPROACHES WITH RTOR	TOTAL STUDIED
	4-LEG	3-LEG	OTHER	TOTAL	FIXED TIME	SEMI-ACTUATED	FULLY ACTUATED					
Charlottesv'e	26	16	2	44	24	6	14	162	39	123	13	13
Danville	21	19	8	48	32	8	8	185	38	147	0	29
Petersburg	35	8	2	45	13	21	11	174	21	153	5	--
Bristol	25	6	1	32	24	4	4	123	5	118	3	10
Colonial Hts.	10	5	0	15	5	10	0	55	1	54	0	0
Covington	12	1	0	13	12	1	0	51	1	50	1	1
Fairfax	16	6	1	23	0	15	8	87	21	66	13	86
Falls Church	24	0	0	24	24	0	0	96	--	96	2	--
Fredericksburg	10	13	5	28	19	8	1	104	26	78	1	0
Harrisonburg	31	0	0	31	28	3	0	124	3	121	0	31
Hopewell	25	4	0	29	3 (est.)	13 (est.)	13 (est.)	112	--	--	18	--
Martinsville	16	12	7	35	4	26	5	135	26	109	0	106
Pulaski	6	1	0	7	6	1	0	27	3	24	0	24
Radford	5	5	0	10	5	5	0	35	1	34	0	2
Salem	26	4	1	31	11	12	8	121	13	108	0	0
Staunton	22	8	1	31	17	0	14	117	39	78	0	0
Vienna	9	0	0	9	0	0	9	36	0	36	9	9
Waynesboro	12	2	0	14	2	10	2	54	--	54	0	54
Winchester	31	2	0	33	29	2	2	130	9	121	1	2
Abingdon	--	--	--	--	--	--	--	--	--	--	--	--
Bedford	7	1	0	8	7	1	0	28	2	26	0	2
Big Stone Gap	--	--	--	--	--	--	--	--	--	--	--	--
Blacksburg	15	0	0	15	0	0	15	60	5	55	1	15
Blackstone	4	3	0	7	7	0	0	25	3	22	0	0
Bluefield	3	1	0	4	4	0	0	15	2	13	2	4
Buena Vista	--	--	--	--	--	--	--	--	--	--	--	--

QUESTIONNAIRE FOR VIRGINIA TRAFFIC ENGINEERS

HIGHWAY JURISDICTION	SIGNALIZED INTERSECTIONS							TRAFFIC APPROACH INFORMATION				
	TYPE OF INTERSECTION				TYPE OF SIGNAL			TOTAL APPROACHES	NO. WHERE RTOR IS NOT POSSIBLE	NO. OF POSSIBLE RTOR APPROACHES	APPROACHES WITH RTOR	TOTAL STUDIED
	4-LEG	3-LEG	OTHER	TOTAL	FIXED TIME	SEMI-ACTUATED	FULLY ACTUATED					
Christiansburg	4	4	0	8	5	3	0	28	4	24	0	0
Clifton Forge	8	2	0	10	10	0	0	38	1	37	1	10
Culpeper	4	2	0	6	5	1	0	22	4	18	0	0
Emporia	3	1	0	4	4	0	0	15	1	14	1	--
Farmville	6	2	0	8	6	2	0	30	5	25	0	2
Franklin	--	--	--	--	--	--	--	--	--	--	--	--
Front Royal	6	0	0	6	1	3	2	24	1	23	0	0
Galax	--	--	--	--	--	--	--	--	--	--	--	--
Herndon	2	0	0	2	2	0	0	8	0	8	3	8
Leesburg	2	1	0	3	3	0	0	11	3	8	0	2
Lexington	--	--	--	--	--	--	--	--	--	--	--	--
Luray	1	0	0	1	0	0	0	4	0	4	0	--
Manassas	9	1	0	10	0	3	7	39	15	24	4	0
Manassas Park	1	0	0	1	0	0	1	4	0	4	0	0
Marion	7	2	0	9	7	2	0	34	4	30	13	20
Norton	3	3	0	6	6	0	0	21	0	21	5	1
Poquoson	0	0	0	0	0	0	0	0	0	0	0	0
Richlands	--	--	--	--	--	--	--	--	--	--	--	--
Rocky Mount	--	--	--	--	--	--	--	--	--	--	--	--
South Boston	7	0	0	7	2	3	2	28	8	20	4	20
South Hill	1	0	0	1	0	0	1	4	0	4	0	0
Suffolk	6	3	2	11	7	2	2	43	43	0	0	11
Tazewell	0	1	0	1	0	1	0	3	0	3	0	0
Vinton	2	2	0	4	2	2	0	14	2	12	0	0
Warrenton	3	0	0	3	0	0	3	12	6	6	0	0
Williamsburg	6	2	0	8	--	--	--	30	--	--	6	6
Wytheville	10	0	0	10	10	0	0	40	0	40	0	0

QUESTIONNAIRE FOR VIRGINIA TRAFFIC ENGINEERS

HIGHWAY JURISDICTION	SIGNALIZED INTERSECTIONS							TRAFFIC APPROACH INFORMATION				
	TYPE OF INTERSECTION				TYPE OF SIGNAL			TOTAL APPROACHES	NO. WHERE RTOR IS NOT POSSIBLE	NO. OF POSSIBLE RTOR APPROACHES	APPROACHES WITH RTOR	TOTAL STUDIED
	4-LEG	3-LEG	OTHER	TOTAL	FIXED TIME	SEMI-ACTUATED	FULLY ACTUATED					
Henrico Co.	25	3	1	29	0	0	29	114	104	10	10	114
Arlington Co.	106	40	8	154	60	33	61	584	84	500	25	75
TOTAL	2243	606	106	2955	1156	575	1224	11,361	1621	9598[(a)]	839	3722

(a) This figure, 9,598, when added to 1,621 (the number of approaches where RTOR is not possible) does not yield 11,361, the total number of traffic approaches in the state, because several traffic engineers did not respond to this part of the question, and hence are not counted in the total.

APPENDIX O

COMPOSITE OF RESPONSES TO QUESTIONNAIRE

FOR VIRGINIA TRAFFIC ENGINEERS

TABLE O-1

All Locations

Section B — Criteria for the Implementation of Right-Turn-On-Red after stop.

Decisions to permit or prohibit right-turn-on-red at signalized intersections must be based upon traffic engineering studies utilizing a number of criteria specific to the intersection under study. In the following section, please check, or X, ALWAYS, USUALLY, RARELY or NEVER in corresponding columns to indicate your decision as to whether you would permit right-turn-on-red based upon the criterion listed below. Please assume that the criterion under consideration would be the final decisive one. Assume also that other factors are not critical to the decision.

	ALL LOCATIONS - PERCENTAGES				
Traffic Volume Considerations	Always	Usually	Rarely	Never	No Comment
(12) If the two-way traffic on the intersecting street has an ADT of 25,000, I would ______ permit RTOR.	0	14.	31	39	16
(13) If the two-way traffic on the intersecting street has an ADT of 15,000, I would ______ permit RTOR.	2	28	34	22	14
(14) If the traffic on the intersecting street has an ADT of 5,000, I would ______ permit RTOR.	11	58	9	8	14
(15) If traffic on the intersecting street has an ADT of 2,000 I would ______ permit RTOR.	23	53	2	8	14
(16) If the percentage of right turn traffic is 30% or greater, I would ______ permit RTOR.	19	50	8	8	15
(17) If the percentage of right turn traffic is 20%, I would ______ permit RTOR.	11	56	13	6	14
(18) If the percentage of right turn traffic is 10% or less, I would ______ permit RTOR.	11	36	27	11	15
Speed Considerations					
(19) If speed on the intersecting street is 55 mph, I would ______ permit RTOR.	2	8	31	42	17
(20) If speed on the intersecting street is 40 mph, I would ______ permit RTOR.	5	27	33	20	15
(21) If speed on the intersecting street is 25 mph, I would ______ permit RTOR.	12.5	66	1.5	6	14
Pedestrian Considerations					
(22) If pedestrian traffic in the path of the RTOR vehicle is 300 persons per hour, I would ______ permit RTOR.	1.5	1.5	9	72	16
(23) If pedestrian traffic in the path of the RTOR vehicle is 100 persons per hour, I would ______ permit RTOR.	0	11	48	27	14
(24) If pedestrian traffic in the path of the RTOR vehicle is 50 persons per hour, I would ______ permit RTOR.	3	53	17	13	14
(25) If the intersection provides a "WALK" phase for pedestrians, I would ______ permit RTOR.	8	17	14	44	17

Table O-1 (continued)

	Always	Usually	Rarely	Never	No Comment
Sight Distance Considerations					
(26) If the intersecting street speed is 25 mph and the RTOR driver's lateral sight distance is 250 feet, I would ______ permit RTOR.	8	36	31	9	16
(27) If traffic speed is 25 mph and the sight distance is 300 feet, I would ______ permit RTOR.	14	55	12.5	4.5	14
(28) If traffic speed is 25 mph and the sight distance is 350 feet, I would ______ permit RTOR.	19	58	3	4.5	15.5
(29) If traffic speed is 40 mph and the sight distance is 350 feet, I would ______ permit RTOR.	1.5	29.5	36	14	19
(30) If traffic speed is 40 mph and the sight distance is 400 feet, I would ______ permit RTOR.	4.5	37.5	28	11	19
(31) If traffic speed is 40 mph and the sight distance is 450 feet, I would ______ permit RTOR.	11	44	15.5	11	18.5
(32) If traffic speed is 55 mph and the sight distance is 600 feet, I would ______ permit RTOR.	6	17	31.5	23.5	22
Number of Approach Lanes Considerations					
(33) If there is one traffic lane, I would ______ permit RTOR.	6	25	37.5	16	15.5
(34) If there are two traffic lanes including an exclusive right turn lane, I would ______ permit RTOR.	23.5	48.5	6	6	16
(35) If there are two traffic lanes without an exclusive right turn lane, I would ______ permit RTOR.	9.5	48.5	20.5	4.5	17
(36) If there are three or more approach lanes to the intersection I would ______ permit RTOR.	19	53	8	4.5	15.5
School Zone Considerations					
(37) If the intersection is at a school crossing or within a school zone, I would ______ permit RTOR.	0	16	28	40.5	15.5
Number of Departure Lanes Considerations					
(38) If there is one departure lane, I would ______ permit RTOR.	9.5	23.5	39	11	17
(39) If there are two departure lanes, I would ______ permit RTOR.	11	58	9	5	17

Table O-1 (continued)

	Always	Usually	Rarely	Never	No Comment
<u>Left Turn</u> **Considerations**					
(40) If the intersection traffic signals provide for a left turn arrow opposing the right turn, I would ______ permit RTOR.	0	17	45	22	16
(41) If dual (double) left turns opposing the right turn are permitted, I would ______ permit RTOR.	0	9.5	28	47	15.5
<u>Other</u> **Considerations**					
(42) If the intersection is characterized by restrictive geometrics (5 or more intersection legs, parallel collector-distributor roads, small curb radius, an adjacent RR crossing, jogged intersection, etc.), I would ______ permit RTOR.	0	1.5	37.5	44	17
(43) If the intersection has a bad accident history or frequent traffic conflicts, I would ______ permit RTOR.	0	6	50	28	16
(44) If the RTOR traffic approach has a "red" interval of 20 seconds or less, I would ______ permit RTOR.	1.5	26.5	42	14	16
(45) If the signal cycle is variable, i.e., if semi or fully traffic actuated detectors are used, I would ______ permit RTOR.	3	45.5	28	8	15.5
(46) If there is a separate signal indication (green arrow) for right turns, I would ______ permit RTOR.	6.5	25	26.5	26.5	15.5

(47) Please provide any specific comments or supportive data you might have about the above questions, or any criteria you recommend for implementing right-turn-on-red. (Use additional pages if necessary.)

(48) Please mention any particular problems with the current RTOR legislation — e.g., public reaction, drivers not coming to full stop, drivers not observing signal heads and lured into intersection by RTOR vehicle, changes in accident rates.

TABLE O-2

Locations With RTOR Signing

Section B — Criteria for the Implementation of Right-Turn-On-Red after stop.

Decisions to permit or prohibit right-turn-on-red at signalized intersections must be based upon traffic engineering studies utilizing a number of criteria specific to the intersection under study. In the following section, please check, or X, ALWAYS, USUALLY, RARELY or NEVER in corresponding columns to indicate your decision as to whether you would permit right-turn-on-red based upon the criterion listed below. Please assume that the criterion under consideration would be the final decisive one. Assume also that other factors are not critical to the decision.

	LOCATIONS WITH RTOR SIGNING - PERCENTAGES (36/64, 56%)				
	Always	Usually	Rarely	Never	No Comment
Traffic Volume Considerations					
(12) If the two-way traffic on the intersecting street has an ADT of 25,000, I would ______ permit RTOR.	0	22	36	39	3
(13) If the two-way traffic on the intersecting street has an ADT of 15,000, I would ______ permit RTOR.	3	44.5	30.5	19.5	2.5
(14) If the traffic on the intersecting street has an ADT of 5,000, I would ______ permit RTOR.	19.5	64	11	3	2.5
(15) If traffic on the intersecting street has an ADT of 2,000 I would ______ permit RTOR.	28	64	2.5	2.5	3
(16) If the percentage of right turn traffic is 30% or greater, I would ______ permit RTOR.	30.5	55.5	5.5	5.5	3
(17) If the percentage of right turn traffic is 20%, I would ______ permit RTOR.	19.5	61	16.5	0	3
(18) If the percentage of right turn traffic is 10% or less, I would ______ permit RTOR.	14	39	33	8	6
Speed Considerations					
(19) If speed on the intersecting street is 55 mph, I would ______ permit RTOR.	3	11	39	41.5	5.5
(20) If speed on the intersecting street is 40 mph, I would ______ permit RTOR.	8	33	39	17	3
(21) If speed on the intersecting street is 25 mph, I would ______ permit RTOR.	16.5	78	3	0	2.5
Pedestrian Considerations					
(22) If pedestrian traffic in the path of the RTOR vehicle is 300 persons per hour, I would ______ permit RTOR.	3	3	16.5	75	2.5
(23) If pedestrian traffic in the path of the RTOR vehicle is 100 persons per hour, I would ______ permit RTOR.	0	19.5	55.5	22	3
(24) If pedestrian traffic in the path of the RTOR vehicle is 50 persons per hour, I would ______ permit RTOR.	5.5	64	22	5.5	3
(25) If the intersection provides a "WALK" phase for pedestrians, I would ______ permit RTOR.	8.5	22	16.5	50	3

Table O-2 (continued)

	Always	Usually	Rarely	Never	No Comment
Sight Distance Considerations					
(26) If the intersecting street speed is 25 mph and the RTOR driver's lateral sight distance is 250 feet, I would ______ permit RTOR.	11	47	36	3	3
(27) If traffic speed is 25 mph and the sight distance is 300 feet, I would ______ permit RTOR.	19	58	19.5	0	3
(28) If traffic speed is 25 mph and the sight distance is 350 feet, I would ______ permit RTOR.	30.5	64	3	0	2.5
(29) If traffic speed is 40 mph and the sight distance is 350 feet, I would ______ permit RTOR.	3	36	44.5	14	2.5
(30) If traffic speed is 40 mph and the sight distance is 400 feet, I would ______ permit RTOR.	8.5	47	36	5.5	3
(31) If traffic speed is 40 mph and the sight distance is 450 feet, I would ______ permit RTOR.	16.5	50	22	8.5	3
(32) If traffic speed is 55 mph and the sight distance is 600 feet, I would ______ permit RTOR.	8.5	19.5	39	25	8
Number of Approach Lanes Considerations					
(33) If there is one traffic lane, I would ______ permit RTOR.	8.5	30.5	41.5	16.5	3
(34) If there are two traffic lanes including an exclusive right turn lane, I would ______ permit RTOR.	28	55.5	11	3	2.5
(35) If there are two traffic lanes without an exclusive right turn lane, I would ______ permit RTOR.	11	58.5	25	0	5.5
(36) If there are three or more approach lanes to the intersection I would ______ permit RTOR.	25	66.5	5.5	0	3
School Zone Considerations					
(37) If the intersection is at a school crossing or within a school zone, I would ______ permit RTOR.	0	25	22	47	6
Number of Departure Lanes Considerations					
(38) If there is one departure lane, I would ______ permit RTOR.	14	25	44.5	11	5.5
(39) If there are two departure lanes, I would ______ permit RTOR.	14	69.5	11	0	5.5

Table O-2 (continued)

	Always	Usually	Rarely	Never	No Comment
Left Turn Considerations					
(40) If the intersection traffic signals provide for a left turn arrow opposing the right turn, I would ______ permit RTOR.	0	19.5	64	14	2.5
(41) If dual (double) left turns opposing the right turn are permitted, I would ______ permit RTOR.	0	11	39	47	3
Other Considerations					
(42) If the intersection is characterized by restrictive geometrics (5 or more intersection legs, parallel collector-distributor roads, small curb radius, an adjacent RR crossing, jogged intersection, etc.), I would ______ permit RTOR.	0	3	47	47	3
(43) If the intersection has a bad accident history or frequent traffic conflicts, I would ______ permit RTOR.	0	11	58.5	28	2.5
(44) If the RTOR traffic approach has a "red" interval of 20 seconds or less, I would ______ permit RTOR.	3	36	44.5	14	2.5
(45) If the signal cycle is variable, i.e., if semi or fully traffic actuated detectors are used, I would ______ permit RTOR.	5.5	61	28	3	2.5
(46) If there is a separate signal indication (green arrow) for right turns, I would ______ permit RTOR.	11	39	16.5	30.5	3

(47) Please provide any specific comments or supportive data you might have about the above questions, or any criteria you recommend for implementing right-turn-on-red. (Use additional pages if necessary.)

(48) Please mention any particular problems with the current RTOR legislation — e.g., public reaction, drivers not coming to full stop, drivers not observing signal heads and lured into intersection by RTOR vehicle, changes in accident rates.

TABLE O-3

Locations Without RTOR Signing

Section B — Criteria for the Implementation of Right-Turn-On-Red after stop.

Decisions to permit or prohibit right-turn-on-red at signalized intersections must be based upon traffic engineering studies utilizing a number of criteria specific to the intersection under study. In the following section, please check, or X, ALWAYS, USUALLY, RARELY or NEVER in corresponding columns to indicate your decision as to whether you would permit right-turn-on-red based upon the criterion listed below. Please assume that the criterion under consideration would be the final decisive one. Assume also that other factors are not critical to the decision.

	LOCATIONS WITHOUT RTOR SIGNS - PERCENTAGES (28/64, 44%)				
Traffic Volume Considerations	Always	Usually	Rarely	Never	No Comment
(12) If the two-way traffic on the intersecting street has an ADT of 25,000, I would ______ permit RTOR.	0	3.5	25	39.5	32
(13) If the two-way traffic on the intersecting street has an ADT of 15,000, I would ______ permit RTOR.	0	7	39.5	25	28.5
(14) If the traffic on the intersecting street has an ADT of 5,000, I would ______ permit RTOR.	0	50	7	14.5	28.5
(15) If traffic on the intersecting street has an ADT of 2,000 I would ______ permit RTOR.	18	39.5	0	14	28.5
(16) If the percentage of right turn traffic is 30% or greater, I would ______ permit RTOR.	3.5	43	11	11	31.5
(17) If the percentage of right turn traffic is 20%, I would ______ permit RTOR.	0	50	7	14.5	28.5
(18) If the percentage of right turn traffic is 10% or less, I would ______ permit RTOR.	7	32	18	14.5	28.5
Speed Considerations					
(19) If speed on the intersecting street is 55 mph, I would ______ permit RTOR.	0	3.5	21.5	43	32
(20) If speed on the intersecting street is 40 mph, I would ______ permit RTOR.	0	18	25	25	32
(21) If speed on the intersecting street is 25 mph, I would ______ permit RTOR.	7	50	0	14.5	28.5
Pedestrian Considerations					
(22) If pedestrian traffic in the path of the RTOR vehicle is 300 persons per hour, I would ______ permit RTOR.	0	0	0	68	32
(23) If pedestrian traffic in the path of the RTOR vehicle is 100 persons per hour, I would ______ permit RTOR.	0	0	39.5	32	28.5
(24) If pedestrian traffic in the path of the RTOR vehicle is 50 persons per hour, I would ______ permit RTOR.	0	39.5	10.5	21.5	28.5
(25) If the intersection provides a "WALK" phase for pedestrians, I would ______ permit RTOR.	7	10.5	10.5	36	36

Table O-3 (continued)

	Always	Usually	Rarely	Never	No Comment
Sight Distance Considerations					
(26) If the intersecting street speed is 25 mph and the RTOR driver's lateral sight distance is 250 feet, I would ______ permit RTOR.	3.5	21.5	25	18	32
(27) If traffic speed is 25 mph and the sight distance is 300 feet, I would ______ permit RTOR.	7	50	3.5	11	28.5
(28) If traffic speed is 25 mph and the sight distance is 350 feet, I would ______ permit RTOR.	3.5	50	3.5	11	32
(29) If traffic speed is 40 mph and the sight distance is 350 feet, I would ______ permit RTOR.	0	21.5	25	14.5	39
(30) If traffic speed is 40 mph and the sight distance is 400 feet, I would ______ permit RTOR.	0	25	18	18	39
(31) If traffic speed is 40 mph and the sight distance is 450 feet, I would ______ permit RTOR.	3.5	36	7	14.5	39
(32) If traffic speed is 55 mph and the sight distance is 600 feet, I would ______ permit RTOR.	3.5	14	21.5	21.5	39.5
Number of Approach Lanes Considerations					
(33) If there is one traffic lane, I would ______ permit RTOR.	3.5	18	32	14.5	32
(34) If there are two traffic lanes including an exclusive right turn lane, I would ______ permit RTOR.	18	39	0	11	32
(35) If there are two traffic lanes without an exclusive right turn lane, I would ______ permit RTOR.	7	36	14	11	32
(36) If there are three or more approach lanes to the intersection I would ______ permit RTOR.	11	36	10.5	10.5	32
School Zone Considerations					
(37) If the intersection is at a school crossing or within a school zone, I would ______ permit RTOR.	0	3.5	36	32	28.5
Number of Departure Lanes Considerations					
(38) If there is one departure lane, I would ______ permit RTOR.	3.5	21.5	32	11	32
(39) If there are two departure lanes, I would ______ permit RTOR.	7	43	7	11	32

Table O-3 (continued)

	Always	Usually	Rarely	Never	No Comment
Left Turn Considerations					
(40) If the intersection traffic signals provide for a left turn arrow opposing the right turn, I would ______ permit RTOR.	0	14.5	21.5	32	32
(41) If dual (double) left turns opposing the right turn are permitted, I would ______ permit RTOR.	0	7	14.5	46.5	32
Other Considerations					
(42) If the intersection is characterized by restrictive geometrics (5 or more intersection legs, parallel collector-distributor roads, small curb radius, an adjacent RR crossing, jogged intersection, etc.), I would ______ permit RTOR.	0	0	39.5	28.5	32
(43) If the intersection has a bad accident history or frequent traffic conflicts, I would ______ permit RTOR.	0	0	39.5	28.5	32
(44) If the RTOR traffic approach has a "red" interval of 20 seconds or less, I would ______ permit RTOR.	0	14.5	39.5	14	32
(45) If the signal cycle is variable, i.e., if semi or fully traffic actuated detectors are used, I would ______ permit RTOR.	0	25	28.5	14.5	32
(46) If there is a separate signal indication (green arrow) for right turns, I would ______ permit RTOR.	0	7	39.5	21.5	32

(47) Please provide any specific comments or supportive data you might have about the above questions, or any criteria you recommend for implementing right-turn-on-red. (Use additional pages if necessary.)

(48) Please mention any particular problems with the current RTOR legislation — e.g., public reaction, drivers not coming to full stop, drivers not observing signal heads and lured into intersection by RTOR vehicle, changes in accident rates.

0904

APPENDIX P
TIME SAVINGS DATA

TABLE P-1
SUMMARY OF DELAY ACCEPTANCE AND COMPLIANCE DATA
(NEW VIRGINIA RTOR APPROACHES)
BEFORE RTOR SIGNING

Approach	Number of Right Turns	Right Turn on Green	Number of Captives	Delay and Acceptance													Compliance	
				Rejected RTOR				Accepted RTOR					Total Measured Delay		Total Delay Not Measured		Number of Motorists Did Not Stop	Number of Motorists Using Shoulder
				Measured Delay		Delay Not Meas.	Total No. Rej.	RTOR No. Delay	Measured Delay		Delay Not Meas.	Total No. RTOR						
				No.	Delay				No.	Delay			No.	Delay				
Rte. 63 SB	380	174		154	3,811	51	110	1	1	2		1	155	3,813	51			
Rte. 58 WB	169	94	10	55	1,095	10	54						55	1,095	10			
Rte. 21 SB	81	64		16	366	1	16						16	366	1			
Rte. 360 WB	37	24		9	317	4	9						9	317	4			
Rte. 360 EB	89	52	20	13	423	4	15						13	423	4			1
Rte. 1 NB	261	159		61	1,116	41	60						61	1,116	41			
Rte. 613 WB	212	82	51	50	1,480	29	54						50	1,480	29			
Jeff. Ave. NB	48	37	4	7	119	—	7						7	119	—			
48th St. WB	178	34	11	110	2,420	23	91						110	2,420	23			
Warwick Blvd. SB	109	76	9	20	252	4	22						20	252	4			
Jeff. Ave. NB	57	39		15	252	3	14						15	252	3			
Rte. 244 WB	198	104		52	1,132	41	50	1	1	2	-	1	53	1,134	41		1	
Rte. 120 SB	247	137	-	64	1,712	46	61						64	1,712	46			
Rte. 123 NB	240	186	2	38	1,240	13	34	1	1	2	-	1	39	1,242	13			
Rte. 677 WB	171	63		50	2,814	51	50				7	7	50	2,814	58			
TOTAL	2,477	1,325	107	714	18,549	321	647	3	3	6	7	10	717	18,555	328		1	1

0905

TABLE P-2

SUMMARY OF DELAY, ACCEPTANCE AND COMPLIANCE DATA

(NEW VIRGINIA RTOR APPROACHES)
AFTER RTOR SIGNING

Approach	Number of Right Turns	Right Turn on Green	Number of Captives	Delay and Acceptance												Compliance	
				Rejected RTOR				Accepted RTOR					Total Measured Delay		Total Delay Not Measured	Number of Motorists Did Not Stop	Number of Motorists Using Shoulder
				Measured Delay		Delay Not Meas.	Total No. Rej.	RTOR No. Delay	Measured Delay		Delay Not Meas.	Total No. RTOR					
				No.	Delay				No.	Delay			No.	Delay			
Rte. 63 SB	335	165		21	403	12	21	50	102	638	35	115	123	1,041	47	4	
Rte. 58 WB	180	95	18	20	338	9	22	25	36	128	2	34	56	466	11		
Rte. 21 SB	102	72		10	164	1	10	8	15	80	4	13	25	244	5		
Rte. 360 WB	41	23		1	40		1	10	15	57	2	17	16	97	2	1	
Rte. 360 EB	83	38	18	4	54	2	4	15	20	99	1	21	24	153	3		
Rte. 1 NB	210	140		2	20	1	2	63	66	171	1	65	68	191	2	2	
Rte. 613 WB	181	54	67	12	404	6	12	12	37	411	5	36	49	815	11		
Jeff. Ave. NB	66	49	10	4	57	1	5	1	2	7	-	2	6	64	1		
48th St. WB	187	39	10	42	1,120	16	43	13	58	794	22	37	100	1,914	38		
Warwick Blvd. SB	87	64	12	3	44	-	3	7	8	24	-	8	11	68		2	
Jeff. Ave. NB	63	44		1	31	-	1	3	14	161	4	11	15	192	4	1	
Rte. 244 WB	177	93	-	13	298	8	13	6	42	519	21	19	55	817	29	1	
Rte. 120 SB	203	79	-	18	455	18	18	15	60	753	28	40	78	1,208	46	3	
Rte. 123 NB	250	199	13	5	204	2	5	13	26	157	5	28	31	361	7		
Rte. 677 WB	248	76		5	332	2	5	67	124	1,301	41	147	129	1,633	43	4	
TOTAL	2,413	1,230	148	161	3,964	78	165	308	625	5,300	171	593	786	9,264	249	18	

TABLE P-3

MEAN DELAY PER DELAYED RIGHT TURNING VEHICLE
BEFORE RTOR

Approach	Signal Type	Recorded Traffic Volume	Right Turns		Delayed Right Turns		Mean Delay Per Delayed Right Turn Vehicle (Seconds)
			Number	% Volume	Number	% Right Turns	
Rte. 63 SB	Full Act.	834	380	45.56	206	54.21	24.60
Rte. 58 WB	Full Act.	469	169	36.03	65	38.46	19.91
Rte. 21 SB	Full Act.	347	81	23.34	17	20.99	22.88
Rte. 360 WB	Full Act.	732	37	5.05	13	35.14	35.22
Rte. 360 EB	Full Act.	529	89	16.82	17	19.10	32.54
Rte. 1 NB	Semi Act.	1,550	261	16.84	102	39.08	18.30
Rte. 613 WB	Semi Act.	514	212	41.25	79	37.26	29.60
Jeff. Ave. NB	Semi Act.	1,994	48	2.41	7	14.58	17.00
48th St. WB	Semi Act.	241	178	73.86	133	74.72	22.00
Warwick Blvd. SB	Semi Act.	1,626	109	6.70	24	22.02	12.60
Jeff. Ave. NB	Semi Act.	540	57	10.56	18	31.58	16.80
Rte. 244 WB	Fixed	1,573	198	12.59	94	47.47	21.40
Rte. 120 SB	Fixed	1,507	247	16.39	110	44.53	26.75
Rte. 123 NB	Full Act.	2,901	240	8.27	52	21.67	31.85
Rte. 677 WB	Full Act.	680	171	25.15	108	63.16	56.28

TABLE P-4

MEAN DELAY PER DELAYED RIGHT TURNING VEHICLE
AFTER RTOR

Approach	Signal Type	Recorded Traffic Volume	Right Turns		Delayed Right Turns		Mean Delay Per Delayed Right Turn Vehicle (Seconds)
			Number	% Volume	Number	% Right Turns	
Rte. 63 SB	Full Act.	823	335	40.70	170	50.75	8.46
Rte. 58 WB	Full Act.	470	180	38.30	67	37.22	8.32
Rte. 21 SB	Full Act.	383	102	26.63	30	29.41	9.76
Rte. 360 WB	Full Act.	753	41	5.44	18	43.90	6.06
Rte. 360 EB	Full Act.	390	83	21.28	27	32.53	6.38
Rte. 1 NB	Semi Act.	1,528	210	13.74	70	33.33	2.81
Rte. 613 WB	Semi Act.	461	181	39.26	60	33.15	16.63
Jeff. Ave. NB	Semi Act.	1,958	66	3.37	7	10.61	10.67
48th St. WB	Semi Act.	245	187	76.33	138	73.80	19.14
Warwick Blvd. SB	Semi Act.	1,635	87	5.32	11	12.64	6.18
Jeff. Ave. NB	Semi Act.	649	63	9.71	19	30.16	12.80
Rte. 244 WB	Fixed	1,382	177	12.81	84	47.46	14.80
Rte. 120 SB	Fixed	1,333	203	15.23	108	53.20	15.49
Rte. 123 NB	Full Act.	2,797	250	8.94	38	15.20	11.65
Rte. 677 WB	Full Act.	685	248	36.20	172	69.35	12.66

TABLE P-5

MEAN TIME SAVED PER RIGHT TURNING DELAYED VEHICLE

Approach	% Right Turns			% Delayed Right Turns			Mean Delay (Seconds)		Time Saved (Seconds)
	Before	After	Average	Before	After	Average	Before	After	
Rte. 63 SB	45.56	40.70	43.13	54.21	50.75	52.48	24.60	8.46	16.14
Rte. 58 WB	36.03	38.30	37.17	38.46	37.22	37.84	19.91	8.32	11.59
Rte. 21 SB	23.34	26.63	24.99	20.99	29.41	25.20	22.88	9.76	13.12
Rte. 360 WB	5.05	5.44	5.25	35.14	43.90	39.52	35.22	6.06	29.16
Rte. 360 EB	16.82	21.28	19.05	19.10	32.53	25.82	32.54	6.38	26.16
Rte. 1 NB	16.84	13.74	15.29	39.08	33.33	36.21	18.30	2.81	15.49
Rte. 613 WB	41.25	39.26	40.26	37.26	33.15	35.21	29.60	16.63	12.97
Jeff. Ave. NB	2.41	3.37	2.89	14.58	10.61	12.60	17.00	10.67	6.33
48th St. WB	73.86	76.33	75.10	74.72	73.80	74.26	22.00	19.14	2.86
Warwick Blvd. SB	6.70	5.32	6.01	22.02	12.64	17.33	12.60	6.18	6.42
Jeff. Ave. NB	10.56	9.71	10.14	31.58	30.16	30.87	16.80	12.80	4.00
Rte. 244 WB	12.59	12.81	12.70	47.47	47.46	47.47	21.40	14.85	6.55
Rte. 120 SB	16.39	15.23	15.81	44.53	53.20	48.87	26.75	15.49	11.26
Rte. 123 NB	8.27	8.94	8.61	21.67	15.20	18.44	31.85	11.65	20.20
Rte. 677 WB	25.15	36.20	30.68	63.16	69.35	66.26	56.28	12.66	43.62

TABLE P-6

TIME SAVED PER RTOR APPROACH PER DAY

Approach	1974 Approach ADT	Mean % Right Turns	Mean % of Right Turn Delayed Vehicles	Time Saved Per Delayed Right Turn Vehicle (Seconds)	Time Saved Per RTOR Approach Per Day (Seconds)
Rte. 63 SB	1,875	43.13	52.48	16.14	6,850
Rte. 58 WB	1,725	37.17	37.84	11.59	2,812
Rte. 21 SB	1,298	24.99	25.20	13.12	1,072
Rte. 360 WB	4,203	5.25	39.52	29.16	2,543
Rte. 360 EB	4,203	19.05	25.82	26.16	5,408
Rte. 1 NB	8,648	15.29	36.21	15.49	7,417
Rte. 613 WB	2,653	40.26	35.21	12.97	4,878
Jeff. Ave. NB	8,737	2.89	12.60	6.33	201
48th St. WB	931	75.10	74.26	2.86	1,485
Warwick Blvd. SB	7,541	6.01	17.33	6.42	504
Jeff. Ave. NB	8,028	10.14	30.87	4.00	1,005
Rte. 244 WB	12,358	12.70	47.47	6.55	4,880
Rte. 120 SB	12,675	15.81	48.87	11.26	11,027
Rte. 123 NB	14,878	8.61	18.44	20.20	4,772
Rte. 677 WB	3,367	30.68	66.26	43.62	29,856

APPENDIX Q
SUMMARY OF DELAY, ACCEPTANCE AND COMPLIANCE DATA

TABLE Q-1
VIRGINIA COMPARISON LOCATIONS (OLD RTOR APPROACHES)

Approach	Number of Right Turns	Right Turn on Green	Number of Captives	Delay and Acceptance												Compliance	
				Rejected RTOR				Accepted RTOR					Total Measured Delay		Total Delay Not Measured	Number of Motorists Did Not Stop	Number of Motorists Using Shoulder
				Measured Delay		Delay Not Meas.	Total No. Rej.	RTOR No. Delay	Measured Delay		Delay Not Meas.	Total No. RTOR					
				No.	Delay				No.	Delay			No.	Delay			
Rte. 301 NB	49	27	5					7	16	158	1	14	16	158	1		8
Rte. 301 SB	101	45		2	61		2	38	54	218		53	56	279		2	2
Grove Ave. EB	65	35	1	4	40		4	10	23	213	2	19	27	253	2		
Malvern NB	18	12						2	6	48		3	6	48			
Rte. 7 EB	85	40		6	151	2	6	35	37	108		36	43	259	2	5	
Green Carlyn Dr. NB	7	2	3					1	2	23		1	2	23			
Glyndon WB	49	10	7	2	107		2	10	22	389	8	15	24	496	8		
Rte. 123 NB	62	38	11	2	51		2	6	10	44	1	11	12	95	1		
Rte. 460 WB	324	189	49	2	51		2	77	84	251		84	86	302		20	40
Rte. 1 SB	476	250		2	39	4	2	140	218	1,174	2	210	220	1,213	6	16	
Rte. 1279 WB	235	113	31	4	221		4	59	86	414	1	84	90	635	1	8	
Rte. 1 SB	117	66		13	273	5	13	30	32	95	1	39	45	368	6	5	
Russell Rd. EB	122	55		9	190	2	9	18	50	397	6	42	59	587	8	1	
TOTAL	1,710	882	107	46	1,184	13	46	433	640	3,532	22	611	686	4,716	35	57	50
RTOR Not Permitted																	
Rte. 622 NB	159	62	41	37	1,548	19	36						37	1,548	19		

TABLE Q-2

NORTH CAROLINA LOCATIONS
(GENERAL PERMISSIVE RULE)

Approach	Number of Right Turns	Right Turn on Green	Number of Captives	Delay and Acceptance: Rejected RTOR: Measured Delay: No.	Rejected RTOR: Measured Delay: Delay	Rejected RTOR: Delay Not Meas.	Rejected RTOR: Total No. Rej.	Accepted RTOR: RTOR No. Delay	Accepted RTOR: Measured Delay: No.	Accepted RTOR: Measured Delay: Delay	Accepted RTOR: Delay Not Meas.	Accepted RTOR: Total No. RTOR	Total Measured Delay: No.	Total Measured Delay: Delay	Total Delay Not Measured	Compliance: Number of Motorists Did Not Stop	Compliance: Number of Motorists Using Shoulder
South St. EB	552	338		17	300	21	17	33	94	1,153	82	101	111	1,453	103	1	
Saunders St. SB	21	13	1	2	69	1	2	4	4	8		4	6	77	1		
Six Forks Rd. EB	1,021	692		17	657	30	17	21	97	2,449	185	152	114	3,106	215	2	
Hillsborough St. EB	19	5	3	5	141	1	5		4	107	1	2	9	248	2		
McDowell St. SB	33	17	3	3	58	1	3	3	9	43		8	12	101	1		
Chatham St. EB	64	42	7	8	129	1	8	6	6	12		6	14	141	1		
Academy St. NB	133	52	25	9	185	3	9	8	38	553	6	31	47	738	9	3	
TOTAL	1,843	1,159	39	61	1,539	58	61	75	252	4,325	274	304	313	5,864	332	6	
RTOR Not Permitted																	
Old Wake Forest Rd. SB	400	254	103	24	1,120	18	27				1	1	24	1,120	19		

APPENDIX R

SUMMARY OF ACCEPTANCE DATA

TABLE R-1

VIRGINIA BEFORE AND AFTER APPROACHES (NEW RTOR LOCATIONS)

Approach	Before			After			
	Rejected RTOR	RTOR	%RTOR	Rejected RTOR	RTOR	%RTOR	
Rte. 63 SB	110	1	0.90	21	115	84.56	
Rte. 58 WB	54	0	0	22	34	60.71	
Rte. 21 SB	16	0	0	10	13	56.52	
Rte. 360 WB	9	0	0	1	17	94.44	
Rte. 360 EB	15	0	0	4	21	84.00	
Rte. 1 NB	60	0	0	2	65	97.01	
Rte. 613 WB	54	0	0	12	36	75.00	
Jeff. Ave. NB	7	0	0	5	2	28.57	
48th St. WB	91	0	0	43	37	46.25	
Warwick Blvd. EB	22	0	0	3	8	72.73	
Jefferson Ave. EB	14	0	0	1	11	91.67	
Rte. 244 WB	50	1	1.96	13	19	59.38	
Rte. 120 SB	61	0	0	18	40	68.97	
Rte. 123 NB	34	1	2.86	5	28	84.85	
Rte. 677 WB	50	7	12.28	5	147	96.71	
TOTAL	647	10	1.52	165	593	78.23	
Rte. 58A WB	—	—	—	—	—	—	Continuous green arrow for right turning vehicle
Maxwell Lane EB	2	163	98.79	6	111	94.87	RTOR permitted both before and after
Denbigh Blvd. EB	28	4	12.50	32	2	5.88	RTOR not permitted before or after

TABLE R-2

VIRGINIA COMPARISON APPROACHES
(OLD RTOR LOCATIONS)

Approach	Reject RTOR	RTOR	%RTOR
Rte. 301 NB	0	14	100.00
Rte. 301 SB	2	53	96.36
Grove Ave. EB	4	19	82.61
Malvern NB	0	3	100.00
Rte. 7 EB	6	36	85.71
Glen Carlyn Dr. NB	0	1	100.00
Glyndon WB	2	15	88.24
Rte. 123 NB	2	11	84.62
Rte. 460 WB	2	84	97.67
Rte. 1 SB	2	210	99.06
Rte. 1279 WB	4	84	95.45
Rte. 1 SB	13	39	75.00
Russell Rd. EB	9	42	82.35
TOTAL	46	611	93.00
Rte. 622 NB (No RTOR Permitted)	36	0	0

TABLE R-3

NORTH CAROLINA APPROACHES
(GENERAL PERMISSIVE RULE)

Approach	Reject RTOR	RTOR	%RTOR
South St. EB	17	101	85.59
Saunders St. SB	2	4	66.67
Six Forks Rd. EB	17	152	89.94
Hillsborough St. EB	5	2	28.57
McDowell St. SB	3	8	72.73
Chatham St. EB	8	6	42.86
Academy St. NB	9	31	77.50
TOTAL	61	304	83.29
Old Wake Forest Rd. SB (No RTOR Permitted)	27	1	3.57

APPENDIX S
SUMMARY OF COMPLIANCE DATA

TABLE S-1

VIRGINIA BEFORE AND AFTER APPROACHES
(NEW RTOR LOCATIONS)

Approach	No. Motorists Not Stopping	No. RTOR	% RTOR Not Stopping
Rt. 63 SB	4	115	3.48
Rt. 58 WB	0	34	0
Rt. 21 SB	0	13	0
Rt. 360 WB	1	17	5.88
Rt. 360 EB	0	21	0
Rt. 1 NB	2	65	3.08
Rt. 613 WB	0	36	0
Jeff. Ave. NB	0	2	0
48th St. WB	0	37	0
Warwick Blvd. SB	2	8	25.00
Jeff. Ave. NB	1	11	9.09
Rt. 244 WB	1	19	5.26
Rt. 120 SB	3	40	7.50
Rt. 123 NB	0	28	0
Rt. 677 WB	4	147	2.72
TOTAL	18	593	3.04

TABLE S-2

VIRGINIA COMPARISON APPROACHES
(OLD RTOR LOCATIONS)

Approach	No. Motorists Not Stopping	No. RTOR	% RTOR Not Stopping
Rt. 301 NB	0	14	0
Rt. 301 SB	2	53	3.77
Grove Ave. EB	0	19	0
Malvern NB	0	3	0
Rt. 7 EB	5	36	13.89
Glen Carlyn Dr. NB	0	1	0
Glyndon WB	0	15	0
Rt. 123 NB	0	11	0
Rt. 460 WB	20	84	23.81
Rt. 1 SB	16	210	7.62
Rt. 1279 WB	8	84	9.52
Rt. 1 SB	5	39	12.82
Russell Rd. EB	1	42	2.38
TOTAL	57	611	9.33

TABLE S-3

NORTH CAROLINA APPROACHES
(GENERAL PERMISSIVE RULE)

Approach	No. Motorists Not Stopping	No. RTOR	% RTOR Not Stopping
South St. EB	1	101	1.00
Saunders St. SB	0	4	0
Six Forks Rd. EB	2	152	1.31
Hillsborough St. EB	0	2	0
McDowell St. SB	0	8	0
Chatham St. EB	0	6	0
Academy St. NB	3	31	1.00
TOTAL	6	304	1.97

0916

APPENDIX T

SUMMARY OF TRAFFIC CONFLICTS DATA

TABLE T-1

VIRGINIA BEFORE AND AFTER APPROACHES (NEW RTOR LOCATIONS)

Approach	Before		After	
	Recorded Approach Volume	No. Conflicts	Recorded Approach Volume	No. Conflicts
Rte. 63 SB	834	1	823	1
Rte. 58A WB	783	7	850	7
Rte. 58 WB	469	0	470	1
Rte. 21 SB	347	3	383	1
Rte. 360 WB	732	3	753	2
Rte. 360 EB	529	13	390	6
Rte. 1 NB	1,550	22	1,528	7
Rte. 613 WB	514	23	461	7
Jeff. Ave. NB	1,994	12	1,958	15
48th St. WB	241	2	245	0
Warwick Blvd. SB	1,626	23	1,635	24
Jeff. Ave. NB	540	6	649	14
Denbigh Blvd. EB	655	3	695	4
Rte. 244 WB	1,573	3	1,382	16
Rte. 120 SB	1,507	9	1,333	7
Rte. 123 NB	2,901	32	2,797	35
Rte. 677 WB	680	9	685	1
TOTAL	17,475	171	17,037	148
Maxwell Lane EB (RTOR Permitted Both Before And After)	368	3	331	1

TABLE T-2

VIRGINIA COMPARISON APPROACHES
(OLD RTOR LOCATIONS)

Approach	Recorded Approach Volume	No. Conflicts
Rte. 301 NB	613	11
Rte. 301 SB	388	6
Grove Ave. EB	517	18
Malvern NB	464	23
Rte. 7 EB	1,043	17
Glen Carlyn Dr. NB	212	3
Glyndon WB	167	2
Rte. 123 NB	1,288	14
Rte. 460 WB	1,460	21
Rte. 622 NB	375	30
Rte. 1 SB	2,580	19
Rte. 1279 WB	820	18
Rte. 1 SB	1,788	9
Russell Rd. EB	363	1
TOTAL	12,078	192

TABLE T-3

NORTH CAROLINA APPROACHES
(GENERAL PERMISSIVE RULE)

Approach	Recorded Approach Volume	No. Conflicts
South St. EB	860	12
Saunders St. SB	610	25
Hillsborough St. EB	204	0
McDowell St. SB	2,063	50
Chatham St. EB	645	9
Academy St. NB	455	8
Old Wake Forest Rd. SB	2,552	136
Six Forks Rd. EB	1,621	14
TOTAL	9,010	254

APPENDIX U

SUMMARY OF RTOR TRAFFIC CONFLICTS DATA

TABLE U-1

VIRGINIA BEFORE AND AFTER APPROACHES (NEW RTOR LOCATIONS)

Approach	Before		After	
	RTOR Conflicts	Other	RTOR Conflicts	Other
Rt. 63 SB	0	1	0	1
Rt. 58A WB	0	7	3	4
Rt. 58 WB	0	0	0	1
Rt. 21 SB	0	3	0	1
Rt. 360 WB	0	3	0	2
Rt. 360 EB	0	13	0	6
Rt. 1 NB	0	22	0	7
Rt. 613 WB	0	23	0	7
Jeff. Ave. NB	0	12	1	14
48th St. WB	0	2	0	0
Warwick Blvd. SB	2	21	7	17
Jeff. Ave. NB	0	6	0	14
Denbigh Blvd. EB	0	3	0	4
Rt. 244 WB	0	3	1	15
Rt. 120 SB	0	9	0	7
Rt. 123 NB	1	31	5	30
Rt. 677 WB	1	8	0	1
TOTAL	4	167	17	131
Maxwell Lane EB (RTOR Permitted Both Before And After)	0	3	1	0

0920

TABLE U-2

VIRGINIA COMPARISON APPROACHES
(OLD RTOR LOCATIONS)

Approach	RTOR Conflicts	Other
Rt. 301 NB	0	11
Rt. 301 SB	0	6
Grove Ave. EB	0	18
Malvern NB	0	23
Rt. 7 EB	0	17
Glen Carlyn Dr. NB	0	3
Glyndon WB	0	2
Rt. 123 NB	0	14
Rt. 460 WB	1	20
Rt. 622 NB	1	29
Rt. 1 SB	1	18
Rt. 1279 WB	3	15
Rt. 1 SB	0	9
Russell Rd. EB	1	0
TOTAL	7	185

TABLE U-3

NORTH CAROLINA APPROACHES
(GENERAL PERMISSIVE RULE)

Approach	RTOR Conflicts	Other
South St. EB	3	9
Saunders St. SB	3	22
Hillsborough St. EB	0	0
McDowell St. SB	0	50
Chatham St. EB	0	9
Academy St. NB	1	7
Old Wake Forest Rd. SB	7	129
Six Forks Rd. EB	14	0
TOTAL	28	226

APPENDIX V
DISTRIBUTION OF TRAFFIC CONFLICTS

TABLE V-1

ALL TRAFFIC CONFLICTS

VIRGINIA BEFORE AND AFTER LOCATIONS

(NEW RTOR APPROACHES)

Approach	Type of Conflict												Total	
	Weave		Right Turn From Wrong Lane		Opposing Left Turn		Right Turn Cross Traffic		Rear End		Pedestrian			
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Rte. 63 SB									1	1			1	1
Rte. 58A WB					4	3		2	3	2			7	7
Rte. 58 WB										1				1
Rte. 21 SB									1	1	2		3	1
Rte. 360 WB									2	2	1		3	2
Rte. 360 EB	1								11	6	1		13	6
Rte. 1 NB	6	1	1	1	3	2			12	3			22	7
Rte. 613 WB					1				22	7			23	7
Jefferson Ave. NB	2					1		1	10	13			12	15
48th Street WB									2				2	
Warwick Blvd. SB					3	5	2	2	18	17			23	24
Jefferson Ave. NB					1				5	14			6	14
Denbigh Blvd. EB		1			1				2	3			3	4
Rte. 244 WB				2		4			1	8	2	2	3	16
Rte. 120 SB	1	2		1		2			7	1	1	1	9	7
Rte. 123 NB		4		2		1	1	4	31	24			32	35
Rte. 677 WB	1				7	1			1				9	1
TOTAL	11	8	1	6	20	19	3	9	129	103	7	3	171	148
RTOR Permitted Before & After														
Maxwell Lane EB	1		1			1			1				3	1

0992

TABLE V-2

ALL TRAFFIC CONFLICTS

VIRGINIA COMPARISON APPROACHES

(OLD RTOR APPROACHES)

Approach	Type of Conflict									Total
	Weave	Right Turn From Wrong Lane	Opposing Left Turn	Through Cross Traffic Left to Right	U-Turn	Left Turn Cross Traffic From Left	Right Turn Cross Traffic	Rear End	Pedestrian	
Rte. 301 NB	2	1						8		11
Rte. 301 SB		1						5		6
Grove Ave. EB	2		1					15		18
Malvern Ave. NB	6		6					11		23
Rte. 7 EB	4							13		17
Glen Carlyn Dr. NB			2					1		3
Glyndon WB			2							2
Rte. 123 NB	2							12		14
Rte. 460 WB	1		1					19		21
Rte. 622 NB			14		1	1		14		30
Rte. 1 SB	3	1	1					13	1	19
Rte. 1279 WB			10				3	5		18
Rte. 1 SB	2	1	1					5		9
Russell Rd. EB				1						1
TOTAL	22	4	38	1	1	1	3	121	1	192

TABLE V-3

ALL TRAFFIC CONFLICTS

NORTH CAROLINA APPROACHES

(GENERAL PERMISSIVE RULE)

Approach	Type of Conflict									Total
	Weave	Left Turn From Wrong Lane	Right Turn From Wrong Lane	Opposing Left Turn	Through Cross Traffic Left to Right	Left Turn Cross Traffic From Left	Right Turn Cross Traffic	Rear End	Pedestrian	
South Street EB	1		1	6				4		12
Saunders Street SB	1			12			1	10	1	25
Hillsborough EB										
McDowell SB		1						48	1	50
Chatham EB								9		9
Academy NB				2				5	1	8
Old Wake Forest SB	1					1	5	128	1	136
Six Forks EB				7	2			4	1	14
TOTAL	3	1	1	27	2	1	6	208	5	254

TABLE V-4

RTOR TRAFFIC CONFLICTS

VIRGINIA BEFORE AND AFTER LOCATIONS

(NEW RTOR APPROACHES)

Approach	Type of Conflict								Total	
	Opposing Left Turn		Right Turn Cross Traffic		Rear End		Pedestrian			
	Before	After	Before	After	Before	After	Before	After	Before	After
Rte. 58A WB				2		1				3
Jefferson Ave. NB				1						1
Warwick Blvd. SB			2	2		5			2	7
Rte. 244 WB								1		1
Rte. 123 NB		1	1	3		1			1	5
Rte. 677 WB	1								1	
TOTAL	1	1	3	8		7		1	4	17

Note: This list includes only those Virginia before and after approaches with RTOR conflicts

TABLE V-5

RTOR TRAFFIC CONFLICTS

VIRGINIA COMPARISON LOCATIONS

(OLD RTOR APPROACHES)

Approach	Type of Conflict				Total
	Opposing Left Turn	Through Cross Traffic Left to Right	Left Turn Cross Traffic From Left	Right Turn Cross Traffic	
Rte. 460 WB	1				1
Rte. 622 NB			1		1
Russell Rd. EB		1			1
Rte. 1 SB	1				1
Rte. 1279 WB				3	3
TOTAL	2	1	1	3	7

Note: This list includes only those Virginia comparison approaches with RTOR conflicts.

TABLE V-6

RTOR TRAFFIC CONFLICTS

NORTH CAROLINA APPROACHES

(GENERAL PERMISSIVE RULE)

Approach	Type of Conflict						Total
	Opposing Left Turn	Through Cross Traffic Left to Right	Left Turn Cross Traffic From Left	Right Turn Cross Traffic	Rear End	Pedestrian	
South St. EB	3						3
Saunders St. SB	1			1		1	3
Academy NB						1	1
Old Wake Forest SB			1	5	1		7
Six Forks EB	7	2			4	1	14
TOTAL	11	2	1	6	5	3	28

Note: This list includes only those North Carolina approaches with RTOR conflicts.

APPENDIX W

INTERSECTION INVENTORY OF VIRGINIA ACCIDENT LOCATIONS

Intersection Number	Roadway Routes	Jurisdiction	Area	Intersection Type	Number of RTOR Legs	RTOR Signing Date	Study Period Dates		Type Signals	Traffic Volumes		Speed Limits	
							Before	After		Before RTOR	After RTOR	Major Road	Crossing Road
1	1 & 636	Prince William	Suburban	T	1	12/2/72	12/2/71	12/2/73	Fully Actuated	24,902	26,524	35	25
2	1 & 120	Arlington	Urban	T	1	2/16/73	2/16/72	2/16/74	Semi-Actuated	39,273	41,265	35	35
3	123 & 695	Fairfax	Suburban	T	1	2/20/73	2/20/72	2/20/74	Semi-Actuated	27,354	25,723	45	25
4	143 & 16th St.	Newport News	Suburban	T	1	12/6/72	12/6/71	12/6/73	Fixed Time	8,200	8,600	25	25
5	29 & Massie	Charlottesville	Urban	Cross	1	3/8/73	3/8/72	3/8/74	Semi-Actuated	24,557	22,047	40	25
6	7 & 650	Fairfax	Urban	Cross	1	6/20/73	6/20/72	6/20/74	Fully Actuated	50,283	52,160	45	35
7	28 & 29/211	Fairfax	Suburban	Cross	1	2/16/73	2/16/72	2/16/74	Fully Actuated	27,317	29,600	45	40
8	617 & 611	Fairfax	Rural	Cross	2	2/20/73	2/20/72	2/20/74	Fully Actuated	18,081	20,084	40	40
9	784 & 1811	Prince William	Suburban	Cross	2	6/20/73	6/20/72	6/20/74	Fully Actuated	21,105	21,109	45	25
10	1 & 619	Prince William	Suburban	Cross	2	12/27/72	12/27/71	12/27/73	Fully Actuated	17,287	18,631	35	25
11	25th St. & Terminal	Newport News	Urban	Cross	2	10/25/72	10/25/71	10/25/73	Fixed Time	18,200	19,000	25	25
12	29/211 & 620	Fairfax	Rural	Cross	2	2/20/73	2/20/72	2/20/74	Fully Actuated	15,442	16,838	40	35
13	29 & 33	Greene	Rural	Cross	2	6/20/73	60/20/72	6/20/74	Fully Actuated	7,870	8,537	55	40
14	7 & 703	Fairfax	Urban	Cross	2	2/13/73	2/13/72	2/13/74	Fully Actuated	33,209	33,437	25	25
15	1 & 1270	Prince William	Suburban	Cross	3	12/26/72	12/26/71	12/26/73	Fully Actuated	24,262	26,282	35	25
16	237 & G. Mason Dr.	Arlington	Suburban	Cross	3	2/16/73	2/16/72	2/16/74	Fully Actuated	22,500	25,770	30	25
17	1 & 642/636	Prince William	Rural	Cross	4	2/13/73	2/13/72	2/13/74	Fully Actuated	27,992	29,745	45	45
18	1 & 1279	Prince William	Suburban	Cross	4	12/26/72	12/26/71	12/26/73	Fully Actuated	31,282	33,404	35	25
19	250 & Alderman	Charlottesville	Suburban	Cross	4	4/9/73	4/9/72	4/9/74	Fully Actuated	17,550	18,256	35	25
20	123 & 620	Fairfax	Rural	Cross	4	2/20/73	2/20/72	2/20/74	Fully Actuated	16,163	17,685	45	40

APPENDIX X

CRASH RATES OF VIRGINIA INTERSECTION APPROACH LEGS
BEFORE AND AFTER RTOR SIGNING

CRASH RATES BY POSTED SPEED AT INDIVIDUAL INTERSECTION APPROACH LEGS

Intersection Number and Approach Leg[(a)]	Speed Limit Approaching RTOR Sign	Speed Limit On Cross Street	Number of Accidents On Approach Leg		Daily Traffic On Intersection Leg		Intersection Leg Accident Rate [(b)]		Type of Leg[(c)]
			Before RTOR	After RTOR	Before RTOR	After RTOR	Before RTOR	After RTOR	
16-G. Mason Dr. EB	25	30	1	1	7,830	11,110	0.35	0.25	ADJ
1-Route 636 WB	25	35	2	6	7,937	7,191	0.69	2.29	NON-ADJ
10-Route 619 EB	25	35	1	9	8,358	8,796	0.33	2.80	NON-ADJ
15-Route 1270 WB	25	35	5	9	6,194	6,259	2.21	3.94	NON-ADJ
15-Route 1270 EB	25	35	1	3	800	825	3.43	9.96	ADJ
18-Route 1279 WB	25	35	8	5	8,192	8,217	2.68	1.67	ADJ
18-Route 1279 EB	25	35	3	3	12,842	13,111	0.64	0.63	ADJ
19-Alderman NB	25	35	2	3	5,492	6,602	1.00	1.25	ADJ
19-Alderman NB	25	35	1	0	5,492	6,602	0.50	0	ADJ
5-29 SB	40	25	5	1	13,114	13,500	1.04	0.20	NON-ADJ
3-Route 695 NB	25	45	3	1	4,938	3,087	1.66	0.89	NON-ADJ
9-Route 1811 SB	25	45	4	1	6,458	6,397	1.70	0.43	NON-ADJ
12-Route 620 NB	35	40	2	0	1,986	2,025	2.76	0	NON-ADJ
12-Route 620 SB	35	40	1	3	1,914	2,001	1.43	4.11	NON-ADJ
20-Route 620 WB	40	45	2	2	6,582	7,212	0.83	0.76	ADJ
20-Route 620 EB	40	45	3	2	4,514	5,119	1.82	1.07	ADJ

(a) Approach leg - all traffic lanes across one intersection roadway.

(b) Intersection leg accident rate - yearly crashes per million intersection leg trips.

(c) Type of intersection leg - either adjacent (ADJ) or non-adjacent (NON-ADJ).

CRASH RATES BY POSTED SPEED AT INDIVIDUAL INTERSECTION APPROACH LEGS

Intersection Number and Approach Leg[a]	Speed Limit Approaching RTOR Sign	Speed Limit On Cross Street	Number of Accidents On Approach Leg		Daily Traffic On Intersection Leg		Intersection Leg Accident Rate[b]		Type of Leg[c]
			Before RTOR	After RTOR	Before RTOR	After RTOR	Before RTOR	After RTOR	
4-16th St. SB	25	25	1	1	5,900	5,800	0.50	0.47	NON-ADJ
11-25th St. NB	25	25	3	7	12,100	12,500	0.68	1.53	NON-ADJ
11-Terminal Ave. EB	25	25	1	1	6,210	6,500	0.44	0.42	ADJ
14-Route 7 WB	25	25	15	8	26,480	26,630	1.55	0.82	NON-ADJ
14-Route 7 EB	25	25	15	21	26,480	26,630	1.55	2.16	NON-ADJ
2-Route 120 EB	35	35	7	4	13,967	15,450	1.37	0.71	NON-ADJ
8-Route 611 SB	40	40	1	3	4,670	5,259	0.59	1.56	ADJ
8-Route 617 EB	40	40	6	5	14,646	16,281	1.12	0.84	NON-ADJ
17-Route 1 NB	45	45	9	8	20,765	22,740	1.19	0.96	ADJ
17-Route 1 SB	45	45	7	4	20,765	22,740	0.92	0.48	ADJ
17-Route 638 WB	45	45	0	0	1,551	1,650	0	0	ADJ
17-Route 642 EB	45	45	2	6	12,500	12,360	0.43	1.33	ADJ
16-Route 237 NB	30	25	0	0	14,670	14,660	0	0	NON-ADJ
16-Route 237 SB	30	25	3	1	14,670	14,660	0.56	0.19	ADJ
10-Route 1 SB	35	25	2	4	10,965	12,170	0.50	0.90	ADJ
15-Route 1 NB	35	25	4	4	20,765	22,740	0.53	0.48	ADJ

(a) Approach leg - all traffic lanes across one intersection roadway.

(b) Intersection leg accident rate - yearly crashes per million intersection leg trips.

(c) Type of intersection leg - either adjacent (ADJ) or non-adjacent (NON-ADJ).

CRASH RATES BY POSTED SPEED AT INDIVIDUAL INTERSECTION APPROACH LEGS

Intersection Number and Approach Leg[(a)]	Speed Limit Approaching RTOR Sign	Speed Limit On Cross Street	Number of Accidents On Approach Leg		Daily Traffic On Intersection Leg		Intersection Leg Accident Rate[(b)]		Type of Leg[(c)]
			Before RTOR	After RTOR	Before RTOR	After RTOR	Before RTOR	After RTOR	
18-Route 1 NB	35	25	6	11	20,765	22,740	0.79	1.33	ADJ
18-Route 1 SB	35	25	6	7	20,765	22,740	0.79	0.84	ADJ
19-Route 250 EB	35	25	3	6	12,342	11,654	0.67	1.41	ADJ
19-Route 250 EB	35	25	2	1	12,342	11,654	0.44	0.24	ADJ
9-Route 784 WB	45	25	1	2	19,624	19,277	0.14	0.28	ADJ
6-Route 7 EB	45	35	31	34	43,070	43,820	1.97	2.13	NON-ADJ
7-Route 28 SB	45	40	4	5	11,025	12,065	0.99	1.14	NON-ADJ
20-Route 123 SB	45	40	2	1	10,615	11,520	0.52	0.24	ADJ
20-Route 123 NB	45	40	1	5	10,615	11,520	0.26	1.19	ADJ
13-Route 29 NB	55	40	3	3	5,420	5,980	1.52	1.37	NON-ADJ
13-Route 29 SB	55	40	1	2	5,420	5,980	0.51	0.92	NON-ADJ

(a) Approach leg - all traffic lanes across one intersection roadway.

(b) Intersection leg accident rate - yearly crashes per million intersection leg trips.

(c) Type of intersection leg - either adjacent (ADJ) or non-adjacent (NON-ADJ).

APPENDIX Y

ECONOMIC ANALYSIS FOR RETAINING SIGN PERMISSIVE RULE, ADOPTING GENERAL PERMISSIVE RULE, AND PROHIBITING RTOR

Comments on Table Y-1

I. Retain Present Sign Permissive Law

1. An assumption is made that all additional signs will be installed over the next two years, with the installation cost being approximately $50 per sign (labor - $9.50, material - $21.50, study cost - $19). Implementation is assumed to proceed reaching a maximum level of 50% of the possible locations (4,031 new signs will be installed).

2. RTOR accident costs are determined by extrapolating the experience of the 20 RTOR intersections studied to the entire state, with a progressive implementation rate totaling 50% of possible approaches over two years. These costs should be maximum figures since the 20 intersections had higher than average traffic volumes. (No increase in accident value or fuel savings cost (greater than 55¢/gal.) are shown since they would be only guesses and be offsetting in the least).

3. Sign maintenance expense is an estimation of $3 per RTOR sign per year. Most signs will require no maintenance. The expense per sign is assumed to increase yearly at a rate of 7% due to general inflation (increase in material and labor costs).

4. Fuel savings are calculated by using the total time delay savings measured in the field by actual observation, the average idle engine fuel consumption of .7 gal./hr., and a constant average fuel cost of 55¢/gal. These factors are used to extrapolate fuel savings in dollars over the entire state due solely to RTOR.

5. Time savings are determined by field measurement and extrapolated over the entire state. The total time saved is then multiplied by the minimum wage level ($2.10/hr.).

6. Totals are total yearly savings or cost associated with RTOR, excluding such subjective items as environmental savings, legal costs, and administrative cost.

7. The total net present value of the yearly cash flows of item 6 above is calculated at 7% to give the value of this alternative over a five-year period.

II. Adopt General Permissive Law

1. As of June 30, 1975, 839 RTOR signs were in place. Removal costs would be approximately $20 per sign, including labor and expenses of removing the sign face.

2. With the general permissive law effective, approximately 20% of possible RTOR locations would be deemed too dangerous for RTOR and would be signed No Right Turn on Red (NRTOR) at a cost of $50 per sign (see comment I.1.).

3. Same as I.2. except implementation would allow the maneuver at 80% of possible approaches at period 0.

4. Maintenance expense for 1,941 signs is estimated to be a maximum of $10 per NRTOR sign per year. Most signs will require no maintenance, but some will probably require replacement. An increase of 7% yearly to account for increased labor and material costs in future years is shown.

5. See I.4.

6. See I.5.

7. See I.6.

8. See I.7.

III. Prohibit RTOR

1. Sign removal costs. See II.1.

TABLE Y-1

ECONOMIC ANALYSIS FOR THE THREE ALTERNATIVES
STATEWIDE COSTS

SAVINGS/COST	PERIOD (YEARS)					
	0	1	2	3	4	5
Retain Sign Permissive Rule						
1) Installing new signs	---	(100,350)	(100,375)	---	---	---
2) Possible RTOR Accident Cost	---	(160,160)	(273,347)	(273,347)	(273,347)	(273,347)
3) Sign Maintenance Expense	---	(8,541)	(14,902)	(15,945)	(16,742)	(17,914)
4) Fuel Savings ($)	---	627,450	1,073,500	1,073,500	1,073,500	1,073,500
5) Time Savings ($)	---	3,925,732	5,853,700	5,853,700	5,853,700	5,853,700
6) TOTAL		$4,284,131	$6,538,576	$6,637,908	$6,637,111	$6,635,939
7) (Net Present Value (7%) = $25,811,800)						
Adopt General Permissive Rule						
1) RTOR Sign Removal Expense	(16,780)	---	---	---	---	---
2) Sign NRTOR Locations	(97,070)	---	---	---	---	---
3) Possible RTOR Accident Cost	---	(437,839)	(437,839)	(437,839)	(437,839)	(437,839)
4) Sign Maintenance Expense	---	(19,410)	(20,770)	(22,220)	(23,780)	(25,440)
5) Fuel Savings ($)	---	1,717,570	1,717,570	1,717,570	1,717,570	1,717,570
6) Time Savings ($)	---	9,366,000	9,366,000	9,366,000	9,366,000	9,366,000
7) TOTAL	(113,850)	$10,626,321	$10,624,961	$10,623,511	$10,621,951	$10,620,291
8) (Net Present Value (7%) = $44,977,855)						
Prohibit RTOR						
1) RTOR Sign Removal	(16,780)	0	0	0	0	0
2) TOTAL	(16,780)	0	0	0	0	0
3) (Net Present Value (7%) = ($16,780))						

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APPENDIX Z

CRITERIA FOR IMPLEMENTATION OF RTOR IN GENERAL PERMISSIVE STATES

TABLE Z-1

ILLINOIS GUIDELINES FOR PROHIBITING RIGHT TURNS ON RED AT SIGNALIZED INTERSECTIONS

Right Turn on red movement should be prohibited when the following conditions exist:

1. More than four approaches to the intersection
2. A separate pedestrian phase that displays all red indications for vehicles
3. Signals that have been installed under school crossing warrants
4. Unusual geometric design that restricts the right-turn movement or the visibility of conflicting traffic
5. Posted speed of 50 miles per hour or more through the intersection (signs would restrict only turns onto the high speed facility)

In addition, posting of "NO TURN ON RED" signs should also be considered when one or more of the following conditions exist:

1. Heavy pedestrian volumes
2. Signals located near schools where large volumes of children cross the street or highway
3. Multiphase signals

Where signs are posted to restrict the right turn on red movement, the sign should be placed on or near the far right signal, where there is a near right signal, an additional sign should also be placed on or near it or on a separate right turn signal if one is present.

TABLE Z-2

OHIO DEPARTMENT OF TRANSPORTATION

NO TURN ON RED POLICY

III. GUIDELINES

Each approach of every signalized intersection shall be studied. The decision by the District Traffic Engineer to recommend a prohibition shall be made on the basis of an unexpected hazard, conflict, or traffic problem created when a right turn on red is permitted.

The following guidelines are offered to support a determination of where a prohibition is necessary:

A. Sight distance from stop position to approaching traffic is less than adequate for the right turning driver to observe safe gaps.

B. Geometrics of the intersection are such that the path of the right turning vehicle crosses rather than merges with the vehicle which has a green indication.

C. Right turning vehicles conflict with other traffic which has been given a green arrow indication.

D. Right turning vehicles create a storage or capacity problem on the street into which they are turning.

E. Right turns are permitted from two or more lanes on an approach.

F. An intersection has five or more approaches.

G. An intersection is used by a substantial number of school children where right turning vehicles would be a hazard to the school children.

Other hazards or conflicts may be found which would warrant a prohibition.

IV. DOCUMENTATION PROCEDURE

It is recommended that the District Traffic Engineer prepare and maintain the following information for each prohibition:

A. Intersection condition diagram

B. Statement of hazard, conflict or traffic flow problem eliminated by prohibition.

C. Location of prohibition sign(s); lane(s) or approach regulated.

D. Date, title and signature of person approving prohibition

E. Date sign(s) erected at intersection.

TABLE Z-3

INDIANA WARRANTS FOR CONTROL OF RTOR REGULATION

A. RTOR should be prohibited for safety reasons where:

1. Sight distance of cross street traffic as shown below is not available to the potential RTOR motorists at the Stop Line on his approach.

Minimum Sight Distance

Speed in mph	Sight Distance in Feet
20	217
25	271
30	325
35	379
40	434
45	488
50	542
55	596

2. A separate signal phase for a turning movement exists at the intersection which would conflict with a RTOR movement (the RTOR motorist may not be aware of this movement and hence not look for it).

3. The intersection has more than four approaches (at such locations cross street traffic which conflicts with the RTOR may not be quickly identified by the RTOR motorist or the RTOR motorist may be able to turn into more than one street, thus creating unexpected conflicts).

B. RTOR may be prohibited because of little benefit from the maneuver at locations where:

1. There is very short red time for the approach.

2. Cross street traffic is heavy for many hours of the signal-operating day (where cross street is operating at capacity for many hours of the day).

3. Pedestrian use of the crosswalk on the approach is heavy for many hours of the signal-operating day (at least one pedestrian is in the crosswalk during the red time for the RTOR motorist for many cycles during the day).

4. Little right turn demand exists and there is no right-turn only lane available.

C. RTOR may be prohibited because of possible adverse public reaction where:

1. A school crossing route passes through the intersection.

2. There are moderate to high pedestrian volumes.