THE IMPACT OF GENERAL PERMISSIVE RIGHT AND LEFT TURN ON RED LEGISLATION IN VIRGINIA

by

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

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ABSTRACT

Right turn on red (RTOR) maneuvers have been permitted at signalized intersections in Virginia since 1972. However, until January 1, 1977, following a study requested by the General Assembly, the maneuver was restricted to intersections at which a sign was posted to inform the motorist that RTOR was permitted. Under the pre-1977 legislation RTOR was allowed at only 8% of the state's intersection approaches. Under the legislation that became effective in 1977, motorists are allowed to make right turns on red and left turns on red from a one-way street onto a one-way street, unless the maneuvers are specifically prohibited by a sign. The purpose of the investigation reported here was to examine the benefits and problems resulting from the new legislation. The scope of the study included questionnaire surveys of the state's law enforcement and traffic officials; a telephone survey of public opinion; an accident analysis at 18 intersections; and field investigations at 48 sites to examine time and energy savings, operational problems, and driver acceptance of and compliance with the laws. The analysis of the study data revealed that the new legislation was working very well and was being enthusiastically supported by the vast majority of Virginia officials and the public. RTOR was permitted at 84% of the state's signalized intersection approaches and LTOR at 73% of the approaches where one-way streets intersected. Driver utilization of turn on red opportunities was found to be higher than had been reported in other states. Benefits in terms of energy savings during 1977 were estimated to be 3.6 million gallons of fuel for RTOR and 2,370 gallons for LTOR. A statewide surveillance indicated that 75 accidents involving RTOR motorists and 3 crashes related to LTOR had occurred in 1977. The majority of collisions had involved only minor property damage. It was found that to encourage uniform implementation of the new legislation there was a need for traffic officials to review all approaches at which turns on red were being prohibited to determine if the prohibition was necessary based on the standards promulgated by the Federal Highway Administration. Selective enforcement, supplemented with local media publicity, was recommended to encourage drivers to come to a full stop before turning on red. Because the benefits of the legislation far outweighed its disadvantages, no changes in the law were recommended.

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INTRODUCTION

During its 1976 and 1977 sessions, the Virginia General Assembly amended Section 46.1-184(a) of the Code of Virginia, effective as of January 1, 1977, to permit motorists to make a right turn on red (RTOR) at signalized intersections after coming to a complete stop and yielding the right-of-way to other traffic and pedestrians, unless the maneuver is specifically prohibited by a sign. Subsequently, on July 1, 1977, it became permissible for motorists to make a left turn on red (LTOR) after stopping and yielding to other traffic and pedestrians, provided that the left turn is made from a one-way street onto a one-way street, and that the maneuver is not prohibited by a sign. These turn on red provisions, known as the general permissive rule, brought Virginia into conformance with ordinances specified in the Uniform Vehicle Code and standards outlined in the Manual on Uniform Traffic Control Devices.[1,2]

The legislative changes were made as a result of a study that had been conducted by the Virginia Highway and Transportation Research Council for the Department of Highways and Transportation and the Virginia Department of Transportation Safety (formerly the Highway Safety Division of Virginia) in response to Senate Joint Resolution No. 155.[3] In that 1975 study it had been found that significant savings in time and energy could be realized by adopting general permissive legislation. By completing an RTOR maneuver, the delayed right turning motorist had saved, on average, 14 seconds. Assuming that the maneuver would be permitted at 80% of the state's signalized intersections, it had been estimated that 3 million gallons of fuel would be saved annually. Also, it had been found that no statistically significant differences in traffic accidents at intersections had resulted from permitting RTOR. It also had been noted that the few crashes related to RTOR had involved only minor property damage. Although the study had not included an evaluation of LTOR, many of the states with the general permissive RTOR rule had also permitted LTOR.[4] No significant problems resulting from LTOR maneuvers had been reported by other states.[5,6]

When the Council's study was completed in September 1975, 27 states had adopted the general permissive rule and the other states were rapidly approving the legislation. As of July 1, 1978, 49 states and Puerto Rico had adopted general permissive RTOR. The only state that has not adopted the legislation is Massachusetts; however in that state, RTOR maneuvers are permitted with a sign. RTOR is prohibited in any form in New York City and the District of Columbia.(7)

In the interest of determining the effects of the general permissive legislation in Virginia, several members of the General Assembly and officials of the Department of Transportation Safety requested that the Research Council conduct a follow-up study. Although the Council's 1975 report and the 1976 national RTOR study sponsored by the Federal Highway Administration had indicated that the general permissive rule would yield substantial time and energy savings for motorists with no increase in the accident rate at intersections, highway and safety officials expressed concern that the legislation was not being implemented uniformly and that motorists often were failing to obey the law.(8) This report is the result of the follow-up study conducted by the Research Council. On February 1, 1978, a summary of the significant findings and recommendations found in this report were published to give legislators and highway safety officials the results of the study before the 1978 session of the General Assembly adjourned.(9)

PURPOSE AND SCOPE

The purpose of the follow-up study was to determine the impact of the general permissive right and left turn on red legislation in Virginia. The benefits and the problems associated with the legislation were examined and recommendations for improving traffic operations and highway safety were offered. The specific objectives of the study were to —

1. examine the opinion of law enforcement officials, traffic engineers, and the public;
2. determine the degree to which RTOR and LTOR legislation was implemented, i.e., the number of intersection approach legs at which turns on red were permitted and the number of legs at which they were prohibited;
3. determine driver utilization of turn on red opportunities;

4. investigate motorist compliance with the law, e.g., if drivers came to a complete stop and yielded the right-of-way to other vehicles and pedestrians lawfully using the intersection;

5. determine if problems had occurred as a result of statewide implementation of the general permissive rule;

6. determine the number and frequency of traffic accidents that could be attributed to RTOR and LTOR;

7. estimate the time and energy savings and other benefits being realized as a result of the general permissive legislation;

8. examine the guidelines used to prohibit turns on red; and

9. provide recommendations for alleviating problems identified by the study.

The scope of the study included field investigations conducted to collect operational and safety data related to RTOR and LTOR maneuvers, questionnaire surveys of the state's law enforcement officials and traffic engineers, and a telephone survey of public opinion. After the project working plan and summary report were prepared, the scope of the study was expanded to include additional accident data supplied by city officials and a six-month before and after accident analysis of 18 RTOR intersections.[9,10] These additional data provide a more comprehensive overview of the turn on red accident experience than was available at the time the summary report was published.

METHODOLOGY

To determine the benefits and problems that resulted from statewide implementation of the general permissive rule, opinion surveys were conducted to document the experience of persons directly affected by the legislation. To validate and quantify the opinions expressed in the surveys, field data were collected at randomly selected signalized intersections. The procedures used to conduct the specific tasks of the study are described in the following subsections.

Questionnaire Survey of Law Enforcement Officials

As law enforcement officials are responsible for enforcing traffic regulations, it was felt that their experience with RTOR and LTOR would provide valuable input in assessing the impact of the new legislation. To obtain their views, a three-page questionnaire was sent to law enforcement officials in Virginia cities and towns with a population of 3,500 or more, to officials in urbanized counties, and to the Department of State Police. The officials were requested to give their opinion of the new laws, to provide an accident summary, and to list intersections where they observed problems with RTOR and LTOR. Space was also provided on the questionnaire for general comments.

The questionnaire was sent to 79 law officials on November 25, 1977, and by February 1, 1978, replies had been received from 75 officials. The 95% return rate was obtained by telephone reminders followed by a second mailing of the survey materials to those who had not responded to the first mailing. Once the responses were received, the data were keypunched and tabulated by computer utilizing software available in the Statistical Package for the Social Sciences.(11) A copy of the transmittal letter and the questionnaire containing a tabulation of the responses appear in Appendix A.

Questionnaire Survey of Traffic Engineers

Officials who are responsible for traffic engineering functions including the implementation of the turn on red laws, also have first-hand experience with the new legislation. To examine their experience, a six-page questionnaire was sent to traffic officials in Virginia cities and towns with a population of 3,500 or more and to the Department's district traffic engineers, who are responsible for traffic engineering activities on the state's rural highways and in towns with populations of less than 3,500. The traffic officials were requested to submit the numbers of intersection approach legs at which RTOR and LTOR maneuvers were permitted and the numbers at which they were prohibited, to give their reasons for prohibiting turns on red, to provide a summary of accident experience, and to list their guidelines for prohibiting turns on red. In addition, several questions requested their opinion of the laws.

The questionnaire was mailed to 75 traffic officials on November 29, 1977, and by February 1, 1978, all of the officials had responded to the survey. The 100% return rate was obtained by telephone reminders followed by a second mailing of the questionnaire to those who had failed to respond to the initial survey. After the replies were received, the data were keypunched and tabulated

by computer utilizing a software program prepared by the Council's data section. A copy of the transmittal letter and the questionnaire containing a tabulation of the responses are given in Appendix B.

Survey of Public Opinion

After the RTOR legislation was approved, the Virginia Department of Transportation Safety contracted with a public relations firm to conduct a public information campaign to advise motorists of the new RTOR law and to inform them of the proper way to turn right on red. As the law became effective on January 1, 1977, the campaign was conducted during the fall of 1976 and the first months of 1977. The campaign included news media releases; short radio messages; a 60-second animated television announcement; and a display of RTOR posters in motor vehicle and other state office lobbies throughout the state. In addition, the Division of Motor Vehicles included an RTOR information card in every driver license renewal notice sent out between November 1976 and April 1977. During January 1977 a public opinion poll, through telephone surveys, was conducted by the consultant in Richmond, Northern Virginia, and Hampton Roads to examine public awareness and knowledge of the law.(12) Interviews were conducted with 907 adults selected at random from telephone directories in the three areas. A copy of the questionnaire used during the survey is given in Part A of Appendix C.

During October 1977 the Research Council conducted a statewide public opinion poll through telephone interviews to examine public opinion on a variety of highway safety topics including RTOR and LTOR.(13) The respondents were selected at random from telephone directories throughout the state. Questions on RTOR required respondents to describe right turn on red, indicate their approval or disapproval of the law, and discuss their experience and problems. Questions concerning LTOR required respondents to describe left turn on red and indicate their approval or disapproval of the law. When the interviews were completed, 1,730 persons 16 years of age and older had responded to the questions on RTOR and LTOR. A copy of the survey questions and the results appear in Part B of Appendix C.

Field Studies

In contrast to the subjective nature of the questionnaire data, the field studies were conducted to obtain quantifiable data that could be used to examine the operational and safety characteristics

of RTOR and LTOR. The field studies constituted a major segment of the study and were designed to determine —

1. time savings directly attributable to RTOR and LTOR;
2. the accident potential of RTOR and LTOR as measured by the traffic conflicts technique;
3. driver acceptance and utilization of RTOR and LTOR;
4. driver compliance with the law by stopping and yielding the right-of-way to other vehicles and pedestrians before turning on red; and
5. unique problems that occurred as a result of statewide implementation of the general permissive rule.

Study Approach

To accomplish the objectives of the field studies, data were collected at 48 urban and rural intersection approach legs located throughout the state. Because the data were collected using the procedure established for the 1975 RTOR study, the results of the two studies were comparable. In addition, the study results were compared to the findings of other studies.[5,8,14] Because the intersections were selected at random, the data were felt to be representative of typical RTOR and LTOR conditions, and the results were extrapolated to apply to all signalized intersections in Virginia.

Study Sites

Although each study site was selected at random from the population of all signalized intersections, general guidelines were used to assure the sites were representative of the population. Specifically, the sites were chosen to represent various volumes of vehicle and pedestrian traffic, geometrical features, signal phasing and timing, land use, and environmental characteristics. For the purpose of comparison, data were collected at 10 approaches used in the 1975 study. Also data were collected at several problem sites identified by law enforcement and traffic officials.

As shown in Table 1, primary emphasis was given to collecting data at sites where RTOR maneuvers were permitted. An attempt was made to collect data at one approach in each major region of the state where RTOR was prohibited by a sign; however, weather conditions, scheduling problems, and other contingencies limited collection of data at these sites to three locations. In comparison to intersections where RTOR maneuvers were permitted, there were few intersections of two one-way streets in Virginia, thus the LTOR maneuver was given less attention than RTOR. Although the original plans for the study included the collection of data at intersections where LTOR was prohibited, no such sites were selected because driver utilization of LTOR was found to be low.*

Of the 48 approaches investigated, 10 (21%) were located in rural areas and towns with a population of less than 25,000. The other 38 approaches were located in major urban areas. As 1,925 of the state's 8,994 (21%) intersection approaches are in rural areas and small towns, both rural and urban areas were proportionally represented by the test sites. Other characteristics of the study sites are given in Appendix D.

Table 1

Classification of Field Study Sites

Type of Maneuver	Number of Signalized Intersection Approaches	
	Statewide	Sites Studied
RTOR Permitted	8,994	40
RTOR Prohibited	1,740	3
LTOR Permitted	135	5
LTOR Prohibited	49	0

Data Collection

Data were collected at the 48 study sites between November 1 and December 22, 1977. Observations were made for a four-hour period at each site on weekdays after 12:00 noon on Mondays and before 12:00 noon on Fridays. Data were not collected during the

*During data collection at two of the five sites where LTOR maneuvers were permitted, no left turns on red were observed.

Thanksgiving holiday (November 24 and 25). As a general rule the observations were made from 7:00 a.m. until 11:00 a.m. and from 2:00 p.m. to 6:00 p.m.; consequently, each sample included either the morning or afternoon peak period and several off-peak hours. Most of the data were collected when the pavement was dry; however, because of time limitations, some observations were made during rain. All data were taken under normal traffic conditions; i.e., intersections in the vicinity of roadway construction or under repair were not selected for study.

For each intersection, data were collected at one main street approach and at the adjacent (right-hand) cross street approach. The data were collected during alternate 15-minute periods as described in the Council's 1975 RTOR report.(3) The observations were made from a concealed position to reduce the possibility of influencing motorist behavior. To supplement the field data, 35-mm slides and super 8-mm color movies were taken to depict typical RTOR and LTOR situations.

The data were collected by a three-person team. The tasks of the observers are outlined in Table 2. To reduce observer error and bias, the team received office and field training for two weeks prior to data collection and performed the same tasks throughout the study. To supplement the training, instructions for collecting data were prepared and used as a reference during the field work.(15

Table 2

Data Collection Task

Observer	Task
Team	Select study intersections and complete intersection data form.
1	Team leader in charge of coordinating field data collection activities. Responsible for collecting data on RTOR and LTOR conflicts and unusual maneuvers.
2	Record right turn delay and driver acceptance of and compliance with RTOR and LTOR. Photograph study approaches and randomly film driver behavior.
3	Record approach volumes, opposing traffic maneuvers, and pedestrian activity.

Data collected at each approach included descriptive information of the intersection, e.g., the geometry; signal type, phasing and timing; posted traffic regulations; weather conditions; right (or left) turn delay; driver acceptance of and compliance with the general permissive law; RTOR and LTOR traffic conflicts and unusual maneuvers; and traffic and pedestrian volumes. Descriptions of the major variables are given below.

Delay Data

The time right (or left) turning vehicles were delayed was measured with a stopwatch and recorded to the nearest second. The delay time was defined as the time the vehicle was stopped at the approach, including the time the vehicle advanced in position as a result of another motorist making a turn on red. The delay time did not include deceleration time needed for initially stopping at the approach or acceleration time required for making the turn. To eliminate a biased sample, the turning vehicles were selected at random from the first six right (or left) turning delayed vehicles, i.e., assuming that more than six vehicles were delayed during the same red phase.

Acceptance Data

The term "acceptance" was defined as an obvious attempt by a motorist to turn on red even through traffic or pedestrians legally using the intersection may have prevented the maneuver. A separate count was made of each motorist who completed a turn on red, including turns when the maneuver was prohibited by a sign. A motorist was classified as rejecting a turn on red if (1) he was driving the lead vehicle, (2) there were sufficient gaps in the the opposing traffic stream (6 seconds of gap time or more); and (3) he obviously made no attempt to turn on red. A motorist who initially rejected the maneuver but later, within the same red phase, turned on red was recorded as accepting RTOR or LTOR.

Compliance Data

Driver compliance with the general permissive law by stopping before turning on red was measured by observing motorists' behavior. The four categories used to record compliance were: (1) A complete stop followed by some delay; (2) a pause where the motorist came to a complete stop but immediately turned on red with little or no additional delay; (3) a creep where the motorist did not come to a complete stop but proceeded to make the turn slowly at a low speed; and (4) a run-through where the motorist did not attempt to stop and made the turn on red at the speed of a normal turn on

green vehicle. The complete stop and pause are comparable to the complete stop criteria used in the 1975 report and the creep and run-through are comparable to the definition for not stopping.

Traffic Conflicts and Unusual Maneuver Data

Traffic conflicts and unusual maneuvers are also measures of driver compliance and safety. For the purpose of this study, only RTOR or LTOR traffic conflicts were recorded because time limitations did not permit training the observer to identify the various conflict patterns associated with all maneuvers at intersections. Movies of RTOR traffic conflicts filmed during the 1975 study were used as a basis for training the observer. The training was reinforced by field observations made during the preliminary tests.

The unusual maneuver data included the following motorists' actions.

1. Horn honking to encourage RTOR and LTOR.
2. Cutting through driveways for businesses to avoid the red light.
3. Using shoulder to turn on red.
4. Running the red light (not RTOR or LTOR).
5. Stopping on green for no apparent reason.
6. Turning left on red on streets carrying two-way traffic.
7. RTOR or LTOR motorists not yielding to other traffic or pedestrians.
8. Inefficient use of the green phase time as a result of RTOR or LTOR maneuvers.
9. Turning on red from the wrong lane.
10. Delaying pedestrians by RTOR and LTOR maneuvers.

Vehicle and Pedestrian Traffic Volume Data

The number of vehicles and the directional movement, i.e., left, through, or right, were recorded for each approach. In addition, the number of vehicles legally using the intersection that prevented a motorist from making a turn on red maneuver from the study approach was recorded. The number of pedestrians who crossed the study approach and the number crossing the adjacent

right-hand approach (for an RTOR site) or the adjacent left-hand approach (for an LTOR site) were also counted. The pedestrians crossing during the red phase on the study approach were noted separately from those who crossed during the green phase. The vehicle and pedestrian traffic volume data are not usable measures of operations or safety in their raw form but are used in conjunction with various other data throughout the remainder of the report.

Data Reduction

After the data were collected for each intersection, the forms were examined for recording mistakes and other errors. The data were then manually tabulated and the results were arrayed in various tables to facilitate keypunching.

Accident Studies

Because turn on red accidents are not specifically coded on accident reports in Virginia, the existing traffic records system cannot be used to conduct a comprehensive statewide analysis of these crashes. To provide an estimate of the impact of the general permissive law on accidents, a two-part analysis was employed.

First, to determine the total number of accidents that could be attributed to turn on red maneuvers in Virginia during 1977, law enforcement and traffic officials were asked to submit a summary of accident experience with their questionnaire results. After the questionnaire data were tabulated, the accident summaries given by the enforcement and traffic officials for each jurisdiction were combined and duplicate reports were eliminated.

The second part of the study consisted of examining the effect of RTOR on the accident history at specific intersections. To accomplish this task, the Accident Section of the Department of Highways and Transportation's Traffic and Safety Division prepared collision diagrams for 18 intersections located throughout the state. Because there is a considerable time differential between the date accidents are reported and the date the Department receives the report, the data cover only a six-month before and a six-month after period. RTOR crashes were identified by information contained on the accident data work sheet and the collision diagram. As the LTOR law did not become effective until July 1, 1977, it was not possible to examine the effects of LTOR on the intersection crash rate.

Fuel Savings and Other Benefits

Permitting RTOR and LTOR maneuvers at intersections reduces the time vehicles are delayed by red lights.[3,8,14] Because vehicle engines operate inefficiently at low speeds and when idling, a reduction in engine idling time saves fuel. An estimate of the fuel saved annually by statewide implementation of the turn on red laws was determined utilizing the following formula:

$$FS = NA \times TS \times EC,$$

where

FS = fuel saved annually due to RTOR or LTOR, in gallons;

NA = number of approaches at which RTOR or LTOR maneuvers are permitted;

TS = time saved annually per intersection approach, in hours; and

FC = fuel consumption of the average vehicle at idling conditions, in gallons per hour.

The data for the fuel savings formula were derived from the field studies and from the data given in other reports.[3,8,16]

In addition to permitting fuel savings, reduced delay also improves air quality. A discussion of the affect of RTOR and LTOR on vehicle emissions was based on a review of the literature.

Factors Affecting RTOR Maneuvers

Several factors that affect the number of RTOR maneuvers at an intersection approach have been investigated by various researchers.[3,5,8,14,17,18,19,20] However, most of the authors examined only a few variables and data collection generally was limited. Because field data collected at the 40 RTOR approaches offered a large sample size with a wide range of characteristics, an examination of the factors that influenced RTOR was conducted. Knowledge of the major factors affecting RTOR is important when considering the impact of RTOR at an intersection where installation of a signal is being considered or when an existing signal system is redesigned.

A stepwise multiple linear regression technique was used to examine the relationship of eight independent variables to the dependent variable, i.e., the number of RTOR maneuvers. The eight independent variables were length of the red phase on the approach; type of right turn lane, i.e., exclusive turn lane, combined right turn and through lane, or single approach lane; pedestrian volume; posted speed limit on the opposite cross street; opposing traffic volume; number of delayed right turns; percentage of right turns comprising the total approach volume; and the number of right turns. Obviously, there are correlations between some of the independent variables; however, the objective of the procedure was to determine which variables taken either individually or in combination, were significantly related to the dependent variable. The independent variables were specifically chosen because they are intuitively appealing and can be estimated or easily measured without expensive equipment.

The data were arranged in a 9 x 40 matrix and keypunched. A multiple regression program available on the Hewlett-Packard 2000C system was employed to perform the analysis.

Guidelines for Prohibiting Turns on Red

One of the concerns expressed by traffic and safety officials was that the new turn on red laws were not uniformly implemented in the state. Because traffic engineers in each jurisdiction are responsible for implementing traffic regulations, a variety of interpretations are possible. To examine the manner in which the legislation was implemented, traffic officials were requested, by means of the questionnaire, to list their reasons for prohibiting RTOR and LTOR and to enclose a copy of their guidelines. These data, along with the results of the field observations and a review of the national guidelines, were used to develop recommendations to encourage uniform statewide implementation of the legislation.

ANALYSIS

The analyses of the study data for each of the major tasks are given below. In most cases, a general overview of the study results is presented, then the specific findings relative to RTOR and LTOR are given.

Questionnaire Survey of Law Enforcement Officials

As 95% of the law enforcement officials responsible for enforcing traffic regulations in Virginia's cities, towns, and rural areas responded to the questionnaire, it is appropriate to conclude that a summary of their experience provides considerable insight into the statewide impact of the general permissive laws. An overview of the survey results, which are given in the questionnaire in Appendix A, indicates that —

1. the laws have not created problems and should be retained;

2. some of the signs prohibiting RTOR and LTOR should be removed;

3. some motorists do not come to a full stop before turning on red; and

4. additional education through driver's training courses, the driver's manual, and news media publicity would be beneficial to motorists.

Right Turn on Red

Part A of the survey, questions 2 through 6, specifically addressed the subject of RTOR. A summary of the responses is given below.

1. Of the 75 officials responding, 68% felt that RTOR had created no enforcement problems, 29% felt that the maneuver had created a minor problem, and no one felt that it had led to a major problem.

2. Generally, motorists' compliance with the RTOR law was rated as good or excellent; however, a majority of the officials (51%) gave motorists a fair or poor rating for not coming to a complete stop before turning on red.

3. Eighty percent of the respondents were not aware of any accidents attributable to RTOR maneuvers.

4. Less than half (43%) of the officials reported having received public comments concerning the new law and most of the comments had been in favor of RTOR.

5. Ninety-five percent of the officials felt that the RTOR law was beneficial and should be retained.

6. One official felt the law should be rescinded because motorists fail to yield to pedestrians and small vehicles, and another respondent suggested that the law be amended to require motorists to remain stopped until the pedestrian walk signal has terminated.

Left Turn on Red

Part B of the survey, questions 7 through 12, pertained to LTOR. In Virginia, there were only 18 cities with signalized intersections where a one-way street intersected a one-way street. Officials from all 18 of these cities responded to the questionnaire and a summary of their opinions is given below.

1. Seventy-two percent of the officials felt that LTOR had created no enforcement problems, 28% felt that the maneuver had created a minor problem, and no one felt that it had presented a major problem.

2. The majority of respondents felt that motorists' compliance with the LTOR law was good or excellent; however, the officials felt that motorists' knowledge of the law was only fair or poor.

3. Only one official indicated that LTOR maneuvers had been observed at intersections other than intersections of one-way streets.

4. None of the respondents were aware of any accidents attributable to LTOR.

5. Only 17% of the officials reported having received public comments concerning LTOR and most of the remarks had been in favor of the law.

6. Eighty-nine percent of the officials felt that the LTOR law was beneficial and should be retained.

7. One official felt that the law was confusing to the public and should be rescinded, and another respondent, who apparently was not familiar with the provisions of the law, suggested that LTOR be allowed only at one-way intersections and not from a two-way street onto a one-way street.

Questionnaire Survey of Traffic Engineers

The impact of the turn on red laws is primarily dependent upon the number of approaches at which the maneuvers are permitted. The sign permissive rule, in effect in Virginia from July 1972 until January 1977, had a limited impact because the maneuver was permitted at only 8% of the state's signalized approaches.[3] Although only 9% of the state's traffic engineers favored the general permissive rule during the 1975 RTOR survey, the researchers anticipated that, with that rule, RTOR would be permitted at 80% of the approaches. This expectation was based on experience found in other states that had switched from the sign permissive to the general permissive rule.[3,8,20] To examine the rate of implementation and assess the opinion of the state's traffic officials, the questionnaire survey was conducted. An overview of the survey results, which are given in Appendix B, indicates that —

1. the number of approaches at which turns on red are permitted is greater than was anticipated, but, there is considerable variation in the rate of implementation with some cities permitting the maneuvers at all their approaches and other cities totally prohibiting turns on red;

2. as anticipated, turns on red initially were prohibited at a large number of locations, then after some experience, there was a tendency to remove many of the prohibiting signs;

3. traffic officials feel that many motorists do not come to a complete stop before turning on red; and

4. most of the officials feel the laws are beneficial, they have not created problems, and the legislation should be retained.

Right Turn on Red

Part A of the survey, questions 2 through 11 pertained to RTOR. A summary of the responses is given below.

1. As of December 1, 1977, RTOR was permitted at 84% of the state's 10,734 signalized intersection approaches.

2. There was considerable variation in the rate of implementation of RTOR throughout the state. As shown in Table 3, RTOR was permitted at all of the approaches in some cities, while the maneuver was totally prohibited in other localities. The primary reason for this variation is that there were differences of opinion on guidelines used to prohibit RTOR.

3. The major reasons cited for prohibiting RTOR were inadequate sight distance at the approach, heavy volumes of pedestrian traffic, and unusual intersection geometrics.

4. After experience with RTOR, there was a tendency for traffic officials to permit the maneuver at locations where they initially prohibited it. The officials indicated that in the near future RTOR would be permitted at 9,163 (85%) of the state's signalized approaches.

5. Seventy-nine percent of the officials were not aware of any accidents attributable to RTOR. However, 12 officials reported that 75 accidents, in which 4 persons were injured, had been related to RTOR maneuvers. A description of the accident problem is given in the accident section of this report.

6. Most of the public comments that had been received by traffic officials had been in favor of RTOR. A majority of persons had requested the removal of prohibiting signs; however, there had been some complaints that motorists did not stop before turning on red.

7. Seventy-four percent of the officials felt that not stopping before turning on red was a problem with RTOR.

8. Ninety-three percent of the traffic engineers felt the RTOR law was beneficial and should be retained.

9. One respondent indicated that the RTOR law was confusing and should be rescinded.

10. One official felt that the state should return to the sign permissive law, and another felt that the law should be amended to permit RTOR after yielding to other vehicles and pedestrians.

Table 3

Summary of RTOR Implementation

Jurisdiction	RTOR Permitted	RTOR Prohibited	% Permitted
Abingdon	24	0	100
Alexandria	378	78	83
Arlington County	517	68	81
Ashland	1	1	50
Big Stone Gap	20	0	100
Blacksburg	43	7	86
Blackstone	2	23	8
Bluefield	12	4	75
Bristol	92	40	70
Bristol District	42	2	95
Bedford	6	25	19
Buena Vista	0	24	0
Charlottesville	92	53	63
Chesapeake	95	12	89
Christiansburg	12	4	75
Clifton Forge	27	2	93
Colonial Heights	35	17	67
Covington	34	16	68
Culpeper	13	3	81
Culpeper District	181	15	92
Danville	115	14	89
Emporia	8	12	40
Fairfax	57	11	84
Falls Church	84	18	82
Farmville	8	15	35
Franklin	19	8	70
Fredericksburg	51	28	65
Fredericksburg District	80	11	88
Front Royal	23	1	96
Galax	21	3	88
Hampton	395	12	97
Harrisonburg	88	4	96
Henrico County	122	19	87
Herndon	7	5	58
Hopewell	61	38	62
Leesburg	2	8	20
Lexington	5	28	15
Luray	0	4	0
Lynchburg	150	37	80
Lynchburg District	87	4	96

Table 3 (continued)

Jurisdiction	RTOR Permitted	RTOR Prohibited	% Permitted
Manassas	40	1	98
Manassas Park	4	0	100
Marion	19	9	68
Martinsville	71	63	53
Newport News	373	32	92
Norfolk	803	120	87
Northern Va. District	1336	82	94
Norton	15	0	100
Petersburg	75	28	73
Poquoson	4	0	100
Portsmouth	408	27	94
Pulaski	22	2	92
Radford	28	3	90
Richlands	6	1	86
Richmond	913	314	74
Richmond District	346	18	95
Roanoke	325	136	70
Rocky Mount	5	3	63
Salem	104	12	90
Salem District	120	10	92
South Boston	18	3	86
South Hill	0	4	0
Staunton	73	9	89
Staunton District	61	29	68
Suffolk	38	10	79
Suffolk District	120	10	92
Tazewell	6	0	100
Vienna	36	0	100
Vinton	8	2	80
Va. Beach	392	98	80
Warrenton	10	2	83
Waynesboro	36	15	71
Williamsburg	30	1	97
Winchester	100	22	82
Wytheville	40	0	100
TOTAL	8994	1740	84

Left Turn on Red

Part B of the survey, questions 12 through 22, pertained to LTOR. A summary of the information from 18 respondents in localities with LTOR is given below.

1. As of December 1, 1977, LTOR was permitted at 73% of the state's 184 signalized intersections where a one-way street intersected a one-way street.

2. Forty-four percent of the approaches at which LTOR was permitted were located in the city of Richmond. As shown in Table 4, there was considerable variation in the rate of implementation of LTOR.

3. The primary reasons for prohibiting LTOR were inadequate sight distance and heavy volumes of pedestrian traffic.

4. After initial experience with LTOR, traffic engineers had made little change in permitting or prohibiting the maneuver and no changes in the near future were anticipated.

5. Five of the 18 officials noted that they had observed motorists making a left turn on red at intersections other than intersections of one-way streets; however, these violations had been noted infrequently.

6. Traffic officials reported that 3 accidents had involved LTOR maneuvers. Details of these accidents are given in the accident section of this report.

7. Most of the public comments concerning LTOR had been requests for information, i.e., questions about the conditions under which an LTOR maneuver could be made; and some persons had opined that the law was confusing.

8. Seventy-eight percent of the officials felt that motorists were not aware of the provisions of the LTOR legislation.

9. Seventy-eight percent of the traffic engineers felt the LTOR law was beneficial and should be retained.

10. Three officials felt that the LTOR law was confusing and should be rescinded.

Table 4

Summary of LTOR Implementation

Jurisdiction	LTOR Permitted	LTOR Prohibited	% Permitted
Alexandria	3	0	100
Arlington County	3	0	100
Charlottesville	4	0	100
Danville	4	0	100
Fairfax	1	0	100
Franklin	1	0	100
Fredericksburg	0	4	0
Harrisonburg	4	2	67
Lynchburg	2	10	20
Martinsville	1	3	25
Newport News	22	1	96
Norfolk	2	3	40
Petersburg	0	8	0
Richlands	2	0	100
Richmond	81	11	88
Roanoke	0	3	0
Staunton	2	4	33
Winchester	3	0	100
Total	135	49	73

Survey of Public Opinion

The ultimate success or failure of a traffic control device is primarily dependent upon public acceptance of the device. During January and October 1977, telephone interviews were conducted to examine public awareness of and attitudes toward the turn on red legislation. The questionnaires are shown in Appendix C and the results of the surveys are summarized below.

January Survey of RTOR

In an attempt to evaluate the effectiveness of the RTOR public information campaign conducted during the fall of 1976 and the spring of 1977, a public relations firm surveyed opinions in three major urban areas. The results of the telephone survey, as given in the consultant's report, are shown in Table 5 and the findings are given below.(12)

1. Only 2% of the respondents admitted that they were not aware of the law, which indicated that 98% of the people surveyed were familiar with the new legislation. However, because opinions were not obtained before the information campaign was conducted, the specific effect of the program could not be determined.

2. The majority of persons surveyed could recite, without aid, major precautions that should be taken before turning right on red; however, only 14% knew that they should look for the No Turn On Red Sign.

3. Only 1% of the respondents did not know the precautions that should be taken before making an RTOR maneuver.

4. Persons least likely to know of the RTOR law and the necessary precautions were from the following socio-economic groups:

    a. Under 25 years of age

    b. Retired

    c. Females

    d. Income under $5,000

    e. Less than high school education

Table 5

Public Awareness of Right Turn On Red

January 1977 Survey

	Richmond	Northern Virginia	Hampton Roads	Total
Did not know of law to turn right on red	1	2	2	2
Complete stop				
Unaided Response	77	73	79	76
Aided Response	19	24	16	20
No cars from left				
Unaided Response	89	89	90	89
Aided Response	8	8	5	7
Yield to all in intersection				
Unaided Response	63	64	76	68
Aided Response	34	33	19	29
No turn on red signs				
Unaided Response	15	12	16	14
Aided Response	81	81	78	80
Other Precautions	0	1	0	0
Don't know precautions	2	0	2	1
Number of respondents	301	302	304	907

NOTE: Results are expressed in percentages.

October Survey of RTOR and LTOR

To determine the residual effect of the RTOR campaign on driver attitudes and knowledge of the law, a statewide telephone survey was conducted. The results of the survey, taken from the Council's report, are shown in Table 6 and are summarized below.(13)

1. Over 41% of the persons surveyed knew the meaning of right turn on red and could recite the necessary precautions that should be taken when turning on red.

2. Over 88% of the respondents gave either a correct or partially correct definition of RTOR.

3. Over 11% of the respondents did not know the meaning of RTOR. While this figure was greater than the 2% value found in the January survey of urban area residents, there was still a high level of knowledge of RTOR by the state's residents.

4. Ninety percent of the respondents approved of the general permissive RTOR rule, while 7% did not approve.

5. Only 15% of the persons contacted noted that they had experienced difficulties with RTOR, and most of the problems cited involved being delayed by a motorist who did not turn on red.

6. Persons who drove few miles per year, older people who had not taken driver education, and respondents who displayed a low level of vehicle safety awareness were most likely not to be aware of RTOR and not to approve of the law.

During June and July 1977, the Department of Transportation Safety sponsored a public information campaign to inform Virginia motorists of the new LTOR law. Because there are few intersections in the state where LTOR is applicable, the campaign was minimal when compared to the RTOR effort. To examine public awareness and knowledge of LTOR, the Council's October telephone survey included two questions concerning the law. The results of the survey are presented in Table 7 and the findings are summarized below.

1. Only 19% of the respondents gave a completely correct definition of LTOR, and only 13% gave a partially correct answer. Although these results indicate that the meaning of LTOR was not widely known throughout the state, in Richmond, where 50% of the LTOR approaches were located, over 61% of the residents surveyed gave a correct or partially correct answer.

2. Over 64% of the persons surveyed approved of LTOR, while 25% did not approve.

Table 6

Results of Questions Dealing With

RIGHT TURN ON RED

Response	Frequency (%)
Definition* of Right Turn on Red	
Completely correct	41.4
Partially correct	47.1
Incorrect/don't know	11.5
Approval of current right turn on red practice	
Yes	90.2
No	7.3
No answer	2.5
Experienced difficulties with right turn on red	
No	85.2
Yes	
Too many prohibitive signs	2.2
Stopped cars where RTOR possible	4.4
Conflicts with left turning vehicles	2.9
Pedestrian problems	1.2
Other	3.4

*"Completely correct" meant that the respondent not only knew that a right turn could be made at a red light, but also the condition under which it could be made. "Partially correct" meant that the respondent knew only that a right turn on red could be made.(13)

Table 7

Results of Questions Dealing With

LEFT TURN ON RED

Response	Frequency (%)
Definition* of left turn on red	
Completely correct	19.0
Partially correct	13.4
Incorrect/don't know	67.6
Approval of left turn on red policy	
Yes	63.9
No	25.3
Undecided	10.8

*"Completely correct" meant that the respondent knew not only that a left turn could be made on red but also the conditions under which it could be made.(13)

Field Studies

Data collected at 48 intersection approaches are summarized below.

Right Turn On Red

Operational and safety data were collected at 40 sites at which RTOR was permitted and at 3 sites at which the maneuver was prohibited. The results of the analyses of these data are given below.

Delay Data

The purpose of measuring the delay of right turning vehicles was to examine the savings in time and energy achieved by permitting RTOR. A precise method of determining these savings would be to measure right turning delay at every intersection approach in the state for a period of one-year before RTOR was implemented and for

a one-year after period. The difference between the measurements would be the saving attributable to RTOR, assuming that no improvements in the traffic signals were made. Because it is not economically feasible to measure the delay at the 8,994 RTOR approaches, the savings were estimated with the use of inferential statistics.

The delay savings were estimated by comparing the mean delay per delayed right turn vehicle at the 40 intersection approaches with delay measurements recorded during the Council's 1975 study. Several comparisons were made using the t statistic and the results are shown in Table 8. Prior to the comparisons, the 1975 data, which were recorded for a 12-hour period, were adjusted to cover the same 4-hour morning or afternoon periods used during the 1977 field studies. As expected there were no significant differences in the mean delay when the 1975 12-hour data were adjusted to a 4-hour period; however, as shown in Table 8, the difference in the mean delay between the before and after period was statistically significant.

Table 8

Intersection Delay Comparisons

Comparison	Number of Sites	Average Intersection Mean Delay Per Delayed Right Turning Vehicle, In Seconds	t Statistic	Significance $\alpha \leq 0.01$
Adjusted 1975 Before vs. 1975 After	15 15	25.61 10.90	5.97, 14 d.f.	Yes
Adjusted 1975 Before vs. 1977 RTOR Prohibited	15 3	25.61 27.26	0.31, 16 d.f.	No
Adjusted 1975 After vs. 1977 RTOR Permitted	15 40	10.90 14.67	1.39, 53 d.f.	No
Adjusted 1975 After vs. Same 1977 Sites	6 6	9.85 9.13	0.48, 5 d.f.	No
1977 RTOR Permitted vs. 1977 RTOR Prohibited	40 3	14.67 27.26	2.60, 3 d.f.	No
Adjusted 1975 Before vs. 1977 RTOR Permitted	15 40	25.61 14.67	4.05, 30 d.f.	Yes

A summary of the delay data at the study sites is given in Appendix E. The average intersection delay per delayed right turning vehicle was 14.67 seconds for the 40 RTOR sites. While 14.67 seconds was greater than the 10.90 seconds measured during the 1975 study of 15 RTOR sites, the difference was not statistically significant. However, the difference between the 1975 before mean delay of 25.61 seconds and the 14.67 seconds delay recorded at the 40 sites was significant. Data at the 3 sites at which RTOR was prohibited are also shown in Table 8; however, it should be noted that the sample size was too small to be considered statistically reliable.

As a further comparison, vehicle delays were recorded at 6 of the approaches used during the 1975 study. The results of this comparison also are not significant, which indicates that there was no significant difference in right turning delay at these sites during the two years between the studies.

Results of the tests indicate that the savings in delay time attributable to RTOR did not change since the data were collected in 1975. Thus, with RTOR, the average motorist saved 14.1 seconds and the total savings per approach per day was 5,647 seconds.

Acceptance Data

The time and energy savings attributable to RTOR are dependent upon the number of motorists who take advantage of the opportunity to turn on red. During the study 3,231 right turns were observed at the 40 RTOR sites; 1,296, or 40%, of these were made on green. For the 60% of the turns that were delayed, 93 motorists rejected the opportunity to turn on red and 1,091 turned on red. Thus the average RTOR utilization (No. RTOR/No. Right Turns) was 34%. Similar measurements were made in 1975 at the 15 sites at which RTOR maneuvers had been permitted for only one month and the results indicated that the utilization rate was 25%. However, in that study data also were collected at 13 sites at which RTOR had been permitted with a sign for more than one year and the results indicated a utilization rate of 36%. As a further basis for comparison, an Indiana study conducted one year after general permissive RTOR maneuvers were allowed indicated that the utilization was 20%.[5] The FHWA researchers found that the utilization rate for the permissive rule was 21%.[8] These data show that the utilization rate in Virginia was equivalent to the rate under the old sign permissive rule and considerably higher than the rate found in other states with the general permissive rule. There had been some concern that drivers' utilization of RTOR would be lower with the general rule because there would be no sign to remind

motorists to turn on red. The data clearly did not support this hypothesis.

Another method of examining driver acceptance of RTOR is to determine the percentage of motorists that accept an opportunity to turn on red (No. Accepting RTOR/Total No. RTOR Opportunities). These data for each of the 40 sites are given in Appendix F. Of the 1,184 motorists who had an opportunity to turn on red, 92% did so. This high rate of acceptance was equivalent to the level found in the 1975 study. The data also indicate the rate of acceptance was somewhat uniform throughout the state, except for some small towns where there were few signals and drivers were not frequently exposed to the maneuver. Although a direct cause and effect relationship was not established, it was felt that the publicity campaign significantly increased driver awareness of RTOR which, in turn, resulted in the high rate of RTOR utilization.

At the 3 sites where RTOR was prohibited, no illegal RTOR maneuvers were observed. Although the sample size was too small to permit a generalization of the results, the data did support the opinions of the law enforcement and traffic officials who felt that most motorists complied with the NO TURN ON RED signs.

Compliance Data

The general permissive RTOR law requires motorists to come to a complete stop before turning on red. To test driver compliance with the law, observations were made of motorist behavior at the 40 RTOR sites. The results of these observations are given in Appendix G. Of the 1,091 RTOR maneuvers observed, in 126 (11%) of them, the motorists did not come to a complete stop. During the 1975 study, at the 15 sites where RTOR had been permitted for one month before the data were collected, 3% of the motorists did not stop before making the maneuver. However, at sites where RTOR had been permitted by a sign for a year or more, 9% of the motorists did not stop. Although there is much discussion in the literature of motorists not stopping before turning on red, comparative figures could not be found. The FHWA study did not address the subject; however, an Indiana researcher found that many drivers do not come to a complete stop before turning on red, but the results were not expressed quantitatively.[5,8]

When compared to the percentage of drivers who fail to stop at a STOP sign, the 11% RTOR noncompliance figure is not unusually high. For example, in a Chicago study, 53% to 76% of all drivers failed to come to a full stop.[21] However, if only motorists travelling in excess of 5 miles per hour had been considered, the violation rate would have been between 5% and 10%. If the motorists who made an RTOR at a slow speed had not been considered in the Council study, the violation rate at the 40 sites would have been 7%.

As shown in Appendix G, there was considerable variation in the violation rates at the study approaches. Nearly half (48%) of the violations occurred at 2 approaches. Most of the violations occurred at sites with 3-phase controllers. The observation team reported that most drivers who failed to stop at these locations did so when there was no opposing traffic. Also, no serious vehicle or pedestrian conflicts were observed as a result of motorists not coming to a complete stop. While RTOR violations did not appear to be causing a serious problem, increased public awareness through selective enforcement and news media articles may be desirable. As indicated in the questionnaire survey, law enforcement officials were aware of RTOR violations.

Traffic Conflicts and Unusual Maneuver Data

A traffic conflict is an evasive maneuver, as indicated by a brake light or a lane change, taken by a driver to avoid a collision with another vehicle or pedestrian. RTOR traffic conflicts definitions were developed during the 1975 study and are described in Appendix H.

Traffic conflicts associated with RTOR were observed at only 18 of the 40 study sites. A summary of the conflicts data is given in Appendix I. Of the 46 conflicts observed, 34 (74%) were caused by a motorist making a turn on red in the path of a motorist traveling through the intersection on a green signal. Only 4 pedestrian conflicts were observed and none of the conflicts involved near miss or serious incidences. These findings were similar to the results that had been obtained during the 1975 study and indicated that statewide implementation of the general permissive rule had not resulted in a more hazardous condition for motorists or pedestrians.

The conflicts data also support the following statements.

1. There was no evidence to suggest that RTOR should have been prohibited at intersections where a separate signal phase permitted left turns or pedestrian movements.

2. Because few RTOR conflicts were observed, statistical relationships between RTOR conflicts and volume, geometrics, and other intersection characteristics could not be ascertained. However, RTOR conflicts appeared to occur more frequently at intersections with heavy main line volumes and long signal cycles.

3. The conflicts data suggested that most RTOR drivers yielded the right-of-way to other vehicles and pedestrians using the intersections.

In addition to the specific field data previously discussed, the observers also noted any unusual or unique motorist actions. A summary of these data is given below.

1. At some locations motorists stopped for a red light in the through lane would back up, move into the right lane, and make a turn on red. These maneuvers did not appear to create a hazardous condition.

2. At several locations drivers would use a shopping center or service station entrance to avoid stopping at a red light.

3. In a few cases, drivers would honk their horns to encourage a motorist to turn on red. This practice was not widespread and did not occur frequently because drivers' utilization of RTOR was high at most locations.

4. RTOR motorists did not appear to cause any delay or hazards to pedestrians. When pedestrian volumes were heavy, there were fewer RTOR maneuvers than during off-peak hours. However, the data collection team observed that most vehicle-pedestrian conflicts occurred during the green phase, but the frequency of these conflicts was not recorded because data collection was limited to RTOR conflicts.

5. During the observation periods, 10 motorists ran the red light (not RTOR). These violations occurred at 8 locations. A further discussion of this problem is given in the Accident Analysis section of the report.

6. Some motorists used the shoulder to make a turn on red at 2 approaches. The maneuver did not appear to create a hazardous condition for motorists or pedestrians.

7. One motorist stopped on a green signal for no apparent reason, then proceeded through the intersection. The concern, as expressed by several traffic officials, that widespread implementation of RTOR would result in some motorists stopping on green as well as on red had not materialized.

8. At several intersections, a number of miscellaneous traffic violations, e.g., making a left turn or a U-turn where the maneuvers were prohibited by a sign, or using an exclusive right or left turn lane to travel through the intersection, were observed. These violations appeared to be unique to the site and unrelated to the RTOR maneuver.

Left Turn on Red

LTOR maneuvers have been allowed in some states for a number of years. In view of the fact the practice is recommended in the Uniform Vehicle Code and the Manual on Uniform Traffic Control Devices, the impact of the law has not been the subject of many investigations. In 1976, Kenneth Agent with the Kentucky Division of Research conducted a questionnaire survey of the use of LTOR, and in 1977 the National Highway Traffic Safety Administration reviewed state laws allowing motorists to turn on red.(6,4) The FHWA study did not address LTOR and the movement was not included in the 1975 Council study because it was not possible to collect empirical data necessary to evaluate the maneuver as LTOR was prohibited in Virginia at that time.(8,3) The only documented field observations of LTOR that could be found was a 1976 Indiana study of 8 intersection approaches; consequently, there were little data available to serve as a basis for comparing the results of the Virginia field studies.(5)

Operational and safety data were collected at 5 sites and the results of the analyses are given below. Although the sample size was too small to permit statistical reliability, the findings gave an indication of the impacts of the LTOR legislation.

Delay Data

Because the LTOR legislation was implemented on July 1, 1977, and data collection did not begin until the following November, it was not possible to make before and after delay measurements at selected sites. It was originally anticipated that to provide an estimate of the time saved delays would be recorded at sites with LTOR and at sites where the maneuver was prohibited. The difference in the mean values could then be compared statistically and used to project probable savings. Data were not collected at sites where LTOR was prohibited because no LTOR movements were recorded at 2 of the approaches where the maneuver was permitted. Thus, data collected at these sites were used to estimate before conditions. A summary of the delay data is given in Appendix E.

The average delay at intersections where no LTOR maneuvers were observed was 21.38 seconds and the delay at sites with LTOR was 15.10 seconds. The difference was not statistically significant ($t = 1.47$, 4 degrees of freedom), probably because the sample size was inadequate. The values, however, as shown in Table 9, were of the same order of magnitude as those recorded at RTOR approaches. It is possible that the delay savings of LTOR were similar to those found for RTOR.

Table 9

Comparison of LTOR and RTOR Vehicle Delay

Condition	LTOR		RTOR	
	No. Of Sites	Mean Delay, Seconds	No. of Sites	Mean Delay, Seconds
Turn on Red Permitted	3	15.10	40	14.67
Turn on Red Prohibited	2	21.38	3	27.26

Vehicle delays were not recorded during the Indiana study; therefore, no comparison data were available. If the weighted group average of a typical LTOR motorist had been considered, as opposed to the intersection averages given above, the difference in the means (18.81 seconds without LTOR and 17.51 seconds with LTOR) would have been only 1.3 seconds.

Because there were only 135 LTOR approaches in Virginia and the other LTOR data indicated there were no major problems with the maneuver, it was not considered economically justified to increase the sample size. In view of the limitations on the sample size, the best estimate of time savings attributable to LTOR was found to be between 1.3 and 14.1 seconds. Assuming a proportional relationship to RTOR, the total savings per approach per day was between 520 and 5,647 seconds.

Acceptance Data

Of the total of 253 left turns made at the 5 LTOR study sites, 42% were made on green. As a comparison, 40% of the motorists turned on green at the RTOR sites and an average of 63% of the drivers turned on green at the 8 LTOR sites in Indiana.[5] The

study data also showed that 26 motorists rejected the opportunity to turn on red, while only 37 drivers made an LTOR. The average LTOR utilization (No. LTOR/No. Left Turns) was only 15%, which was considerably less than the 34% figure recorded for RTOR. However, at the Indiana sites the utilization rate was only 1%.[5] The LTOR rejection rate in Virginia (10%) was also less than that found in Indiana (20%). These data indicated that LTOR was utilized more in Virginia than was reported in Indiana, but LTOR utilization in the state had not approached the level of RTOR utilization.

Another method of examining driver acceptance of LTOR is to determine the percentage of motorists who accept an opportunity to turn on red (No. Accepting/Total No. of LTOR Opportunities). These data for the 5 study sites are given in Appendix F. Of the 63 motorists who had an opportunity to turn left on red, 59% did so. The acceptance rate for RTOR was 92%. The data show that acceptance of LTOR was not uniform throughout the state. There were few LTOR intersections in Charlottesville and Staunton, and no one made an LTOR maneuver at those sites. However, in Richmond and Newport News, which contained the majority of the LTOR intersections in the state, the average acceptance rate was 88%, which was nearly equivalent to the RTOR rate of 92%.

Although driver acceptance of LTOR was lower than that for RTOR on a statewide basis, the rates were nearly the same in Richmond and Newport News where exposure to LTOR was frequent. A publicity campaign may increase LTOR utilization in the other 16 localities with LTOR intersections, but the benefits of the program in terms of its cost would not be justified.

Compliance Data

Of the 37 LTOR maneuvers observed, only 1 (3%) of the motorists failed to come to a complete stop before turning on red. Although the sample size was small, it appeared that compliance with the law was not a problem.

Traffic Conflicts and Unusual Maneuvers Data

Only 2 traffic conflicts associated with LTOR maneuvers were observed at the 5 study sites. One involved a pedestrian but was not a serious or near miss incident. The number of conflicts was insignificant, which indicated that implementation of the general permissive LTOR rule had not increased hazards for pedestrians or motorists.

A summary of the unusual maneuvers data is given below.

1. At one location several motorists were observed traveling the wrong way on a one-way street. The sequence of events that precipitated the wrong-way driving are unknown as the drivers were traveling in the wrong direction when they entered the study site.

2. Drivers at one location used a side street to avoid stopping at the red light.

3. The only incident that could be related to an illegal LTOR maneuver occurred at an intersection carrying two-way traffic. The motorist approached the intersection, stopped in the right lane for a red light, then backed up, pulled into the left lane and made a left turn while the light was red. Whether the motorist made the maneuver because he was confused about LTOR or not is unknown. The incident occurred in a city with only 4 LTOR intersections and the maneuver was prohibited at all of the approaches.

Accident Studies

The results of numerous accident studies of RTOR have indicated that the maneuver does not have a significant effect on intersection accidents.[3,5,8,17,18] Several accident investigations concerning LTOR have been conducted and no accident problems have been found; however, the findings have been based on small sample sizes.[6]

To allow examination of the effect of the general permissive rule on accidents, Virginia law enforcement and traffic officials were requested to submit summaries of intersection accidents related to RTOR and LTOR. In addition, a six-month before and after analysis of accidents at 18 RTOR intersections was conducted to examine the effect of the maneuver on the accident frequency at the intersections.

Right Turn On Red

A summary of the accident data submitted by the law enforcement and traffic officials is given in Appendix J. The data do not necessarily include all RTOR accidents that occurred during 1977 because some localities did not conduct an accident surveillance.

In other cases, an accident may have involved an RTOR maneuver but the investigating officer or persons involved may not have submitted a report because the property damage was less than the $250 limit required for filing a report. Even with these deficiencies and other limitations normally associated with accident data, the summary did provide an estimate of the magnitude of the accident problem associated with RTOR. The pertinent findings of the accident study are given below.

1. Seventy-five accidents involving RTOR motorists were reported during the first year of the general permissive rule in Virginia. This figure represents an insignificant percentage of the 142,270 crashes that occurred in Virginia in 1977.(22)

2. There were no fatalities during the study period; however, 4 persons were injured. Two of the 4 persons injured were pedestrians.

3. Most of the accidents were not serious and involved minor property damage.

4. The highest numbers of accidents occurred in Newport News and Roanoke, where 18 RTOR crashes were reported in each city.

5. Two of the accidents occurred at approaches where RTOR was prohibited.

6. Factors that contributed to the accidents included failure to yield the right-of-way, failure to stop before turning on red, poor driver judgement, changing lanes, and making wide right turns.

In addition to the statewide inventory of RTOR accident data, collision diagrams were obtained for 18 intersections to examine the change in accident experience after implementation of RTOR. A summary of the accident data covering a six month before and six month after period is shown in Table 10, and the significant findings of the analysis are given below.

1. There was a 21% decrease in the number of accidents after RTOR; however, the change was not statistically significant ($t = 1.09$ with 17 degrees of freedom).

2. Of the 54 accidents that occurred in the after period, 7 involved a right turn maneuver. Four of the 7 crashes were related to RTOR and 3 involved motorists turning on green.

Table 10

Intersection Accidents

Six Months Before and After RTOR

Intersection	Location	No. of Accidents		RTOR Accidents		Right Turn on Green		Disregarded Stop Light	
		Before	After	Before	After	Before	After	Before	After
Rte. 60 & Rte. 30 and 160Y	James City County	4	2				1		
Rte. 1 & Rte. 73	Henrico County	3	8		1		1	1	1
Rte. 460 & Rte. 61	Town of Narrows Giles County	0	1				1		
Rte. 143 & Rte. 641	York County	3	3					1	2
Rte. 11 & Rte. 140	Washington County	1	0						
Rte. 17 & Rte. 216 and 1219	Gloucester County	5	2		1	2		3	1
Rte. 58 & Rte. 501	Halifax County	7	6					2	2
Rte. 50 & Rte. 522 and I-81 Ramps	Frederick County	4	1					1	
Rte. 11 & Service Road (MP 24.36)	Botetourt County	1	2						
Rte. 60/220 & Rte. 1104	Alleghany County	4	2					1	1
Rte. 21 & Rte. 58/221	Town of Independence Grayson County	1	0						
Rte. 3 & Rte. 301	King George County	5	4					1	3
Rte. 50 & Rte. 699	Fairfax County	7	6					2	
Rte. 1 & From 150 ft. North of Rte. 608N to 150 ft. South of Rte. 1411	Chesterfield County	5	0						
Rte. 7 & Rte. 676 West	Fairfax County	2	6		1				1
Rte. 29 Bus. & Rte. 40	Pittsylvania County (Town of Gretna)	1	3		1				
Rte. 1 & Rte. 234	Town of Dumfries Prince William County	2	3						1
Rte. 11 & 115	Roanoke County	13	5						
Total		68	54	0	4	2	3	12	12

3. No fatalities or injuries occurred as a result of the RTOR accidents. The primary factor that contributed to these crashes was driver failure to yield the right-of-way.

4. Implementation of the general permissive rule did not appear to have increased accident occurrences resulting from motorists disregarding the stop light.

The analysis indicated that RTOR did not have a significant effect on intersection accidents. It is interesting to note that 84% of the traffic officials also felt that RTOR and LTOR did not have a significant effect on the intersection accident rate (see Question 25, Appendix B). Due to the limited length of the study period, the sample size was too small to permit placing a high degree of confidence in the results; however, the data support the findings of previous studies. Accident experience at the intersections will be collected and analyzed for two additional before and after periods to monitor the effects of RTOR. Supplemental reports, which will cover one- and two-year study periods, will also address the crash rates at intersections and changes in the severity of accidents and in crash patterns.

Left Turn on Red

As shown in Appendix J, from the time LTOR was implemented on July 1, 1977, until the end of the year, only 3 LTOR related accidents were reported in the state. The low frequency of accidents was expected because of the limited number of LTOR intersection approaches and the moderate rate of driver utilization of an opportunity to turn left on red. The LTOR accidents involved minor property damage and no injuries were reported. In one incidence, the accident occurred as a result of a motorist making a left turn on red at an intersection carrying two-way traffic. Although the data base was limited, the findings suggested that permitting LTOR had not resulted in a serious accident problem in the state.

Fuel Savings and Other Benefits

The field studies data indicated that permitting turns on red significantly reduced delay at signalized intersections. This reduction in delay also reduced fuel consumption and auto emissions. To estimate these benefits on a statewide basis, several simplifying assumptions were necessary. First the time saved per day at a typical or average approach was obtained from the field data. Secondly, fuel consumption of an average vehicle was obtained from the

literature.[3,23] While it was impossible to precisely measure the saving attributable to the general permissive rule because of the wide variety of intersection and vehicle characteristics involved, the results gave an indication of the magnitude of the benefits.

Right Turn On Red

The field data indicated that implementation of RTOR resulted in delay saving of 5,647 seconds (1.57 hour) per day at the average intersection approach. Gasoline consumption for idling vehicles have been estimated to range between 0.63 gallon per hour for the average auto to 0.89 gallon per hour for truck combinations; however, these data are based on vehicles built in the late 1960's.[23] During the Council's 1975 study, the Ethyl Corporation and the Ford Motor Company Emission Research Laboratory conducted tests on 1975 automobiles and found the fuel consumption rate to range from 0.6 to 0.8 gallon per hour.[3] As no studies were found that refuted the validity of these data, the consumption rate of 0.70 gallon per hour was selected as being representative of the typical vehicle.

The amount of fuel saved, FS, in Virginia during 1977 due to implementation of RTOR at 8,994 intersection approaches is given below.

$$FS = NA \times TS \times EC$$

$$FS = 8{,}994 \text{ approaches} \times 1.57 \text{ hour per day per approach} \times 0.70 \text{ gallon per hour}$$

$$FS = 9{,}880 \text{ gallons per day} = 3.6 \text{ million gallons per year.}$$

If the traffic engineers were to permit RTOR at additional locations during 1978, as they indicated they would in the questionnaire survey, the implementation rate would be 85% and the annual fuel savings would be 3.7 million gallons.

The estimated fuel savings are based on a reduction in stopped delay due to RTOR. Man-Feng Chang et al. of the General Motors Research Laboratories have shown that RTOR also saves time and fuel as a consequence of other factors such as reduced queue lengths and coordinated signals in a typical urban traffic situation.[16] A grid network study conducted by McGee et al., found that the average fuel consumption savings was 2.6% for all vehicles due to RTOR.[8] While the numerical results of these studies cannot be extrapolated to apply to all urban traffic situations, the analyses indicate that the actual fuel saved due to RTOR is greater than the estimated 3.6 million gallons per year.

Within the next several years increased uniformity in the implementation of RTOR could yield greater fuel savings; however, as greater fuel economy measures are built into future autos, the fuel savings due to RTOR will decrease in proportion to the decrease in idling fuel consumption. Regardless of future engine economy, RTOR will continue to significantly reduce delay and conserve energy.

Implementation of RTOR also provides benefits in terms of reduced vehicle emissions. A computer simulation analysis conducted by McGee et al. indicated that RTOR reduced auto emissions for most intersection configurations and volume conditions.(8) The prediction of levels of carbon monoxide, hydrocarbons, oxides of nitrogen, and other pollutants is a complex process which depends upon the age of vehicles in the population, meteorological conditions, and other factors.(24) Because a simplified procedure of estimating amounts of emissions was not available, no estimate of the statewide impact of RTOR on air pollution was attempted. It is, however, logical to assume that RTOR would have a more beneficial effect on air pollution in larger urban areas such as Richmond, Northern Virginia, and the Southeastern Tidewater area which contain the majority of the RTOR approaches than it would elsewhere.

Left Turn On Red

Although the sample size was small, analysis of the field data indicated that the delay savings due to LTOR varied from 520 to 5,647 seconds (0.14 to 1.57 hours) per approach per day. The amount of fuel saved during the period July 1 through December 31, 1977, at 135 LTOR approaches was estimated as

FS = 135 approaches x 0.14 hour per day per approach
x 0.70 gallon per hour

FS = 13 gallons per day = 2,370 gallons per 6 months.

Assuming that LTOR savings per approach will be equivalent to that of RTOR, the fuel savings are

FS = 135 approaches x 1.57 hours per day per approach
x 0.70 gallon per hour

FS = 148 gallons per day = 54,000 gallons per year.

Factors Affecting RTOR Maneuvers

Intuitively, a variety of factors may be expected to influence the number of RTOR maneuvers at an intersection approach. To examine the relationship between RTOR maneuvers and traffic and intersection characteristics, a stepwise linear regression technique was employed. It should be emphasized that the purpose of this procedure was not to fit the data to a mathematical model, but to determine which factors significantly affected RTOR measures, and to develop a simple model which could be used to predict the number of RTOR maneuvers at a specific approach. The basic selection criterion of the independent variables was that they be easy to measure or estimate from existing data.

As the first step in the modeling process, the relationship between RTOR maneuvers and each of the 8 independent variables was determined and the results are presented in Table 11. Based on the study data, the best single predictors of RTOR activity are number of delayed right turns, number of right turns, and percentage of approach volume making a right turn. It is interesting to note that the volume of pedestrian traffic and the volume of vehicular traffic on the opposing approach did not explain much of the variability in RTOR maneuvers, and were poor indicators.

The next step in the analysis was to combine several of the independent variables to determine their effect on RTOR. After numerous combinations were examined, a two-variable model was selected. Standard regression statistics for the model are given in Table 12.

The model is conceptually appealing because the independent variables can easily be obtained for most intersection configurations. The equation can be applied to examine expected RTOR activity at an existing site or at a location where signalization is being considered. In addition to traffic engineers, designers, planners, and researchers also could use the model to estimate RTOR benefits for alternative signal designs.

Table 11

Relationship Between Number of RTOR Maneuvers and 8 Independent Variables

Independent Variable, X	R^2	Standard Error of the Estimate	Regression Equation
Length of red phase, seconds	0.26	26.93	Y* = -4.95 + 0.67 X
Number of approach lanes	0.18	28.41	Y = -13.99 + 19.83 X
Pedestrian volume, per hour	0.002	31.34	Y = 27.89 + 0.097 X
Speed limit on adjacent approach, mph	0.08	30.14	Y = -10.30 + 1.26 X
Traffic volume opposing RTOR, per hour	0.19	28.24	Y = 12.67 + 0.042 X
Number of delayed right turns, per hour	0.85	12.01	Y = -3.24 + 0.66 X
Percentage of approach volume making a right turn	0.47	22.82	Y = 1.98 + 1.28 X
Number of right turns, per hour	0.75	15.72	Y = -10.63 + 0.49 X

* Y = Average number of right turns on red on the study approach per hour.

Table 12

Regression Statistics for RTOR Model

Index	Coefficient	Standard Error	t-Ratio
Constant	-24.51	5.45	-4.50
X_1, Length of red phase, seconds	0.356	0.098	3.62
X_2, Number of right turns per hour	0.439	0.042	10.49
R^2 = 0.81 $\bar{R}^2$ = 0.90			
Standard Error of Estimate =	13.69	d.f. = 37	

Regression equation is

$$Y = -24.51 + 0.356\ X_1 + 0.439\ X_2 ,$$

where

Y = average number of right turns on red at the study approach per hour;

X_1 = length of the red signal phase for the study approach, in seconds; and

X_2 = average number of right turns at the approach, per hour.

Guidelines for Prohibiting Turns on Red

In many cases, traffic engineers in states that switched from the sign permissive rule to the general permissive rule initially prohibited the maneuvers at a high number of locations.(3,8,20) However, after a test period, many of the prohibiting signs were removed. Based on the results of the survey of traffic engineers, a similar phenomenon occurred during the first year of RTOR and LTOR in Virginia; however, there was still considerable variation in the implementation of the legislation.

In May 1976, the Virginia Department of Highways and Transportation developed and transmitted a copy of guidelines for prohibiting RTOR to traffic officials in every urban area in Virginia. The guidelines did not constitute a mandatory standard but were offered to encourage uniform implementation of the law. As shown in Table 13, the guidelines were not used by most officials.

The variety of guidelines used resulted in RTOR and LTOR prohibitions at more intersections than may have been necessary. For example, it is usually not necessary to prohibit turns on red for the following reasons: (1) "Walk - Don't Walk" phase on the approach leg, (2) separate left turn phase opposing RTOR, (3) exclusive right turn lane cannot be provided, (4) short red phase on the approach, (5) heavy cross street traffic volume, and (6) cross street traffic speed greater than 45 miles per hour. For 1977, RTOR was found to be prohibited at 230 approaches for the above cited reasons and LTOR was prohibited at 4 locations.

To encourage nationwide uniformity in turn on red prohibition at intersections, on October 20, 1977, the FHWA transmitted the final MUTCD standards.[7] A copy of the standard is given in Appendix K and the specific provisions are shown in Table 14. Because these standards have been incorporated into the MUTCD, they should be used in lieu of any other guidelines.

Table 13

Summary Guidelines Used to Prohibit Turns on Red in Virginia

Number of Responses	Guidelines Used
28	No formal guidelines
20	VDH&T guidelines — issued May 1977
3	FHWA guidelines
3	Developed own criteria
1	Guidelines in 1975 Council Report
20	No response

NOTE: Responses are to question 26 of the survey of traffic officials (Appendix B).

Table 14

MUTCD Provisions for Prohibiting Turns on Red

A NO TURN ON RED sign may be considered whenever an engineering study finds that one or more of the following conditions exist.

1. Sight distance to vehicles approaching from the left (or right, if applicable) is inadequate.
2. The intersection area has geometrics or operational characteristics which may result in unexpected conflicts.
3. There is an exclusive pedestrian phase.
4. Significant pedestrian conflicts are resulting from RTOR maneuvers.
5. More than three RTOR accidents per year have been identified for the particular approach.
6. There is significant crossing activity by children, or by elderly or handicapped people.

The standards were developed as a result of comprehensive research conducted by a consulting engineering firm for the FHWA. Dr. Hugh W. McGee, principal investigator for the study, prepared an article outlining the findings and considerations involved in the development of the MUTCD standards. The article was published in the January 1978 issue of the Institute of Transportation Engineer's magazine, Transportation Engineering (now ITE Journal), and is reprinted in Appendix L with the permission of the author and ITE. The article should be read by all traffic officials responsible for prohibiting turns on red. It should be noted that the results of the present study also support the MUTCD standards.

During the collection of the field data and the preparation of this report, several problems in implementation were observed. These problems are discussed below.

Signs Prohibiting RTOR and LTOR

The majority of NO TURN ON RED signs had been placed adjacent to the signal head; however, in some jurisdictions the signs were mounted in a post located on the approach. While intersection geometrics and other signing occasionally dictate the location of the prohibiting sign, it is important that the sign be placed where it is most effective. Because the driver must observe the signal

indication, it is desirable to place the sign in close proximity to the signal for maximum effectiveness. Now that the general permissive rule is used nationwide, uniform sign placement is highly desirable to reduce the possibility of a motorist missing the sign.

Traffic engineers in 5 Virginia areas were using a supplementary sign, e.g., NO TURN ON RED — between 7 - 9 a.m. and 4 - 6 p.m., to permit RTOR except for certain hours. The supplemental sign was used at approaches with heavy volumes of pedestrian traffic and at school crossings to prohibit turns on red during the hours of concentrations of pedestrian activities. Widespread adoption of this practice is not recommended because if the MUTCD standards are followed, turns on red will be permitted at most locations.(8) However, if the traffic official perceives that a pedestrian or safety problem exists for only a few hours during the day, it would be more appropriate to use supplemental signing than to prohibit RTOR or LTOR altogether.

The FHWA has completed a laboratory evaluation of symbolized and printed message signs concerning a variety of traffic regulations including RTOR and LTOR.(26) The researchers evaluated 3 symbolized and 2 message signs related to turns on red and found that the symbolic sign shown in Figure 1 had the highest performance rating of the group. The purpose of the report on the evaluation was to provide empirical data to the National Advisory Committee (NAC) to aid it in making decisions relating to sign messages. As of this writing, no action has been taken by the NAC regarding the symbolic no turn on red sign.

Figure 1. Symbolic NO TURN ON RED sign.

Signal Detectors

Although during the study the occurrence was infrequent, occasionally an RTOR or LTOR vehicle would activate a detector causing the signal to delay main line traffic by allocating green time to an empty approach. Similar incidences had been observed during the 1975 field studies.(3) To increase the efficiency of traffic flow, presence detectors should be used when replacing old or designing new signal systems.

Stop Bars

One recommendation in the 1975 study report had been to offset stop bars on multilane approaches to allow the RTOR motorist a clear view of the intersection. It was noted during the field studies that, except for one city, localities had not followed this recommendation. It was also observed that the stop bar locations did not create any problems for RTOR motorists. Although it is a preferred practice to offset the stop bar, it does not appear to be a necessary criterion for RTOR operations.

Pedestrian Safety

One of the major concerns with allowing turns on red is the effect of the maneuvers on pedestrians. The field study team was especially observant of pedestrian problems related to RTOR and LTOR. Although the findings suggested that the effect of RTOR and LTOR on pedestrian delay and safety was insignificant, there was a general vehicle-pedestrian problem at signalized and unsignalized intersections. As noted in the 1975 Council report, Virginia's laws do not afford pedestrians the same degree of safety as do laws in other states.(3) Revision of the pedestrian laws, as outlined in the 1975 report, and increased driver and pedestrian awareness of the problem will be necessary to improve conditions.

Continuing Program

Most traffic regulations, including RTOR and LTOR, should be periodically reviewed to ensure safe and efficient operation of the system. Traffic officials in every jurisdiction should occasionally review their signalized intersections and examine the RTOR and LTOR operations. In view of the recent MUTCD standards and the wide variation in the manner in which the general permissive laws were implemented, it would be desirable for traffic officials in every locality to inspect NO TURN ON RED sites to determine if the prohibiting controls should be removed. Also, periodic spot checks of turn on red sites should be conducted.

SUMMARY OF FINDINGS

Right Turn on Red

1. Of the 75 Virginia law enforcement officials who responded to the survey, 68% felt that RTOR was causing no enforcement problems, while 29% indicated that it was a source of minor problems.

2. Over 95% of the law officials felt that the new RTOR law should be retained because the energy and time savings outweighed its disadvantages.

3. Law enforcement officials and traffic engineers felt that motorists failing to come to a complete stop before turning was a problem with RTOR.

4. Most of the public comments that had been received by law enforcement and traffic officials had been in favor of the RTOR law.

5. As of December 1, 1977, RTOR was permitted at 84% of the state's 10,734 signalized intersection approaches.

6. There was considerable variation in the rate of implementation of RTOR throughout the state.

7. The major reasons cited for prohibiting RTOR were inadequate sight distance at the approach, heavy volumes of pedestrian traffic, and unusual intersection geometrics.

8. After initial experience with RTOR, there was a tendency for traffic officials to permit the maneuver at locations where they originally had prohibited it. Several officials indicated that they planned to permit RTOR at more locations in the near future.

9. Of the state's 75 traffic officials responsible for implementin RTOR, 93% felt the new law was beneficial and should be retained.

10. The results of a January 1977 survey of public opinion in 3 major urban areas indicated that 98% of the persons polled were familiar with the new legislation. The high degree of familiarity was probably attributable to the public information campaign conducted during the latter part of 1976 and early months of 1977.

11. The results of an October 1977 statewide survey of public opinion revealed that only 41% of the respondents had a complete understanding of RTOR; 47% of the respondents offered a partially correct answer; and 7% did not know the meaning of RTOR.

12. Over 90% of the respondents contacted during the October survey approved of RTOR and 83% said they had not encountered problems with it.

13. An analysis of field data collected at 43 sites revealed that with RTOR a motorist saved an average of 14 seconds for every delayed right turn.

14. With RTOR, an average of 5,647 seconds per day was saved at a typical intersection approach.

15. Of the motorists who had an opportunity to turn right on red, 92% did. The rate of utilization was equivalent to the rate found with the sign permissive rule, and it was higher than reported in other states.

16. No illegal RTOR maneuvers were observed at approaches posted with a NO TURN ON RED sign.

17. In 1,091 RTOR maneuvers, 11% of the motorists did not come to a full stop. (During the 1975 Council study only 3% of the motorists had not stopped.) No serious traffic or pedestrian conflicts were observed as a result of motorists not stopping.

18. An insignificant number of traffic conflicts were observed between RTOR vehicles and other vehicles and pedestrians. Of these conflicts, none involved near miss situations.

19. RTOR motorists appeared not to cause any delay or hazards to pedestrians.

20. A summary of accident data submitted by law enforcement and traffic officials indicated that during 1977, 75 accidents involving RTOR had occurred in the state. Four persons, including two pedestrians, had been injured as a result of these accidents; however, most of the collisions had involved minor property damage.

21. A six-month before and six-month after analysis of accidents at 18 RTOR intersections revealed that there was no significant difference in the mean number of accidents after the introduction of general permissive RTOR.

22. Estimated fuel savings in 1977 due to RTOR were 3.6 million gallons.

23. Factors found to significantly affect the number of RTOR maneuvers were the number of delay right turns; the percentage of approach volume making a right turn; the number of right turns; and the length of the red phase. A regression equation was developed that can be used to predict the number of RTOR maneuvers to be expected at an approach.

24. A variety of guidelines were used to prohibit RTOR at approaches.

Left Turn On Red

1. For the 18 localities with LTOR, 13 (72%) of the law enforcement officials felt that LTOR did not create any enforcement problems, while 5 other officials indicated it was a minor problem.

2. Over 89% of the law officials felt that the LTOR law was beneficial and should be retained.

3. Law enforcement officials and traffic engineers felt that motorists' knowledge of the LTOR law was poor.

4. Most of the public inquiries made to law officials and traffic engineers had related to questions concerning how, when, and where LTOR maneuvers could be made.

5. A few enforcement officials and traffic engineers indicated that they had observed motorists turning left on red at intersections with two-way traffic. Only one illegal left turn on red maneuver was observed during the field study.

6. As of October 1, 1977, LTOR was permitted at 73% of the state's 184 signalized intersections where a one-way street intersected a one-way street.

7. Only 18 Virginia localities had the LTOR feature and 50% of those approaches were in the city of Richmond.

8. The primary reasons for prohibiting LTOR were inadequate sight distances and heavy volumes of pedestrian traffic.

9. After their initial experience with LTOR, traffic engineers had made little change in permitting or prohibiting the maneuver and no changes were anticipated in the near future.

10. Over 78% of the traffic engineers felt that LTOR was beneficial and should be retained.

11. Three traffic officials felt the LTOR law was confusing and should be rescinded.

12. The results of an October 1977 statewide survey of public opinion revealed that only 19% of the respondents had a complete understanding of LTOR; 13% of the respondents gave a partially correct answer; and 68% did not know the meaning of LTOR. However, in the Richmond area, over 61% of the persons contacted gave a correct or partially correct definition.

13. Of the persons who responded to the statewide telephone survey, 64% approved of LTOR, while 25% did not.

14. Although the sample size was too small to permit placing a high degree of confidence in the statistical comparisons, the field study data indicated that with LTOR a motorist saves an average of 1.3 seconds for every delayed left turn. There is evidence, however, that LTOR savings at an approach will be equivalent to the savings found with RTOR (14 seconds).

15. Of the 63 motorists who had an opportunity to turn left on red, only 59% did so. In Richmond and Newport News the acceptance rate was 88%.

16. In 37 LTOR maneuvers observed at 5 approaches, only 1 motorist did not come to a complete stop before turning on red.

17. Only 2 traffic conflicts were observed between LTOR vehicles and other traffic and pedestrians.

18. Since LTOR became effective on July 1, 1977, 3 accidents involving LTOR motorists have been reported. These accidents involved only minor property damage and no injuries were reported.

19. The estimated fuel saving due to LTOR during the last 6 months of 1977 was 2,370 gallons. Assuming the LTOR fuel saving per approach will be equivalent to that of RTOR, the annual saving is estimated to be 54,000 gallons.

CONCLUSIONS

Based on an analysis of the study data, the general permissive turn on red laws appeared to be working very well in Virginia. The laws had the overwhelming support of the state's law enforcement officials, traffic engineers, and citizens.

Right turn on red has had a significant impact on improving traffic flow at intersections and in saving motorists time and fuel. The estimated annual fuel saving in Virginia was in excess of 3.6 million gallons. With the new legislation, RTOR maneuvers were permitted at 84% of the state's signalized intersection approaches. While there was a trend for localities to remove some prohibitive NO TURN ON RED signs during 1977, there were still considerable variation and inconsistencies in the manner in which RTOR was implemented. When the general permissive rule came into effect, there was a significant increase in the number of motorists failing to come to a full stop before turning on red. Accidents and pedestrian problems with RTOR appeared to be minor, with the benefits of the legislation far outweighing any disadvantages.

Because there are few signalized intersections of one-way streets in Virginia, left turn on red has not had the statewide impact of RTOR. However, in the cities of Newport News and Richmond, which contained the majority of the state's LTOR approaches, LTOR appeared to be working as well as RTOR.

RECOMMENDATIONS

Based on the results of the study, the general permissive rule has been favorably accepted by the motoring public and has received the strong support of law enforcement and traffic officials. The following recommendations are offered to encourage uniform implementation of the legislation.

1. Traffic officials should review all approaches at which turns on red are prohibited to determine if the prohibition is needed based on the MUTCD standards shown in Appendix K. Periodic spot observations of all RTOR and LTOR approaches should be made to identify problem areas and ensure safe and efficient movement of pedestrians and vehicles.

2. Selective enforcement of the requirement to come to a full stop before turning on red would be desirable at problem sites to encourage motorist compliance with

the law. Some local publicity of the enforcement activity may also be an effective method of encouraging compliance.

3. Signs prohibiting RTOR and LTOR should be placed in close proximity to the signal indicator for maximum effectiveness. Double signing, i.e., an overhead and post-mounted sign may be needed at some locations. Now that the general permissive rule is used nationwide, uniform sign placement is necessary to reduce the possibility of a motorist missing the sign.

4. To increase the efficiency of traffic operations at intersections with RTOR or LTOR, presence detectors should be used when replacing old equipment or when designing new signal systems.

Although it was found that most Virginians were not familiar with LTOR, a statewide public information campaign is not warranted as the opportunity to use LTOR is rare. There is a need to review Virginia's pedestrian protection law and to increase public awareness of measures to promote pedestrian safety at signalized and unsignalized intersections.

No legislative action concerning Section 46.1-184(a) of the Code is recommended.

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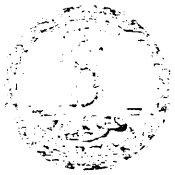
26. Roberts, K. M., E. W. Lareau, Jr., and D. Welch, "Preceptual Factors and Meanings of Symbolic Information Elements," FHWA-RD-77-64, Federal Highway Administration, Washington, D. C., June 1977.

APPENDIX A

QUESTIONNAIRE SURVEY OF VIRGINIA LAW ENFORCEMENT OFFICIALS

PART A: TRANSMITTAL LETTER



COMMONWEALTH of VIRGINIA

HIGHWAY & TRANSPORTATION RESEARCH COUNCIL

BOX 3817 UNIVERSITY STATION
CHARLOTTESVILLE, VIRGINIA 22903

November 25, 1977

IN REPLY PLEASE REFER TO FILE NO. 23-7-43

Dear

At the request of several members of the General Assembly and officials of the Department of Highways & Transportation and the Highway Safety Division, the Virginia Highway & Transportation Research Council is conducting a study to determine the effects of the new general permissive right and left turn on red laws that became effective this year.

The scope of the study includes field investigations designed to examine time and energy savings and driver acceptance and compliance with the law. The study will also include input from the state's traffic engineers, law enforcement officials, and the general public. To enable us to examine law enforcement and accident problems associated with right and left turn on red, I would appreciate your completing the attached questionnaire and returning it by Friday, December 23, 1977.

If you have any questions or would like more information concerning the study, please contact Martin R. Parker, Jr., of our office, telephone (804) 977-0290. Thank you for your cooperation and assistance.

Sincerely,

Jack H Dillard

J. H. Dillard, Head
Virginia Highway & Transportation
Research Council

MRPjr/bsm
Attachment

PART B: QUESTIONNAIRE WITH A SUMMARY OF RESULTS

QUESTIONNAIRE SURVEY OF VIRGINIA LAW ENFORCEMENT OFFICIALS

Right and Left Turn on Red

1. Jurisdiction 75 Virginia Law Enforcement Officials Date February 1, 1978

PART A - Right Turn on Red

Note: Responses are from 75 localities with RTOR. Results are expressed in percentages.

2. How would you categorize law enforcement associated with the new general permissive right turn on red (RTOR) law that became effective on January 1, 1977?

0 Major Problem 29 Minor Problem 68 No Problem 3 No Reply

3. Based on your experience, please rate motorists' compliance with the new RTOR law with regard to the following items. Check one condition for each item.

ITEM	Excellent	Good	Fair	Poor	Not Applicable	No Repl
a. Yielding to other vehicles	20	60	15	1	0	4
b. Yielding to pedestrians	17	49	26	5	0	3
c. Coming to a complete stop before turning on red	8	36	43	8	0	5
d. Obeying NO TURN ON RED signs at locations where RTOR is prohibited	17	52	12	3	11	5
e. Motorist knowledge of the law	7	48	35	5	0	5
f. Other observations (please specify type) Making RTOR when permitted	0	0	1	0	0	99

4. Are you aware of any accidents that can be attributed to the new RTOR law?

17 yes. Please give a summary of the accident experience including the number, severity, and type of accident.

75 accidents were reported in which 4 persons were injured. See Appendix for summary of accident experience.

80 no.
3 have not conducted accident study.

5. Has your department received public comment regarding the new RTOR law?

43 yes. Please indicate the number and nature of the comments received.

Most comments were in favor of RTOR. Numerous requests were received to permit RTOR at more intersections. There were some complaints that RTOR motorists did not stop and yield the right-of-way.

55 no.
2 no reply.

Based on your experience, what is your opinion of the new RTOR law? Please give a reason for your answer.

Opinion		Reason
95	Law should be retained.	Expedites the movement of traffic and saves fuel
1	Law should be rescinded.	Failing to yield to pedestrians and small vehicles
1	Law should be amended. How?	To include stop and remain until after pedestrian walk phase has terminated
3	No reply.	

THERE ARE NO SIGNALIZED INTERSECTIONS IN YOUR JURISDICTION WHERE A ONE-WAY STREET TERSECTS A ONE-WAY STREET, SKIP TO QUESTION 13.

PART B - Left Turn on Red

ote: Responses are from 18 cities with LTOR. Results are expressed in percentages.

How would you categorize law enforcement associated with the new general permissive left turn on red (LTOR) law (from a one-way street onto a one-way street) that became effective on July 1, 1977?

0 Major Problem 28 Minor Problem 72 No Problem 0 No Reply

Based on your experience, please rate motorists' compliance with the new LTOR law with regard to the following items. Check one condition for each item.

ITEM	Excellent	Good	Fair	Poor	Not Applicable	No Reply
a. Yielding to other vehicles	11	61	22	0	0	6
b. Yielding to pedestrians	17	55	22	0	0	6
c. Coming to a complete stop before turning on red.	0	72	22	0	0	6
d. Obeying NO TURN ON RED signs at locations where LTOR is prohibited	0	56	0	0	38	6
e. Motorist knowledge of the law	0	39	33	22	0	6
f. Other observations. (please specify type) _____	0	0	0	0	0	100

Have you observed motorists turning left on red at intersections other than intersections of one-way streets?

6 yes. Please indicate the number and nature of these violations.
Several LTOR maneuvers have been witnessed at intersections other than one-way streets.

94 no.

Are you aware of any accidents that can be attributed to the new LTOR law?

0 yes. Please give a summary of the accident experience including the number, severity and type of accident. No accident experience was reported. However, see the results of the traffic engineer's questionnaire - Appendix B.

100 no.

11. Has your department received public comment regarding the new LTOR law?

17 yes. Please indicate the number and nature of the comments received. Generally, public comment has been favorable; however, some unfavorable comments were received. Most people are not aware of the LTOR law.

83 no.

12. Based on your experience, what is your opinion of the new LTOR law? Please give a reason for your answer.

Opinion		Reason
89	Law should be retained.	Facilitates the movement of traffic and has not caused prob
5.5	Law should be rescinded.	Law is confusing to the public.
5.5	Law should be amended. How?	Allow left turn from a one-way street onto a one-way str not from a two-way street onto a one-way street.

PART C - General

13. Please list intersections where you have observed problems with RTOR or LTOR. Several intersections were listed and some were included in field studies.

14. Additional comments or observations. Some signs prohibiting RTOR and LTOR should be be removed. Some people do not stop before turning on red. The public should be educated through driver training, the driver's manual, and news media publicity.

15. Would you like a copy of our final report on this project?

91 yes.

6 no. 3 no reply.

Your name _____

Title _____

Mailing Address _____

Phone Number Area Code ( ) _____

Thank you for your cooperation and assistance. The information you have provided will be tabulated along with data from other jurisdictions and summarized in the final report. If you have any questions or would like more information concerning the study, please contact: Martin R. Parker, Jr., Virginia Highway & Transportation Research Council, Charlottesville, Virginia, Telephone (804) 977-0290.

QUESTIONNAIRE SURVEY OF VIRGINIA TRAFFIC ENGINEERS

PART A: TRANSMITTAL LETTER

COMMONWEALTH of VIRGINIA

HIGHWAY & TRANSPORTATION RESEARCH COUNCIL

November 29, 1977

23-7-43

Dear

At the request of several members of the General Assembly and officials of the Department of Highways & Transportation and the Highway Safety Division, the Virginia Highway & Transportation Research Council is conducting a study to determine the effects of the new general permissive right and left turn on red laws that became effective this year.

The scope of the study includes field investigations designed to examine time and energy savings and driver acceptance and compliance with the law. The study will also include input from the state's traffic engineers, law enforcement officials, and the general public. To enable us to examine the manner in which the right and left turn laws were implemented, I would appreciate your completing the attached questionnaire and returning it by Friday, December 23, 1977.

If you have any questions or would like more information concerning the study, please contact Martin R. Parker, Jr. of our office, telephone (804) 977-0290. Thank you for your cooperation and assistance.

Sincerely,

Jack H. Dillard

J. H. Dillard, Head
Virginia Highway & Transportation
Research Council

MRPjr/bsm

Attachment

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PART B: QUESTIONNAIRE WITH A SUMMARY OF RESULTS

QUESTIONNAIRE SURVEY OF VIRGINIA TRAFFIC ENGINEERS

Right and Left Turn on Red

1. Jurisdiction 75 Virginia Traffic Engineers Date February 1, 1978

PART A - Right Turn on Red

2. Please indicate the number of signalized intersection approach legs in your jurisdict at which right turn on red (RTOR) is permitted and the number at which it is prohibit under the new general permissive RTOR law that became effective on January 1, 1977.

8994 Number of approach legs at which RTOR is permitted as of December 1, 1977.

1740 Number of approach legs at which RTOR is prohibited with a NO TURN ON RED sign as of December 1, 1977.

3. Indicate the number of approach legs at which RTOR is prohibited for each reason list below. If RTOR is prohibited at an approach for more than one reason, use the most important reason.

Number of approach legs at which RTOR is prohibited	Reason
885	Inadequate sight distance
121	"Walk-Don't Walk" phase on the approach leg
87	All red pedestrian phase at the intersection
40	Separate left turn phase opposing RTOR
20	Exclusive right turn lane cannot be provided
13	Dual left turn lanes on opposite approach
152	Heavy pedestrian volumes
95	School children frequently use the approach
13	Railroad preemption phase
0	More than 3 RTOR accidents per year
107	Intersection has more than 4 approaches
3	Short red phase (less than 20 seconds) on the approach
45	Heavy cross street traffic volume
1	Cross street traffic speed is greater than 45 mph
158	Other. Please specify reason Dual right turn lanes, complex intersection design, fire station preemption, etc.

4.* Since January 1, 1977, have you permitted RTOR at any approaches where you initially prohibited the maneuver?

29 yes. Please give number of approaches and reason(s) for the change.

RTOR permitted at 269 approaches due to improved sight distance, intersecti redesign, public request, etc.

67 no.

4 No Reply

* Denotes that responses are expressed in percentages.

Since January 1, 1977, have you prohibited RTOR at any approaches where you initially permitted the maneuver?

24 yes. Please give number of approaches and reason(s) for the change.

RTOR prohibited at 67 approaches due to public complaint, near accidents, inadequate sight distance, and heavy pedestrian activity.

75 no.

1 No Reply

Do you contemplate changing (permitting or prohibiting) RTOR at any approaches in the near future?

17 yes. Please indicate the number of approaches and type of change.

RTOR may be permitted at 172 approaches and prohibited at 3 in the near future.

79 no.

4 No Reply

Are you aware of any accidents that can be attributed to the new RTOR law?

16 yes. Please give a summary of the accident experience including the number, severity, and type of accident. This information also has been requested from your local law enforcement official. 75 accidents were reported in which 4 persons were injured. See Appendix for summary of accident experience.

79 no.

5 No Reply

Has your department received public comment regarding the new RTOR law?

63 yes. Please indicate the number and nature of the comments received.

Numerous comments were received requesting removal of "NO TURN ON RED" signs. Most comments were in favor of RTOR, however, there were some complaints concerning motorists not stopping before turning on red.

33 no.

4 No Reply

Based on your experience, please rate motorists' compliance with the new RTOR law with regard to the following items. Check one condition for each item.

ITEM	Excellent	Good	Fair	Poor	Not Applicable	No Reply
a. Yielding to other vehicles	16	58	16	1	1	8
b. Yielding to pedestrians	8	44	32	7	1	8
c. Coming to a complete stop before turning on red	0	17	43	31	1	8
d. Obeying NO TURN ON RED signs at locations where RTOR is prohibited	23	48	8	4	9	8
e. Motorist knowledge of the law	7	48	25	7	4	9
f. Other observations (please specify type) Using shoulder, D. C. and Maryland motorists not aware of RTOR law.	0	0	0	3	0	97

Based on your observations, what do you feel are the benefits and problems with the new RTOR law? Include implementation problems if any difficulties were encountered.

Benefits Improves movement of traffic and saves time and fuel. Reduces the number of vehicles delayed by the red light.

Problems Motorists do not stop before turning on red. Motorist expect RTOR at all intersections. Motorists switch lanes to utilize RTOR. Out of state drivers do not utilize RTOR.

Denotes that responses are expressed in percentages.

11.* Based on your experience, what is your opinion of the new RTOR law? Please give a reason for your answer.

	Opinion	Reason
93	Law should be retained.	Saves time and fuel with few problems
1	Law should be rescinded.	Creates confusion.
3	Law should be amended. How?	Return to sign permissive law; Use right turn yield
3	No Reply	

IF THERE ARE NO SIGNALIZED INTERSECTIONS IN YOUR JURISDICTION WHERE A ONE-WAY STREET INTERSECTS A ONE-WAY STREET, SKIP TO QUESTION 23.

NOTE: Responses are from 18 cities with LTOR.

PART B - Left Turn on Red

12. Please indicate the number of signalized intersection approach legs at which left turn on red (LTOR) is permitted and the number at which it is prohibited from a one-way street onto a one-way street under the general permissive LTOR law that became effective on July 1, 1977.

135 Number of approach legs at which LTOR is permitted as of December 1, 1977.

49 Number of approach legs at which LTOR is prohibited with a NO TURN ON RED sign as of December 1, 1977.

13. Indicate the number of approach legs at which LTOR is prohibited for each reason listed below. If LTOR is prohibited at any approach for more than one reason, use the most important reason.

Number of approach legs at which LTOR is prohibited	Reason
23	Inadequate sight distance
4	"WALK-DON'T WALK" phase on the approach leg
7	All red pedestrian phase at the intersection
0	Exclusive left turn lane cannot be provided
7	Heavy pedestrian volumes
0	School children frequently use the approach
0	Railroad preemption phase
0	More than 3 LTOR accidents per year
0	Short red phase (less than 20 seconds) on the approach
0	Heavy cross street traffic volume
0	Cross street traffic speed is greater than 45 mph
8	Other. Please specify reason: Dual left turn permitted; multileg intersection

14.* Since July 1, 1977, have you permitted LTOR at any approaches were you initially prohibited the maneuver?

0 yes. Please give the number of approaches and reason(s) for the change.

89 no.

11 No Reply

15.* Since July 1, 1977, have you prohibited LTOR at any approaches where you initially permitted the maneuver?

6 yes. Please give number of approaches and reason(s) for the change.

LTOR prohibited at one intersection because of motorist confusion.

94 no.

* Denotes that responses are expressed in percentages.

Do you contemplate changing (permitting or prohibiting) LTOR at any approaches in the near future?

0 yes. Please indicate the number of approaches and type of change.

100 no.

Have you observed motorists turning left on red at intersections other than intersections of one-way streets?

28 yes. Please indicate the number and nature of these violations.

Several left turns from a two-way street onto a one-way street and left turns from a one-way street onto a two-way street were reported.

72 no.

Are you aware of any accidents that can be attributed to the new LTOR law?

11 yes. Please give a summary of the accident experience including the number, severity, and type of accident. This information also has been requested from your local law enforcement official. Three accidents involving LTOR vehicles were reported. See Appendix for further details.

83 no.

6 No Reply

Has your department received public comment regarding the new LTOR law?

44 yes. Please indicate the number and nature of the comments received.

Several inquiries requesting information on LTOR and commenting that the law is confusing.

56 no.

Based on your experience, please rate motorists' compliance with the new LTOR law with regard to the following items. Check one condition for each item.

ITEM	Excellent	Good	Fair	Poor	Not Applicable	No Reply
a. Yielding to other vehicles	28	44	6	0	22	0
b. Yielding to pedestrians	11	56	11	0	22	0
c. Coming to a complete stop before turning on red	6	50	17	5	22	0
d. Obeying NO TURN ON RED signs at locations where LTOR is prohibited	27	17	0	0	61	0
e. Motorist knowledge of the law	0	0	50	28	22	0
f. Other observations. (please specify type)	0	0	0	0	0	0

Based on your observations, what do you feel are the benefits and problems with the new LTOR law? Include implementation problems if any difficulties were encountered.

Benefits Improves the movement of traffic and saves fuel and time.

Problems Motorists are not aware of the LTOR law.

Denotes that responses are expressed in percentages.

22.* Based on your experience, what is your opinion of the new LTOR law? Please give a reason for your answer.

	Opinion	Reason
78	Law should be retained.	Reduces congestion and saves fuel.
17	Law should be rescinded.	Law is confusing.
0	Law should be amended.	How?
5	No Reply	

PART C - General

23. Please list intersections where you have observed problems with RTOR or LTOR.

Several intersections were listed and some of these approaches were included in the field studies.

24.* Do you use a supplementary sign in conjunction with a NO TURN ON RED sign, e.g., NO TURN ON RED - From 7:00 to 9:00 a.m., instead of prohibiting the maneuver altogether?

7 yes. Please describe condition(s) During hours of heavy pedestrian traffic and school traffic volumes. One city is considering their use at school crossi

85 no. 1 Not applicable 7 No reply

25.* Do you feel the new RTOR and LTOR laws have led to a significant change in the accide rate at signalized intersections?

0 Significant increase

84 No change

0 Significant decrease

9 Other. Please comment Accident studies will be conducted in the near future.

7 No Reply

26. Please list (or enclose a copy of) your guidelines for prohibiting turns on red.

Response were: 28 cities had no formal guidelines; 3 used FHWA guidelines; 20 used VDH guidelines; 3 had formally developed their own criteria; 1 used RTOR study guidelines; and 20 cities did not respond.

27. Additional comments or observations. Overall observations of turn on red maneuvers inc the benefits outweigh any problems. Motorists should be reminded to stop and yield th right-of-way before turning.

28.* Would you like a copy of our final report on this project?

90 yes.

5 no.

5 No Reply

* Denotes that responses are expressed in percentages.

Your name _____

Title _____

Mailing address _____

_____

_____

_____

Phone number (area code) ( ) _____

ık you for your cooperation and assistance. The information you have provided will be ılated along with data from other jurisdictions and summarized in the final report. If have any questions or would like more information concerning the study, please contact: tin R. Parker, Jr., Virginia Highway & Transportation Research Council, Charlottesville, ginia, Telephone (804) 977-0290.

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APPENDIX C

SURVEY OF PUBLIC OPINION

PART A: QUESTIONNAIRE PREPARED BY A PUBLIC RELATIONS FIRM

Note: Questions submitted by George Douglas, Public Relations, Inc. for the January 1977 public opinion poll.

Are you aware of the law that went into effect January 1, 1977 allowing drivers to turn Right on red lights at intersections?

(Go to Q) ◁ No/DK

Yes: ☐ What are the precautions that should be taken before you turn Right on a red light? What else? (FOR THOSE NOT MENTIONED:) Are you aware that you should _____? How about _____?

	UNAIDED	AIDED
Come to a complete stop	-	0
Check to see that no cars are coming from left	1	2
Yield to all cars and pedestrians in intersection	3	4
Check for "No Right Turn On Red" Signs	5	6
Other Precautions _____		8
DK Precautions (Unaided or Aided)		9

PART B: RESULTS OF THE RESEARCH COUNCIL'S TELEPHONE SURVEY

Note: Results were taken from the 1977 Virginia Highway Public Opinion Poll[13]. Responses are expressed in percentages and are based on replies from 1730 persons 16 years of age or older.

17. Tell me what the term "right turn on red" means.

	Category	Percent Reply
1.	Completely correct	41.3
2.	Conceptually correct	47.0
3.	Incorrect	4.1
4.	Don't know	7.4
5.	Refused	0.2

18. The current "right turn on red" rules allow you to make a right turn after making a complete stop at the red light, as long as there is no sign prohibiting it and as long as the way is clear. Do you approve of "right turn on red" as it is currently practiced?

	Category	Percent Reply
1.	Yes	90.1
2.	No	7.3
3.	Undecided	1.2
4.	No opinion	1.3
5.	Refused	0.1

19. Have you experienced any difficulty with "right turn on red"?

	Category	Percent Reply
1.	Yes	15.5
2.	No	83.2
3.	Don't know	1.1
4.	Refused	0.2

20. What sort of problems have you encountered?

	Category	Percent Reply
1.	Too many prohibitive signs	2.2
2.	Conflicts with pedestrian traffic	0.6
3.	Difficulty as a pedestrian	0.6
4.	Stopped cars where RTOR possible	4.3
5.	Conflicts with RTOR vehicles (cross traffic)	2.9
6.	Other	3.9
7.	No specific problem	0.4
8.	Refused	0.1
9.	No problems	85.0

21. What does the term "left turn on red" mean?

	Category	Percent Reply
1.	Completely correct	18.8
2.	Conceptually correct	13.2
3.	Incorrect	10.0
4.	Don't know	56.8
5.	Refused	1.2

22. You can make a left turn at a red light as long as you are turning from a one-way street onto a one-way street, and as long as the way is completely clear. Do you approve of the policy of "left turn on red"?

	Category	Percent Reply
1.	Yes	63.9
2.	No	25.2
3.	Undecided	5.0
4.	No opinion	5.7
5.	Refused	0.2

APPENDIX D

FIELD STUDY SITE CHARACTERISTICS

Intersection	Jurisdiction	Area	Int. Type	Number Turn on Red Legs	Signal Description	Approach Studied	Turn on Red Approach	Lanes No.	Lanes Type	Est. 1977 Approach ADT	Speed Limit	Estimated Pedestrians Per Day 1977
Arlington Blvd. & Emmet St.	City of Charlottesville	Commercial	T	2 RTOR	Actuated, 3 Phase	E.B. Arlington	RTOR	1 1	RTL LTL	3,790	25	10
						S.B. Emmet	RTOR	1 1	Thru RT & Thru	11,945	40	80
N. Poplar & Rt. 250	City of Waynesboro	Commercial	+	2 RTOR	Fixed Time, 2 Phase	W.B. Rt. 250	RTOR Prohibited	1 1 1	LTL Thru RT & Thru	7,910	35	30
						S.B. N. Poplar	RTOR	1 1	RT & Thru LTL	3,980	25	10
Monument Ave. & Willow Lawn Dr.	Richmond Highway District	Residential Commercial	+	4 RTOR	Actuated, 3 Phase	N.B. Willow Lawn	RTOR	1 2 1	LTL Thru RTL	2,400	35	80
						W. B. Monument Ave	RTOR	1 1 1	LTL Thru RT & Thru	4,800	45	140
Ivy Rd. & Alderman Rd.	City of Charlottesville	Commercial	+	4 RTOR	Actuated, 2 Phase	N.B. Alderman	RTOR	1 1	LTL RT & Thru	2,230	25	110
						E.B. Ivy	RTOR	1 1 1	LTL Thru RTL	5,980	35	80
Euclid Ave. & Vance St.	City of Bristol	Commercial	+	4 RTOR	Actuated, 2 Phase	E.B. Euclid	RTOR	1 1 1	LTL Thru RT & Thru	4,120	35	40
						N.B. Vance	RTOR	1	RT & LT & Thru	1,450	25	30
Euclid Ave. & Commonwealth Ave.	City of Bristol	Commercial	+	4 RTOR	Actuated, 4 Phase	S.B. Euclid	RTOR	1 1 1	LTL Thru RT & Thru	6,200	25	0
						E.B. Commonwealth	RTOR	1 2 1	LTL Thru RTL	9,200	35	120
Rt. 11 & 4th St.	City of Wytheville	Central Bus. District	+	4 RTOR	Fixed Time, 2 Phase	N.B. Rt. 11	RTOR	1	RT & LT & Thru	5,100	25	210
						W.B. 4th St.	RTOR	1	RT & LT & Thru	960	25	370
Route 29 & Greenbrier Dr.	Culpeper Highway District	Commercial	+	4 RTOR	Actuated, 3 Phase	S.B. Rt. 29	RTOR	1 2 1	LTL Thru RTL	10,150	45	0
						E.B. Greenbriar	RTOR	1 1	RTL LT & Thru	3,010	35	10
Memorial Ave. & Wadsworth St.	City of Lynchburg	Residential Commercial	+	4 RTOR	Actuated, 2 Phase	E.B. Wadsworth	RTOR	1 1	LT & Thru RTL	3,340	25	130
						S.B. Memorial	RTOR	1 1	LTL RT & Thru	6,130	35	260
Grove Ave. & Malvern St.	City of Richmond	Residential	+	4 RTOR	Actuated, 2 Phase	E.B. Grove	RTOR	1 1	LT & Thru RT & Thru	3,920	35	80
						N.B. Malvern	RTOR	1 1	LT & Thru RT & Thru	3,200	35	20
Boulevard St. & Broad St.	City of Richmond	Commercial	+	4 RTOR	Fixed Time, 3 Phase	N.B. Blvd.	RTOR	2 1	Thru RTL	14,400	25	360
						E.B. Broad	RTOR	2 1	Thru RT & Thru	7,810	35	780
Fall Hill Ave. & Jefferson Davis Highway	City of Fredericksburg	Commercial	+	4 RTOR	Fixed Time, 4 Phase	E.B. Fall Hill	RTOR	1 1	LTL RT & Thru	3,510	25	60
						S.B. Jeff. Davis	RTOR	1 1 1	LTL Thru RT & Thru	8,600	35	70

Intersection	Jurisdiction	Area	Int. Type	Number Turn on Red Legs	Signal Description	Approach Studied	Turn on Red Approach	Lanes No. Type	Est. 1977 Approach ADT	Speed Limit	Estimated Pedestrians Per Day 1977
College Ave. & Jefferson Davis Highway	City of Fredericksburg	Commercial	+	2 RTOR	Fixed Time, 3 Phase	W.B. College	RTOR Prohibited	1 LT & RT & Thru	1,470	25	20
						S.B. Jeff. Davis	RTOR	1 LTL 2 Thru 1 RTL	11,100	35	0
Longview Dr. & Jefferson Davis Highway	Culpeper Highway District	Commercial	+	4 RTOR	Actuated, 4 Phase	W.B. Longview Dr.	RTOR	1 LTL 1 RT & Thru	4,500	25	50
						S.B. Jeff. Davis	RTOR	1 LTL 2 Thru 1 RTL	11,120	35	0
Rt. 1 & Russell Rd.	City of Alexandria	Commercial	+	4 RTOR	Fixed Time, 2 Phase	E.B. Russell Rd.	RTOR	1 LTL 1 RT & Thru	1,710	25	50
						S.B. Rt. 1	RTOR	1 LT & Thru 1 Thru 1 RTL	3,540	45	60
Glyndon St. & Maple St. (Rt. 123)	City of Vienna	Commercial	+	4 RTOR	Fixed Time, 2 Phase	N.B. Maple Ave.	RTOR	1 LTL 1 Thru 1 RT & Thru	13,120	30	80
						W.B. Glyndon St.	RTOR	1 LTL 1 RT & Thru	1,410	25	120
Maple St. & Main St.	City of Fairfax	Commercial	T	2 RTOR	Fixed Time, 2 Phase	E.B. Main St.	RTOR	1 LT & Thru 1 RT & Thru	7,960	35	60
						N.B. Maple St.	RTOR	1 LT & RT & Thru	1,560	25	120
Rt. 1 & Willis Rd.	Richmond Highway District	Commercial	+	3 RTOR	Actuated, 2 Phase	N.B. Rt. 1	RTOR	1 LT & Thru 1 Thru 1 RTL	6,510	45	0
						E.B. Willis Rd.	RTOR	1 LT & RT & Thru	360	35	0
Rt. 60 & Monticello Rd.	City of Williamsburg	Commercial	+	4 RTOR	Actuated, 3 Phase	N.B. Monticello Rd.	RTOR	1 LTL 1 RT & Thru	2,540	25	40
						W.B. Rt. 60	RTOR	1 LTL 1 RT & Thru	6,500	25	30
1st St. & Water St.	City of Charlottesville	Central Bus. District	+	1 LTOR	Fixed Time, 3 Phase	W.B. 1st St.	LTOR	1 LT & Thru	1,110	25	140
						S.B. Water	RTOR Prohibited	1 RTL 2 Thru	5,300	25	190
E. Frederick & N. Augusta	City of Staunton	Central Bus. District	+	1 RTOR 1 LTOR	Fixed Time, 2 Phase	S.B. E. Frederick	LTOR	1 LT & Thru 1 Thru	3,060	25	250
						E.B. N. Augusta	RTOR	2 Thru 2 RTL	4,250	25	220
Franklin St. & First St.	City of Richmond	Central Bus. District	+	1 RTOR 1 LTOR	Fixed Time, 2 Phase	S.B. First St.	LTOR	1 LT & Thru 1 Thru	3,190	25	810
						E.B. Franklin	RTOR	1 Thru 1 RT & Thru	7,040	25	310
Huntington Ave. & 50th St.	City of Newport News	Residential Part Business	+	1 RTOR 1 LTOR	Fixed Time, 2 Phase	S.B. 50th St.	LTOR	1 LT & Thru 1 Thru	330	25	60
						E.B. Huntington Ave.	RTOR	2 Thru 1 RT & Thru	6,950	25	90
Main St. & Third St.	City of Richmond	Central Bus. District	+	1 RTOR 1 LTOR	Fixed Time, 2 Phase	W.B. Main	LTOR	2 Thru 1 LT & Thru	6,310	25	430
						S.B. Third St.	RTOR	1 Thru 1 RT & Thru	1,960	25	0

APPENDIX E

SUMMARY OF DELAY, ACCEPTANCE, AND COMPLIANCE DATA

Table E-1

Data for RTOR Sites

Location	Right Turn on Green	ACCEPTANCE		TYPE OF STOP				No. Captive RTOR	REJECTED OR NO RTOR			Total No. RTOR	No. of Right Turns	Mean Delay per Delayed Right Turn Vehicle (seconds)
		Timed	Not Timed	Complete	Pause	Creep	Run-thru		Timed	Not Timed	Total No. Rejected			
W.B. Monument Ave.	40	26-283	8	14	5		1	10				20	84	10.48
N.B. Willow Lawn	37	36-512	28	29	7		3		3-130		3	39	104	16.48
S.B. Poplar St.	28	4-153	50	6				3 3-101	7-288	1	8	6	96	38.71
S.B. Emmet St.	57	1-17	13	10	1		2	7 3-52			0	13	81	11.50
E.B. Arlington	74	23-388	135	90	11	3	5			6	6	109	238	12.52
E.B. Ivy	59	21-130	33	32	9	1	2		1-13	2	3	44	116	5.72
N.B. Alderman	27	10-76	21	13	3			2 5-107				16	65	12.2
E.B. Euclid Ave.	28	2-24	4	3	3			1				6	35	12.0
N.B. Vance	23	13-206	11	20	2	1	2	7 2-30				25	56	13.11
E.B. Commonwealth	47	39-905	128	65	28	23	18			7	7	134	221	11.31
S.B. Euclid Ave.	17	3-108	3	5			1	14 3-104	1-43	3	4	6	44	31.38
N.B. Rt. 11	10	3-59	4	6			1	3	1-17	1	2	7	22	15.2
W.B. 4th St.	13	4-48	1	3	2			1		1	1	5	20	12.0
S.B. Rt. 29	56	20-331	16	15	6	1	2		2-39	3	5	24	97	16.8
E.B. Greenbrier	40	49-1089	70	62	12	10	9		4-170	4	8	93	167	17.49
E.B. Wadsworth St.	70	67-1407	97	62	6	2	2		1-65		1	72	235	20.44
S.B. Memorial Ave.	31	1-7	3	3				1-27	1-17		1	3	37	17.0
E.B. N. Augusta	30	9-114	9	11	1	2	1		11-258	3	14	15	62	16.17
E.B. Grove Ave.	38	20-152	15	16	4	1	1		1-22		1	22	74	7.57
N.B. Malvern St.	5	3-28	4	5	1	1		1			0	7	13	7.0
S.B. Third St.	48	35-727	19	33	1		5	14	1-35		1	39	117	18.59
E.B. Broad St.	44	28-491	4	9	1		4	17 2-17			0	14	95	14.94
N.B. Blvd. St.	35	66-1333	26	52	2		1		5-268	1	6	55	133	22.24

Table E-1 (continued)

Location	Right Turn on Green	ACCEPTANCE		TYPE OF STOP				No. Captive RTOR	REJECTED OR NO RTOR			Total No. RTOR	No. of Right Turns	Mean Delay per Delayed Right Turn Vehicle (seconds)
		Timed	Not Timed	Com-plete	Pause	Creep	Run-thru		Timed	Not Timed	Total No. Re-jected			
E.B. Franklin St.	39	12-121	5	8	3			1	2-51	4	6	11	63	12.29
S.B. Jeff. Davis	20	5-246	13	4				7		1	1	4	46	49.2
E.B. Fall Hill Ave.	13	27-774	7	17	1	1		35	3-236	2	5	19	87	32.58
S.B. Jeff. Davis	22	23-183	13	15	12	1	4		2-70		2	32	60	6.93
S.B. Rt. 1 - Jeff. Davis	27	35-147	10	34	7	2	2		1-40	1	2	45	74	4.68
W.B. Longview Dr.	13	54-390	15	47	12		3	16			0	62	98	10.35
E.B. Russell Dr.	31	35-312	4	24	4			2	3-94	1	4	28	76	10.68
S.B. Rt. 1	42	11-40	15	13	4		2				0	19	68	3.08
N.B. Rt. 123 - Maple Ave.	37	8-71	9	10	1			21			0	11	75	8.88
W.B. Glyndon	16	21-359	9	9				1				9	47	17.1
E.B. Main St.	49	5-28	5	1			1	12				2	71	4.67
N.B. Maple St.	20	14-276	4	11	1			4	1-62		1	12	43	22.53
N.B. Rt. 1	39	26-113	10	19	5						0	24	75	4.35
E.B. Willis Rd.	1		1	1								1	2	0
E.B. Huntington Ave.	44	8-47	12	4	4	2	1					11	64	4.27
N.B. Monticello Rd.	26	20-276	15	22	2	1	1	4	1-32		1	26	66	13.39
W.B. Rt. 60	0	1-19	1	1				2				1	4	19.00
Total	1296	788-12,190	850	804	161	52	74	19-438 185	52-2053	41	93	1,091	3231	14.90

Data for RTOR Prohibited Sites

Location	Right Turn on Green	ACCEPTANCE		TYPE OF STOP				No. Captive RTOR	REJECTED OR NO RTOR			Total No. RTOR	No. of Right Turns	Total Delay
		Timed	Not Timed	Com-plete	Pause	Creep	Run-thru		Timed	Not Timed	Total No. Re-jected			
W.B. 250	160								19-636	51	42	0	230	33.47
S.B. Water St.	98								19-348	25	35	0	142	18.32
W.B. College Ave.	30							13-48	15-462	2	16	0	62	30.00
Total	288							13-48	53-1494	78	93	0	434	27.16

Table E-3

Data for LTOR Sites

Location	Left Turn on Green	ACCEPTANCE		TYPE OF STOP				No. Captive LTOR	REJECTED OR NO LTOR			Total No. LTOR	No. of Left Turns	Total Delay
		Timed	Not Timed	Com-plete	Pause	Creep	Run-thru		Timed	Not Timed	Total No. Re-jected			
W.B. First St.	14							2-27	2-47	7	9	0	26	24.67
S.B. E. Frederick	15	11-180	8					3-22	11-232	1	12	0	51	18.08
W.B. Main St.	39	6-82	3	8				0			0	8	48	13.67
S.B. First St.	34	34-676	4	15	1		1	27	4-117		4	17	103	20.33
S.B. 50th St.	5	13-124	6	12					1-34		1	12	25	11.29
Total	107	64-1062	21	35	1		1	32 3-49	18-430	8	26	37	253	17.92

Table F-1

Data for RTOR Sites

Approach	Rejected RTOR	Accepted RTOR	% Accepted RTOR
W.B. Monument Ave.	0	20	100
N.B. Willow Lawn	3	39	93
S.B. Poplar St.	8	6	43
S.B. Emmet St.	0	13	100
E.B. Arlington	6	109	95
E.B. Ivy Rd.	3	44	94
N.B. Alderman Rd.	0	16	100
E.B. Euclid Ave.	0	6	100
N.B. Vance	0	25	100
E.B. Commonwealth	7	134	95
S.B. Euclid Ave.	4	6	60
N.B. Rt. 11	2	7	78
W.B. 4th St.	1	5	83
S.B. Rt. 29	5	24	83
E.B. Greenbrier	8	93	92
E.B. Wadsworth	1	72	99
S.B. Memorial Ave.	1	3	75

Table F-1 (continued)

Approach	Rejected RTOR	Accepted RTOR	% Accepted RTOR
E.B. N. Augusta	14	15	52
E.B. Grove Ave.	1	22	96
N.B. Malvern St.	0	7	100
S.B. Third St.	1	39	98
E.B. Broad St.	0	14	100
N.B. Blvd. St.	6	55	90
E.B. Franklin St.	6	11	65
S.B. Jeff. Davis	1	4	80
E.B. Fall Hill Ave.	5	19	79
S.B. Jeff. Davis	2	32	94
S.B. Rt. 1	2	45	96
W.B. Longview Dr.	0	62	100
E.B. Russell Rd.	4	28	88
S.B. Rt. 1	0	19	100
N.B. Maple Ave.	0	11	100
W.B. Glyndon	0	9	100
E.B. Main St.	0	2	100
N.B. Maple St.	1	12	92

Table F-1 (continued)

Approach	Rejected RTOR	Accepted RTOR	% Accepted RTOR
N.B. Rt. 1	0	24	100
E.B. Willis Rd.	0	1	100
E.B. Huntington Ave.	0	11	100
N.B. Monticello Rd.	1	26	96
W.B. Rt. 60	0	1	100
TOTAL	93	1,091	92

Table F-2

Data for LTOR Sites

Approach	Rejected LTOR	Accepted LTOR	% Accepted LTOR
W.B. Main St.	0	8	100
S.B. First St.	4	17	81
S.B. 50th St.	1	12	92
W.B. First St.	9	0	0
S.B. E. Frederick	12	0	0
TOTAL	26	37	59

730

APPENDIX G

SUMMARY OF COMPLIANCE DATA

Table G-1

Data for RTOR Sites

Approach	TYPE OF STOP				Total No. Not Stopping	No. RTOR	% RTOR Not Stopping
	Complete	Pause	Creep	Run-thru			
W.B. Monument Ave.	14	5		1	1	20	5
N.B. Willow Lawn	29	7		3	3	39	8
S.B. Poplar St.	6				0	6	0
S.B. Emmet St.	10	1		2	2	13	15
E.B. Arlington	90	11	3	5	8	109	7
E.B. Ivy	32	9	1	2	3	44	7
N.B. Alderman	13	3			0	16	0
E.B. Euclid	3	3			0	6	0
N.B. Vance	20	2	1	2	3	25	12
E.B. Commonwealth	65	28	23	18	41	134	31
S.B. Euclid Ave.	5			1	1	6	17
N.B. Rt. 11	6			1	1	7	14
W.B. 4th St.	3	2			0	5	0
S.B. Rt. 29	15	6	1	2	3	24	13
E.B. Greenbrier	62	12	10	9	19	93	20
E.B. Wadsworth	62	6	2	2	4	72	6
S.B. Memorial Ave.	3				0	3	0
E.B. N. Augusta	11	1	2	1	3	15	20
E.B. Grove Ave.	16	4	1	1	2	22	9
N.B. Malvern St.	5	1	1		1	7	14
S.B. Third St.	33	1		5	5	39	13

Table G-1 (continued)

Approach	TYPE OF STOP				Total No. Not Stopping	No. RTOR	% RTOR Not Stopping
	Complete	Pause	Creep	Run-thru			
E.B. Broad St.	9	1		4	4	14	29
N.B. Blvd. St.	52	2		1	1	55	2
E.B. Franklin St.	8	3			0	11	0
S.B. Jeff. Davis	4				0	4	0
E.B. Fall Hill Ave.	17	1	1		1	19	5
S.B. Jeff. Davis	15	12	1	4	5	32	16
S.B. Rt. 1	34	7	2	2	4	45	9
W.B. Longview Dr.	47	12		3	3	62	5
E.B. Russell Rd.	24	4			0	28	0
S.B. Rt. 1	13	4		2	2	19	11
N.B. Maple Ave.	10	1			0	11	0
W.B. Glyndon	9				0	9	0
E.B. Main St.	1			1	1	2	50
N.B. Maple St.	11	1			0	12	0
N.B. Rt. 1	19	5			0	24	0
E.B. Willis Rd.	1				0	1	0
E.B. Huntington Ave.	4	4	2	1	3	11	27
N.B. Monticello Rd.	22	2	1	1	2	26	8
W.B. Rt. 60	1				0	1	0
Total	804	161	52	74	126	1,091	12

Table G-2

Data for LTOR Sites

Approach	TYPE OF STOP				Total No. Not Stopping	No. LTOR	% LTOR Not Stopping
	Complete	Pause	Creep	Run-thru			
W.B. First St.					0	0	0
S.B. E. Frederick					0	0	0
W.B. Main St.	8				0	8	0
S.B. First St.	15	1		1	1	17	6
S.B. 50th St.	12				0	12	0
Total	35	1		1	1	37	3

APPENDIX H

DESCRIPTION OF TURN ON RED TRAFFIC CONFLICTS

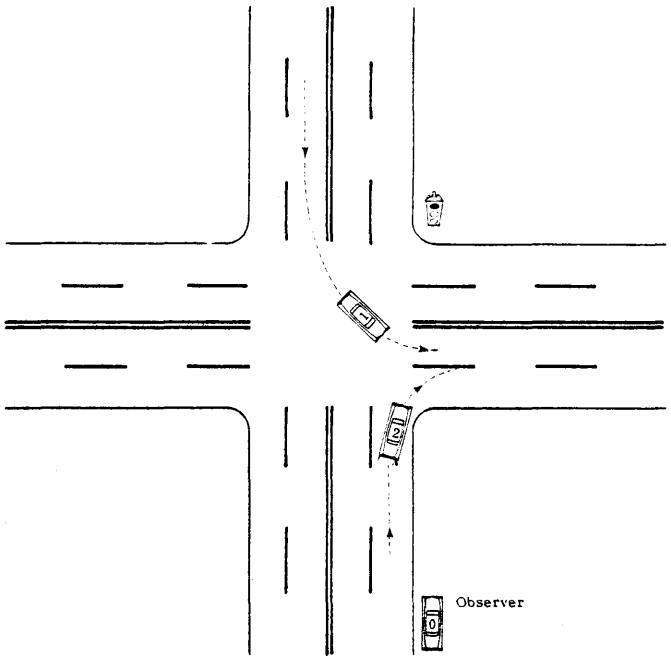

Figure H-1. Opposing left turn RTOR conflict. The RTOR vehicle (No. 2) attempts to turn right on red and must brake to avoid hitting vehicle No. 1 making a left turn on a green signal.

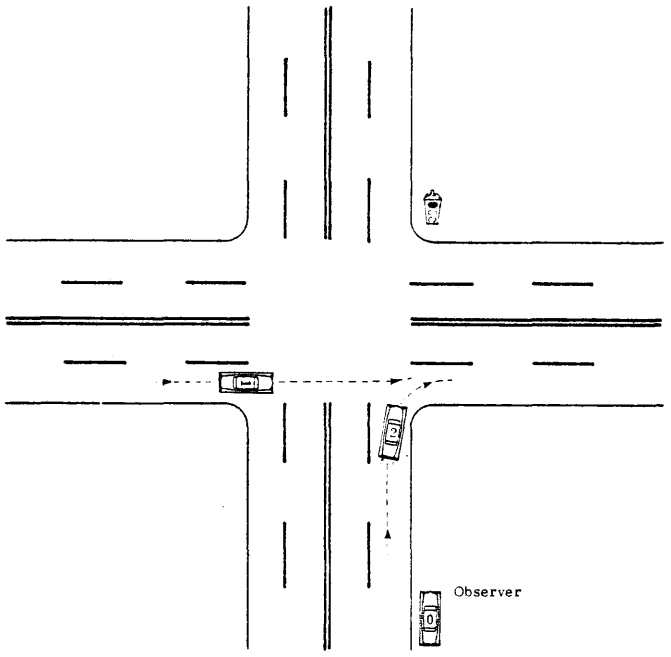

Figure H-2. Through (left to right) cross traffic RTOR conflict. The RTOR vehicle (No. 2) attempts an RTOR maneuver and must brake to avoid hitting vehicle No. 1 traveling through on a green signal.

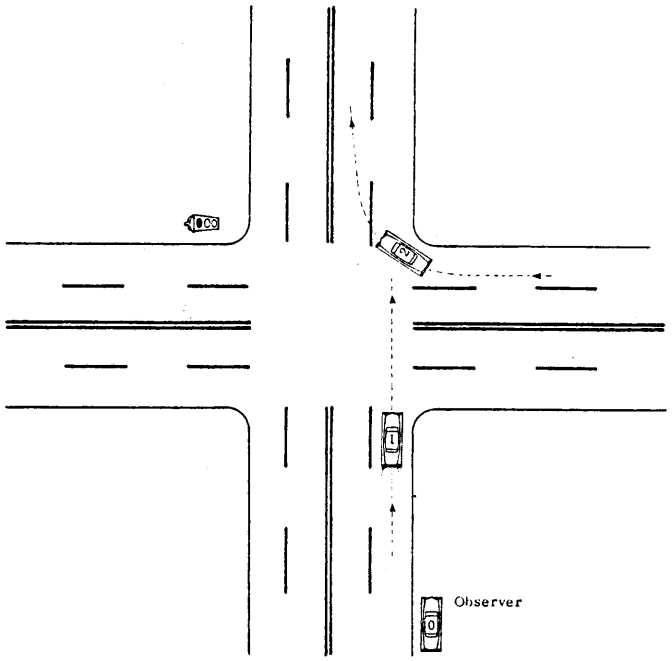

Figure H-3. Right turn cross traffic RTOR conflict. Vehicle No. 1 traveling through the intersection on a green light must brake to avoid a collision with vehicle No. 2 making a right turn on red signal.

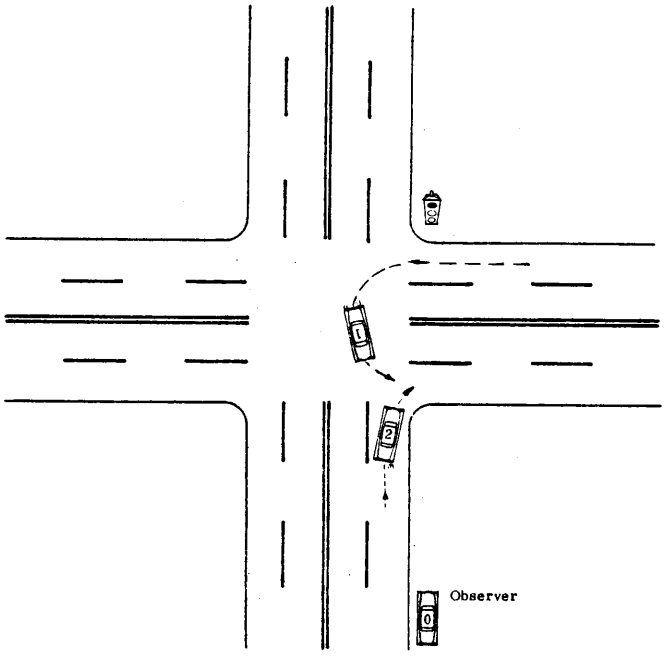

Figure H-4. Opposing U-turn RTOR conflict. The RTOR vehicle (No. 2) attempts to turn right on red and must brake to avoid a collision with vehicle No. 1 making a U-turn on a green signal.

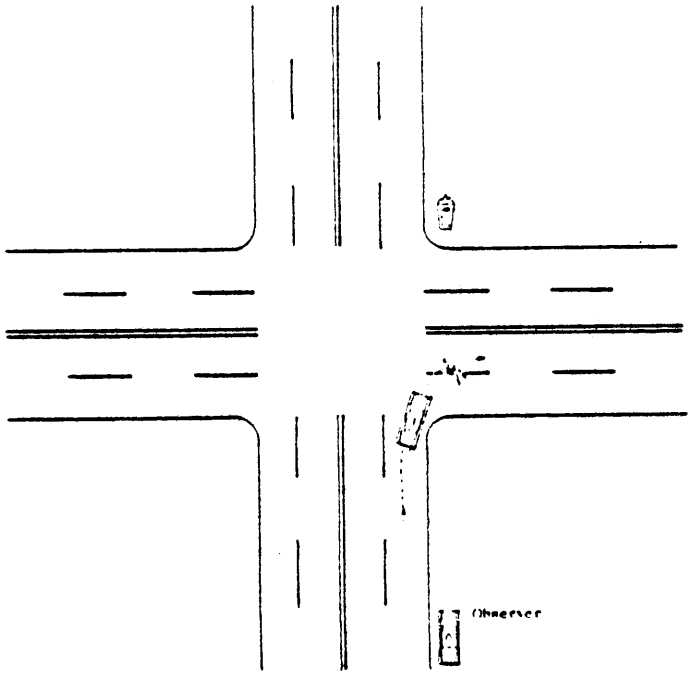

Figure H-5. Pedestrian RTOR or LTOR conflict. Vehicle (No. 1) attempting to turn on a red signal must brake to avoid hitting a pedestrian.

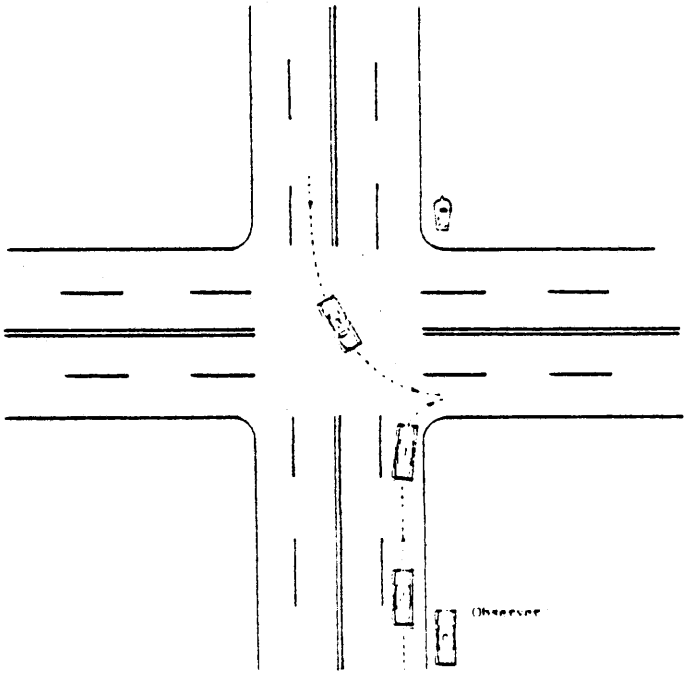

Figure H-6. Previous (Rear end) RTOR conflict. Vehicle No. 1 begins to make an RTOR maneuver but stops due to traffic in the intersection (vehicle No. 3). Vehicle No. 2 anticipates vehicle No. 1 will complete the turn and begins to move to the head of the queue but must apply brakes to avoid a collision with No. 1 when No. 1 stops.

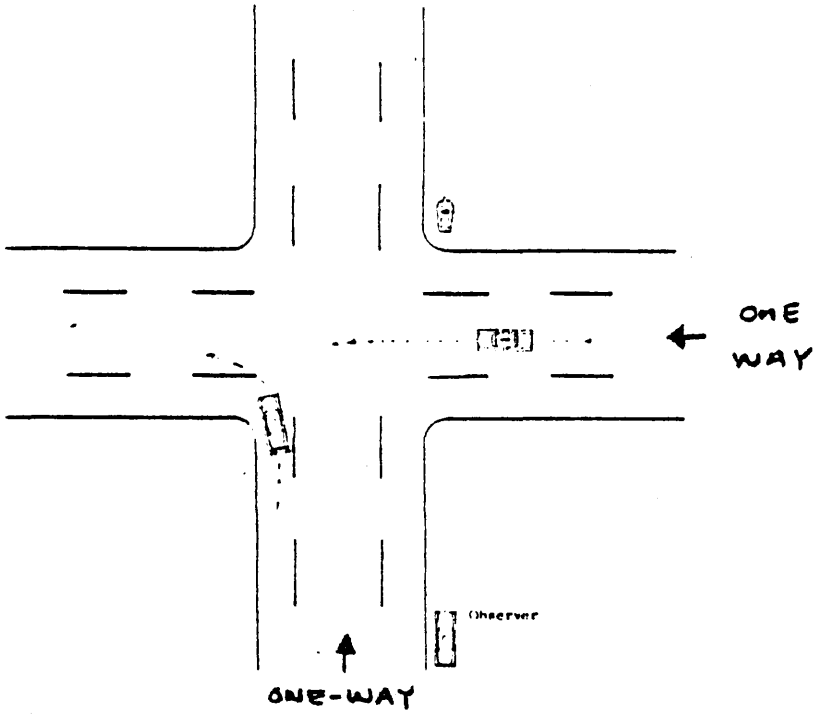

Figure H-7. Through (right to left) cross traffic LTOR conflict. The LTOR vehicle (No. 1) attempts an LTOR maneuver and must brake to avoid a collision with vehicle No. 1 travelling through on a green signal.

APPENDIX I

SUMMARY OF TRAFFIC CONFLICTS DATA

Table I-1

Data for RTOR Sites

Approach	TYPE OF CONFLICT						Total
	Opposing Left Turn	Cross Traffic Left to Right	Right Turn Cross Traffic	U Turn	Pedes-trian	Previous Traffic Conflict	
N.B. Monticello Rd.		1					1
E.B. Main St.			1				1
N.B. Rt. 123			1				1
S.B. Richmond Hwy.			3		2		5
W.B. Longview Dr.	2						2
E.B. Fall Hill Ave.	2		2			1	5
E.B. Broad St.					1		1
N.B. Malvern St.			2				2
E.B. Grove St.			1				1
S.B. Memorial Ave.			6			1	7
S.B. Rt. 29			3	1			4
S.B. Euclid Ave.			7				7
E.B. Commonwealth			2				2
E.B. Euclid Ave.			1				1
E.B. Ivy Rd.			2				2
N.B. Alderman Rd.			1				1
W.B. Monument Ave.			1		1		2
S.B. Emmet St.			1				1
Total	4	1	34	1	4	2	46

Note: This list contains only approaches with RTOR conflicts.

APPENDIX J

SUMMARY OF TURN ON RED ACCIDENTS REPORTED DURING 1977

Jurisdiction	No. of Accidents	No. of Persons Injured	Comments
Charlottesville	2 RTOR	none	Making right turns on red has resulted in 2 accidents since 1-1-77, approx. $750 total damage.
	1 LTOR	none	Making left turn on on red has resulted in 1 accident since 1-1-77, appro. $300 damage.
Covington	1 RTOR	none	Making right turn on red resulted in 1 accident, est. $350 damage.
Fairfax	2 RTOR		At least 2 RTOR accidents occurred at the same intersection; both property damage accidents occurred on a 4-lane divided highway as a result of a vehicle changing from passing lane to right lane and colliding with vehicle making a right turn.
Falls Church	1 RTOR	none	Have had only one accident, of a relatively minor nature.
Galax	5 RTOR	none	These property damage only accidents occurred due to driver failure to come to stop before entering intersection.
Hampton	2 RTOR	none	These are minor rear end collisions where the first car may stop, move up and stop again, and the following car hits it in the rear.

J-2

Jurisdiction	No. of Accidents	No. of Persons Injured	Comments
Hopewell	2 RTOR	none	One officer quizzed had investigated 2 accidents at Winston Churchill Drive and Arlington Road where he felt that the person on Arlington Road failed to yield right of way while making a RTOR. Both motorists claimed they had a green light, other comment was that persons neglected to yield right of way while making a right turn on red. They reported observing some close calls.
Martinsville	1 RTOR	none	One observed rear-end accident; several near misses; failure to stop or yield; the one observed not reported to law.
	1 LTOR	none	At a "T" intersection a lady turned left from 2-way 4-lane to a 2-way 3-lane in front of an on-coming car; hit head-on; no injuries; she was charged and argued with officer over her rights under LTOR.
Newport News	18 RTOR 1 LTOR	2	18 accidents reported in 12 months; 3 pedestrians struck 1 rear-end and 15 angle accidents, with an average of $583.33 damage.

Jurisdiction	No. of Accidents	No. of Persons Injured	Comments
Norfolk	5 RTOR	none	Available accident experience indicates that fewer than 5 accidents have occurred since 1-1-77 and these have occurred as a result of the thru traffic hitting the rear end of the right turning vehicle.
Petersburg	1 RTOR	none	One accident, est. $550 damage, angle type.
Richmond	9 RTOR	2	One of these 9 accidents resulted in injury to 2 individuals. The remainder were property damage accidents with an average reported damage of $785.
Richmond District	1 RTOR	none	At the intersection Rte. 1 & 10, Chesterfield County, a lady turned right from E.B.L. Rte. 10 to S.B.L. Rte. 1 and turned into left lane instead of right lane; minor collision with a bus resulted.
Roanoke	18 RTOR	none	From 1-1-77 through 11-23-77 there have been 18 accidents. Average property damage per accident was $365.83.
Salem	6 RTOR	none	Experienced 6 accidents this year.. Damages were medium and no injuries were involved. Failing to yield, poor driver judgment, making wide right turns, cutting in, and changing lane movement were noted causal factors.

Jurisdiction	No. of Accidents	No. of Persons Injured	Comments
Waynesboro	2 RTOR	none	A vehicle was hit in rear because driver thought other vehicle was going to turn right on red. The second vehicle proceeded through intersection because driver assumed signal had turned green.
Total RTOR	75	4	
Total LTOR	3	0	

Note: Two of the 18 RTOR accidents in Newport News were at No Turn on Red Approaches

APPENDIX K

FINAL MUTCD STANDARDS FOR PROHIBITING TURNS ON RED

U. S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

SUBJECT	FHWA BULLETIN
Right-Turn-On-Red at Signalized Intersections	October 20, 1977

The purpose of this Bulletin is to transmit the final MUTCD standards for permitting right-turns-on-red (RTOR) after stopping at signalized intersections to all Federal Highway Administration and State highway organization offices.

As of July 1, 1977, 48 States and Puerto Rico have adopted legislation for the generally permissive RTOR after stopping rule in general conformance with the final standards. The city of New York was excluded from the New York State legislation. In Maryland and Maine the legislation is effective July 1, 1978, and May 1, 1978, respectively. Only Connecticut and Massachusetts now permit right turns at a signal only when a sign so permits. The District of Columbia does not permit any turns at a red signal but draft legislation is being considered.

In response to the public comments received on tne interim policy on RTOR, Federal Register July 12, 1976, the final provisions for prohibiting these movements have been liberalized and incorporated into the MUTCD. The interim policy was deleted from 23 CFR 655 as of August 23, 1977, (Federal Register, August 18, 1977). More detailed criteria to fit particular needs may be developed by the respective States.

The following are the approved revisions to the MUTCD Sections 2B-35 and 4B-5.

A. Delete the last portion of the fifth paragraph of Section 2B-35, "Traffic Signal Signs (R10-1 to 4) on page 56, beginning with "and RIGHT TURN ON RED AFTER STOP . . . ."

B. Substitute the following for the paragraph added by official ruling Sn-116 (Chng.), FHWA, OTO, NO TURN ON RED sign. Thus the paragraph following the fifth paragraph of Section 2B-35 would read:

The NO TURN ON RED sign (R10-11a, 11b) shall be used to indicate that a right turn on red (or left turn on red for one-way streets) is not permitted. For part time prohibitions see Section 2B-15. The NO TURN ON RED sign should have standard dimensions of 24" x 30" and 24" x 24" for R10-11a and R10-11b respectively. The sign should be erected near the appropriate signal head.

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H-W(HO/HS/MC/NG/TO)-4
H-DM-4

OPI: HTO-21

A NO TURN ON RED sign may be considered whenever an engineering study finds that one or more of the following conditions exist.

1. Sight distance to vehicles approaching from the left (or right, if applicable) is inadequate.

2. The intersection area has geometrics or operational characteristics which may result in unexpected conflicts.

3. There is an exclusive pedestrian phase.

4. Significant pedestrian conflicts are resulting from RTOR maneuvers.

5. More than three RTOR accidents per year have been identified for the particular approach.

6. There is significant crossing activity by children, elderly, or handicapped people.

C. Revise Section 4B-5, Meaning of Signal Indications, Item 3 on page 217 to read as follows:

3. Steady red indications shall have the following meanings:

   a. Vehicular traffic facing a steady CIRCULAR 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 (c) below.

   b. Vehicular traffic facing a steady RED ARROW signal shall not enter the intersection to make the movement indicated by the arrow and, unless entering the intersection to make a movement permitted by another signal, 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 permitting the movement indicated by such red arrow is shown except as provided in (c) below.

c. Except when a sign is in place prohibiting a turn, vehicular traffic facing any steady red signal may cautiously enter the intersection to turn right, or to turn left from a one-way street into a one-way street, after stopping as required by (a) and (b) above. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.

d. Unless otherwise directed by a pedestrian signal, pedestrians facing a steady CIRCULAR RED or RED ARROW signal alone shall not enter the roadway.

J. J. Crowley, Director
Office of Traffic Operations

APPENDIX L

ARTICLE SUMMARIZING RTOR GUIDELINES

Guidelines for Prohibiting Right Turn on Red At Signalized Intersections

By Hugh W. McGee, P.E.

Right turn on a red traffic signal, once used almost exclusively in Western states, is now a practice which is permitted in all but two states. As defined by most state vehicle codes, right turn on red (RTOR) means permitting a right turn on a red traffic signal after stopping and yielding to right-of-way vehicles and pedestrians lawfully in the intersection.

Even though RTOR dates back as far as 1937, when California first permitted the movement with an authorizing sign, it is only recently that the practice has gained wider acceptance and use. This is evidenced by the fact that according to an ITE Technical Council committee in 1968, only 20 states reported using RTOR in any fashion.[1] In 1974—which saw the beginning of a comprehensive research study of RTOR by the Federal Highway Administration[2]—some states allowed RTOR at all intersections unless otherwise signed (the generally permissive rule), others allowed the maneuver only where properly signed (the sign permissive rule).

It now appears that there will be a uniform RTOR rule throughout the United States. Therefore, it would be beneficial to have uniform guidelines which states and cities can follow for identifying specific locations where RTOR should be prohibited. This paper presents a recommended set of such guidelines based on the results of intersection operations and safety studies conducted at several locations for the FHWA.

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The bulk of the study undertaken for the FHWA comprised five tasks designed to provide the data upon which recommendations could be made for an RTOR policy and implementation guideline. One task involved both field data collection and extensive computer simulation analyses (using the UTCS-1 model) to quantify the effect of RTOR on vehicle delay, intersection throughout, fuel savings and vehicle emissions. Another primary effort was devoted to a series of accident analyses in two states (Virginia and Colorado) and four cities (Denver, Chicago, Los Angeles and Dallas) to quantify the magnitude of the RTOR accident problem and to identify the geometric factors that affect RTOR accident frequency. Other analyses included:

- A legal issues review of state vehicle codes and court decisions;
- A survey of police officials to surface law enforcement problems;
- A driver survey in six states and a pedestrian survey in four cities to define public attitudes and understanding of RTOR; and
- An assessment of RTOR signing requirements and how those may influence the RTOR rule selection.

From the results of these studies, it was concluded that RTOR is a desirable and safe practice for a vast majority of intersection conditions. Based on the positive findings, it was recommended that the generally permissive rule was preferred over the sign permissive rule in order that maximum benefit could be derived from the maneuver.

Development of Guidelines for Prohibiting RTOR. Since the generally permissive rule was recommended as a national standard, it was necessary to develop guidelines for prohibiting RTOR where the feature is considered hazardous. The generally permissive rule had been recommended because of the benefits attained without a significant degradation of safety. Therefore, as a general principle, it was believed that RTOR should be prohibited at specific locations only when one of the following three conditions where:

- RTOR accident frequency is related to the specific type of intersection (geometric or operational features);
- potential conflicts would result unknown to the motorist;
- a significant number of conflicts with vehicles or pedestrians are occurring.

These conditions, however, are too broad to serve the purpose of guidelines which the practicing engineer can follow in evaluating the applicability of RTOR at specific locations. Therefore, to expand these principles in more specific criteria, all factors or criteria that various states had developed over the years were analyzed in light of the research results.

As more and more states adopted the generally permissive rule, the list of criteria for prohibiting the maneuver at specific locations expanded and became more restrictive. Shown in Table 1 are 19

Table 1. Summary of Factors Considered in Prohibiting RTOR Under the Generally Permissive Rule

	Factors	Number of States Reporting
1.	Five or More Approaches	11
2.	Restrictive Geometrics	11
3.	Inadequate Sight Distance	10
4.	Significant Pedestrian Volumes	9
5.	High Speeds Through Intersection	5
6.	Exclusive Pedestrian Phase (All-Red)	5
7.	RTOR Conflicts With Other Vehicle Movements, e.g., Left Turn Phase	5
8.	Signals Under School Crossing Warrant	4
9.	Vehicle Conflict Serious	3
10.	Right Turn Permitted From Two or More Lanes	3
11.	History of Accidents Related to RTOR (5 or More)	2
12.	Complex Signal Phasing	2
13.	Signed School Crossing	2
14.	No Appreciable Right Turns	1
15.	Short Red Interval	1
16.	Pedestrian Signal Locations	1
17.	Fully Actuated Signals	1
18.	Capacity Problems for Acceptance Lane	1
19.	Railroad Crossing Interconnection	1

separate factors or criteria, listed in order of frequency, that have been established collectively by the states following the generally permissive rule (as of January 1975). Most of the factors were based on intuitive engineering judgment, few resulted from research studies or actual experiences.

In developing guidelines for prohibiting RTOR, it seemed beneficial to review the factors in Table 1 in context of the general principles formulated earlier and in light of the specific findings of the various studies. This analysis is presented in the following. For ease of analysis and presentation, some of the factors are discussed collectively.

Five or More Approaches. An intersection with five or more approaches is one of the two most often cited criteria for prohibiting the RTOR maneuver. The problem that arises in this situation is that for some of the potential RTOR's, multiple and/or unexpected conflicts can occur. These conflicts are not easily discernible to either the RTOR motorist or to the motorist traveling through the intersection on green.

The schematic shown in Figure 1 can be used to illustrate two such scenarios. In one case, RTOR motorist (A) may look for cross-street traffic from approach (1) and may be unaware of cross-street traffic from approach (5) or vice versa. In another case, RTOR motorist (B), observing a safe gap in traffic from the approach (3), could turn right into leg (5) and as a result get into a dangerous conflict situation with vehicles from approach (1).

The approaches where a prohibition sign would be required is dependent upon the specific geometrics. It is not necessary to prohibit the movement for approaches where there is no additional conflict problem, as illustrated in Figure 1.

Restrictive Geometrics. The other factor that was cited as often as five or more approaches was restrictive geometrics. Most states are not precise in defining this term, it is a catch-all criterion which can account for several conditions, including five or more approaches, inadequate sight distance, small turning radius, etc., that would inherently make an RTOR maneuver more hazardous.

While several examples could be mentioned, one that occurs with some frequency is a highly skewed intersection where the right-turn maneuver, even on green, is difficult to negotiate. While the intersection performance or accident analysis did not specifically identify this situation to be a problem, it seems logical that this could be a criterion for prohibiting RTOR at specific approaches. However, because there are many unique situations that could be identified as restrictive geometrics, a field evaluation would be required of the sites which may be involved. In most cases, a sight distance limitation will be the most critical factor.

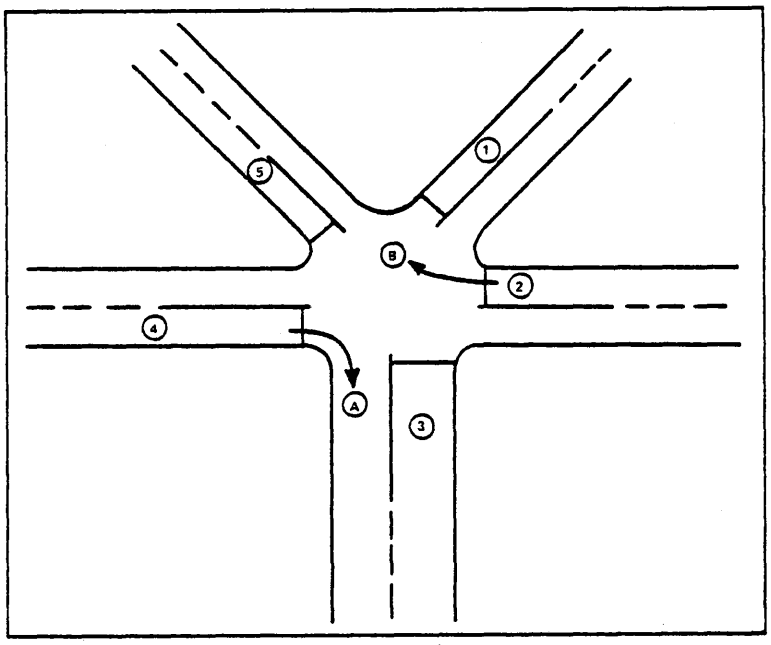

Figure 1. *Examples of RTOR conflicts at a five-leg intersection.*

Inadequate Sight Distance. Many states have selected sight distance limitations as a factor for prohibiting RTOR. The theory underlying this criterion is that an acceptable gap for the maneuver must be visible if the movement is to be made safely.

There appear to be two schools of thought regarding what is an appropriate sight distance for the RTOR maneuver. One holds that the cross-street traffic moving on green should not even have to decelerate because of a right-turn-on-red vehicle turning in its path. For example, Indiana,[3] using an average acceptable gap of 7.37 seconds, developed the following minimum sight distance for various speeds:

Speed	*Sight Distance (Feet)*
20	217
30	325
40	434
50	542

A more liberal philosophy is that the sight distance should be based on stopping requirements for the cross-street traffic, that is, the cross-street traffic should have sufficient sight distance for stopping in the event that an RTOR motorist is in the traveled lane. Under this condition, the following minimum sight distances would be required:

Speed	*Sight Distance (Feet)*
20	120
30	190
40	270
50	360

In view of the few accidents even at locations that had limited sight distances, it would appear that the more liberal stopping sight distance requirements would be an appropriate limitation for the RTOR maneuver.

The sight distance need not be measured from the stop bar because in reality right-turn-on-red vehicles move up to the actual intersection line to gain better line-of-sight. However, where there is heavy pedestrian density, the sight distance should be measured from behind the crosswalk line to prevent the motorist from moving into the crosswalk.

Significant Pedestrian Volumes. The fourth most frequently cited criterion for prohibiting RTOR is significant pedestrain volume. Two other criteria could be discussed within the context of pedestrian activity: 1) signal phasing with an exclusive pedestrian phase (all red); and 2) intersections with pedestrian signals. Few states have stipulated what volume level necessitates prohibiting RTOR. Two states, which had a sign permissive rule at that time, stipulated, respectively, 50 and 100 pedestrians per hour during each of eight hours of an average weekday.

The RTOR accident analysis with respect to pedestrians did not reveal any relationship between pedestrian volumes and RTOR accidents. This is primarily a result of the fact that there was such a small number of pedestrian accidents. Therefore, there is no evidence either from this study or from previous studies to state categorically that RTOR should be prohibited on the basis of pedestrian volume. From field observations of intersections where heavy pedestrian flows are experienced, it was noted that heavy pedestrian flow acted as a self-enforcing control for restricting the maneuver. With few exceptions, potential RTOR motorists do not make the maneuver where heavy pedestrian volumes occur.

Some jurisdictions may want to prohibit the RTOR maneuver where there are significant pedestrian volumes merely to be responsive to citizen complaints. One of the results of the pedestrian attitude survey was that many pedestrians, especially the elderly, feel endangered by RTOR motorists. As a result, pedestrians, in practice, may relinquish their rights-of-way to agressive RTOR motorists. Where this conflict is occurring with substantial frequency, it may be desirable to prohibit RTOR. However, a more positive approach would be to conduct a selective enforcement program and give citations to RTOR motorists who violate the pedestrian right-of-way law.

Exclusive Pedestrian Phase. Some jurisdictions make use of an exclusive pedestrian phase whereby all approaches have a red indication and the pedestrian signals display a steady WALK signal. During this all-red phase, pedestrians can cross all legs and in some cases walk diagonally across the intersection.

Once again, the study did not result in any safety or performance data that specifically addressed this condition. For example, in Denver, where an all-red pedestrian scramble phase is employed extensively in the central business district, the pedestrian accident data did not include these intersections since they were signed to prohibit RTOR.

Where such a pedestrian signal control is used, it is important that pedestrians move across intersections with complete freedom. RTOR in this situation would be undesirable even though the maneuver could not be made legally while pedestrians were crossing either leg. Usually, the RTOR motorist is primarily attentive to pedestrians crossing on green or Walk directly in front and would not expect pedestrians are moving legally in all directions and, therefore, it would be difficult for the motorist wanting to make an RTOR maneuver to identify gaps in two pedestrian crossings.

Intersections with Pedestrian Signals. Only one state has recommended that RTOR be prohibited wherever there are pedestrian signals, i.e., WALK—DONT WALK signals. These signals are normally where there are heavy pedestrian flows or exclusive pedestrian phases. These two conditions were discussed above, and the reasons for prohibiting or allowing RTOR are the same for this case. Therefore, the mere presence of pedestrian signals would not be reason for prohibiting the RTOR maneuver. What is more important is how the pedestrian signals are operated, e.g., all-red phase.

High Speeds Through Intersection. Five states have stipulated that RTOR should be prohibited where speeds through the intersection are high; speeds of 50-55 mph have been suggested as a high. The apparent reason for prohibiting the movement in this case is that RTOR motorists have greater difficulty in identifying safe gaps in the cross traffic because of the higher speeds. Also, as noted under the sight distance criterion, a longer sight distance is required.

Again, there was no evidence from field observations or from the accident analyses that RTOR maneuvers into high-speed cross traffic results in more accidents than where there are lower speeds. Given adequate sight distance as recommended earlier, the RTOR motorist is capable of making the maneuver safely just as is done where there is a stop sign control. Therefore, there does not seem to be any justification for prohibiting RTOR on the basis of cross-street speed alone.

RTOR Conflicts with Other Movements. Five states have recommended that RTOR be prohibited where the maneuver conflicts with other vehicular movements besides the normal cross-street flow. This situation usually involves the conflict that occurs when there is a left-turn phase for opposing traffic. The problem that can arise is that the RTOR motorist looks for gaps in cross-street traffic flow but forgets the traffic that might be turning left into the same lane during a left-turn phase. This conflict potential is more serious if there is only one lane on the receiving link.

The situation does result in some RTOR left-turn accidents. Of all the identified RTOR accidents that could be classified by type, 18 percent were found to involve this situation. However, while this is a sizeable percentage of all RTOR accidents, it still represents an extremely small percentage of all intersection accidents. Since this type of accident occurs so infrequently, presumably most locations where there is a left-turn phase never experience an RTOR accident. Therefore, it would not be justified to prohibit the RTOR movement at all intersection approaches opposite a separate left-turn phase. However, it may be desirable to prohibit RTOR where there is only one lane into which the movements are made when the opposing left-turn volume is heavy during several hours of the day, or where there is a double left turn.

Another criterion which is listed in Table 1 is where "Vehicle Conflict is Serious." The states that have noted this criterion are not specific as to what constitutes a serious conflict; presumably, this could include the left-turn conflict, complex intersection situations or possibly simply heavy cross-street volumes. The first two conditions have been addressed previously. With regard to heavy cross-street volumes as a serious conflict, no evidence could be found in the accident analyses that would indicate that RTOR maneuvers into high-volume streets are especially hazardous. When there are higher volumes, there are, quite obviously, less acceptable gaps for the RTOR maneuver and, therefore, less RTOR use; this is borne out by the field surveys. The heavy cross-street volumes tend to act as self-enforcing control and, therefore, higher RTOR accident rates do not result. High volumes alone would not be a justified criterion for prohibiting RTOR.

Signals Under School Crossing Warrant. Four states have stipulated in their guidelines that RTOR should be prohibited at any intersection where the signal has been installed under the school crossing warrant. The accident analyses conducted in various locations did not provide any data that specifically addressed this problem. In fact, in both Denver and Chicago, RTOR is frequently prohibited at these types of locations. However, restriction of RTOR at school crossings has come about frequently from citizen desires rather than as a result of actual safety problems.

Since stricter safety precautions are, by practice, normally followed near schools or play areas, it may be desirable to prohibit the RTOR movement at these locations, especially in deference to citizen desires. If so, these are locations where the RTOR maneuver could be prohibited during certain hours of the day or where "children are present," as is done in Denver.

Right Turn from Two or More Lanes. Three states have recommended that RTOR be prohibited for approaches where right turns can be made from two lanes. RTOR maneuvers made under this situation can be more hazardous when there are right-turn vehicles in both lanes. In fact, a few sideswipe accidents involving two RTOR vehicles were identified in the accident analysis.

A general prohibition of RTOR at these locations would preclude substantial savings in delay for the right-

turning vehicles. Presumably, when there are two lanes for the right turns, there is a high right-turn volume. Consequently, it would be desirable to allow RTOR in order to improve traffic flow. Since the chief hazard associated with this situation is the RTOR maneuver from the inside lane, it would be desirable to prohibit RTOR from that lane only. However, providing appropriate signing for this special control would be difficult. The most practical recommendation is that where there are double-turn lanes, these locations be studied carefully before prohibition signs are installed.

Accidents Related to RTOR. Two states have recommended that RTOR be prohibited where five or more RTOR-related accidents have occurred, the time frame being unspecified. As indicated in the accident analyses, the probability of an RTOR accident occurring at any intersection is low and even lower for more than one accident. For example, in Los Angeles during a two-year study period, 187 RTOR accidents occurred at 267 intersections, which is only 8.3 percent of all the signalized intersections. Furthermore, only one intersection had three RTOR accidents and only 18 intersections had two RTOR accidents during the two years.

Because of the randomness of RTOR accident occurrence, it would be desirable to evaluate any intersection where there were more than one RTOR accident within a year's period. If the accidents involved RTOR's from the same approach, a field study might identify operational or geometric features that might be causative factors. If this determination can be made, then the RTOR should be prohibited, at least for that approach.

The difficulty in applying this criterion is that RTOR accidents are difficult to identify. Assuming that RTOR accidents were coded into a computerized record system, they could be tabulated by intersection on a yearly basis as was done in the Los Angeles accident analysis. However, few jurisdictions code RTOR accidents into their computer system, if one exists at all. Without such a capability, the identification of high RTOR accident locations would be purely coincidental and would rely on citizens' or police complaints.

Complex Signal Phasing. Another factor for prohibiting RTOR which has been recommended at least by two states is complex signal phasing. "Complex" is not rigidly defined, but presumably it could apply wherever there is a signal with more than a simple two-phase system. More likely, it applies to fully actuated signal control with quad left turns or to a signal control for a geometrically complex intersection. The problem of left-turn conflicts resulting from a left-turn phase was discussed previously, as were intersections with more than four approaches.

One factor which has not been addressed is the desirability of RTOR where there is vehicle-actuated signal control. At first glance, it would seem undesirable to have a vehicle trigger an actuated signal and then execute a right turn on red causing the cross-street traffic to stop for no reason. While this may be an irritation to the cross-street motorists, they would have had to stop even if the vehicle did not make an RTOR. With RTOR permitted, at least the RTOR vehicle would save time and reduce its fuel consumption. Also, there are vehicle detector placement strategies for overcoming this problem.

The results of the limited field studies indicate that savings in delay are realized for right-turn vehicles under fixed-time and actuated signal control. Also, there was no evidence in the accident analyses that would support prohibiting RTOR where there is actuated signal control. It would seem, then, that prohibiting RTOR where there is complex signal phasing would have to be considered a special situation requiring field evaluation.

No Appreciable Right Turns or Short Red Interval. These two factors, each suggested by one state, are related with regard to RTOR. Where there are "no appreciable" right turns, there is little opportunity for delay savings. Likewise, where the red signal interval is short for a particular approach, there is less chance for a right-turn vehicle to make an RTOR and, consequently, little opportunity for delay savings. Unless there is some other reason, such as safety or citizen complaint, there would be no benefit from prohibiting the RTOR movement under these circumstances. As with any traffic control device, excessive and unnecessary use or restrictive regulatory signs—where not warranted in the view of the motorists—tends to erode the respect for these signs where they are truly justified.

Capacity Problems for Acceptance Lane. One problem which can occur during traffic congestion periods in urban areas is that the acceptance of departure lanes are backed up leaving little or no space for an RTOR vehicle. It has been suggested that where this occurs with regularity, RTOR should be prohibited. The results of the computer simulation analysis and field data indicate that delay savings can be accrued even during peak periods. However, there are situations when the back-up problem would be so severe as to nullify the RTOR movement. A capacity problem for the acceptance lane is not manifested until there is a demand volume which approaches that capacity. Therefore, if there is a back-up problem on the acceptance lane, it is likely that RTORs could not be made because of traffic density on the cross street. Consequently, this situation, when it occurs, should be a self-enforcing control and, therefore, should not require signing.

However, if during a field inspection it is noted that motorists are forcing the RTOR maneuvers during heavy traffic low periods and are adding to the congestion on the cross street, it might be desirable to limit the movement during certain hours.

Railroad Crossing Interconnection. As stipulated in the new Part VIII (Sec. 8C-6) of the MUTCD,[4] "When the grade crossing is equipped with an active traffic control system, the normal sequence of highway intersection signal indications should be preempted upon approach of trains to avoid entrapment of vehicles on the crossing by conflicting aspects of the highway traffic signals and the grade crossing signals." Only one state has made particular reference to this situation for prohibiting RTOR.

To be in conformance with the MUTCD recommendation, RTOR should be prohibited for the one approach that is applicable. If allowed, the RTOR motorist may, without knowledge, turn into the railroad crossing exposing himself to a conflict with the train. This restriction should apply at any location where the traffic signal controller is preempted regardless of whether there is a train approach signal.

Recommended Guidelines for Prohibiting RTOR.

On the basis of the previous analyses and in keeping with the general principles for prohibiting the RTOR maneuver, the following guidelines are recommended:

RTOR should be prohibited where:

1. Sight distance of vehicles approaching from the left is less than the following minimums:

Cross Street Speed Limit (MPH)	*Minimum Sight* Distance (Feet)*
20	120
25	150
30	190
35	220
40	270
45	320
50	360
55	410

*Sight distance as measured from the stop line if pedestrian crosswalks are presented or, if none, from the edge of the cross-street pavement or curb line.

2. The intersection has more than four approaches or has restricted geometrics which cause additional conflicts. (The restriction should apply only to approaches which have multiple or unusual conflicts that are not easily identified by the motorist.)

3. There is an exclusive pedestrian signal phase during which pedestrians can use all crosswalks.

4. The intersection is within 200 feet of a railroad grade crossing, and the signal controller is preempted during train crossings. (The prohibition should apply only to the approach from which right turns are made into the lane crossing the railroad. See Sec. 8B-7, MUTCD.)

RTOR may be prohibited where:

1. Significant pedestrian conflicts are resulting from RTOR maneuvers.

2. More than one RTOR accident per year has been identified for any particular approach.

3. There is an unusual movement, such as double-left turns, that would not be anticipated by the RTOR driver.

4. There are school crossings or large numbers of children or elderly expected.

The first four guidelines are coined in "should" terms, which indicates that they are advisable and recommended but not mandatory. The second set are noted as "may" since it would be permissible to use NO TURN ON RED signs under the stated conditions.

These guidelines provide sufficiently detailed criteria for the traffic engineer to determine whether a specific intersection or approach should have an RTOR prohibition. However, they are also sufficiently general so that they can be adapted to problems or conditions unique to any one location.

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