

# **No Turn on Red Implementation Guidelines**



**City of Minneapolis, MN**

**October 18, 2005**

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## Appendix A

Table A-1 No Turn on Red Policy Survey of Metropolitan Cities

Table A-2 No Turn on Red Research Studies and Publications

# Summary of No Turn on Red Implementation Guidelines

City of Minneapolis, MN  
October 18, 2005

Minneapolis Public Works conducted a thorough review of research studies and publications on the safety effectiveness of no turn on red (NTOR) sign installations. Many researchers have concluded that there is no clear or directly correlated safety benefit of the NTOR.

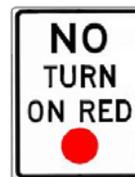
Public Works conducted surveys of the NTOR policies of several other municipalities in the metro area. The NTOR policies are generally that a NTOR sign should be installed at only those locations where an engineering investigation deems it appropriate. A NTOR sign shall be installed in accordance with the Minnesota Manual on Uniform Traffic Control Devices (MMUTCD) and the following situations:

1. On an approach where the sight distance is limited or obstructed and cannot be reasonable corrected.
2. Intersections consisting of unique geometrics (e.g., five leg intersection).
3. On any approach where a crash analysis determines the right turn on red (RTOR) maneuver directly results in an average of one crash per year.
4. At signalized intersections where a designated school crosswalk and school crossing guard are present.
5. There can be unusual circumstances where after an engineering study the RTOR should be installed. These could include LRT tracks, railroad tracks, protected turning movements and unusual pedestrian movements.

## Other Considerations

When an engineering investigation determines a NTOR is warranted for installation, the following shall apply:

- The NTOR sign should be installed only for the approach or approaches which apply, using the R10-11 signs.



Public Works is beginning an operational audit of the existing signalized locations over the next 5 years and as a part of the audit the need for any NTOR signs will be included. If the intersection has a NTOR sign that is not needed it will be removed. Conversely, if one is needed the signs will be installed. The respective Council Ward office will be notified when this action is taken.

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City of Minneapolis, MN

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## 1. Background

The Arab Oil Embargo of 1973-1974 increased national interest in right turn on red (RTOR) as an energy conservation measure. As a result, the allowance of permissive RTOR movements became a national standard. Subsequent to the adoption of the national RTOR standard, the Minnesota State Legislature approved an action allowing permitted RTOR movements (left turn on red for one-way to one-way roadway intersections). At that time, the City of Minneapolis Public Works Department performed a generalized review of all signalized intersection types to determine if any no turn on red (NTOR) restrictions were needed to protect pedestrian and/or vehicle movements. Based on this previous review, Minneapolis currently installs and retains NTOR signs at the following types of locations:

- All signalized school crossings.
- All signalized intersections with more than four approach legs.

In addition to these locations, intersections with the following characteristics are frequently approved for NTOR prohibitions:

- Intersections with sight distance restrictions.
- Intersections with fast moving traffic (i.e., freeway exit ramps crossing City streets).
- Locations consisting of a high volume of senior citizen pedestrians
- Intersections adjacent to parks.
- Intersections adjacent to hospitals.
- Specialty areas such as activity centers for the blind or persons with disabilities.
- Other locations where a high volume of pedestrian activity exists.
- Intersections with protected left turn movement conflicts.
- Intersections with multiple vehicle directions (i.e., one-way to two-way traffic flow).

## 2. Purpose

Over time, the City guidelines for the installation of NTOR signs has been interpreted and applied rather liberally. Historically most requests for the installation of NTOR signs have been approved. Unfortunately, this has resulted in inconsistency and overuse of NTOR signs throughout the City. The purpose of this document is to:

- Present the NTOR sign justification and installation guidelines provided by the Minnesota Manual on Uniform Traffic Control Devices (MMUTCD).
- Present NTOR policies and guidelines obtained through a survey of other metropolitan cities.
- Present the key findings and conclusions found through research of previous studies and publications prepared on the NTOR subject.
- Present the proposed NTOR guidelines for City of Minneapolis Public Works review and adoption.
- Provide other recommendations regarding NTOR/RTOR/LTOR.

### 3. MMUTCD Guidelines

According to the MMUTCD, a NTOR sign should be considered when an engineering study finds that one or more of the following conditions exist:

1. Inadequate sight distance to vehicles approaching from the left (or right, if applicable).
2. Geometrics or operational characteristics of the intersection that might result in unexpected conflicts.
3. An exclusive pedestrian phase (Also referred to as a pedestrian scramble phase)
4. An unacceptable number of pedestrian conflicts with right turn on red maneuvers, especially involving children, older pedestrians, or persons with disabilities.
5. More than three right turn on red crashes reported in a 12-month period for a particular approach.

If used, the NTOR sign should be installed near the appropriate signal indication for the approach or approaches, which it applies to.

### 4. Survey of Other Cities' Policies or Guidelines

Research of NTOR policies was completed for surrounding Twin City metro area cities and other large metropolitan regions. The purpose of this section is to document current practices and published policies or guidelines (if available) and to summarize information solicited from each city.

In general, all of the cities contacted try to minimize the use of the NTOR sign. Installation is often only considered on a case-by-case basis and is generally only subjected to the criteria stated in the Federal MUTCD. Few cities had written documentation providing additional considerations beyond the MUTCD criteria or further definition of “an unacceptable number of pedestrian conflicts with right turn on red maneuvers”, as stated in the manual. Table A-1, provides an overview of the general practices obtained for cities surveyed.

## 5. NCITE Pedestrian Committee Survey

The North Central Institute of Transportation Engineers (NCITE) pedestrian committee conducted a survey in 2002 of perimeter and suburban cities in Minnesota in regards to their policies on NTOR signs. General practices obtained for the cities surveyed as part of the NCITE pedestrian committee research is also illustrated in Table A-1.

## 6. Review of Research Studies and Publications

A review of research studies and publications discussing RTOR and the safety aspects of providing NTOR signs was completed. A total of sixteen publications were researched and reviewed. Table A-2 provides a comprehensive summary of the key findings and conclusions obtained from each reference source. Aspects of the publications include discussion of crash and safety statistics, documentation of driver behavior and violations, vehicle-pedestrian conflict countermeasures, installation guidelines and evaluations of the efficiency of various NTOR sign types.

Previous studies and publications serve as an important resource in forming the Minneapolis NTOR guidelines; and provide valuable information for addressing issues relative to this signage. Key conclusions extracted from the studies identified in Table A-2 are summarized below:

### *Safety and Operation*

- RTOR crashes were found to account for less than 0.6 percent of all intersection crashes. (Source 2, 5, 12 and 15)
- A 1981 study (Source 6) found that right turn crashes comprised 1.47 percent of all pedestrian crashes prior to RTOR laws. Subsequent to the adoption of the RTOR national standard this proportion increased to 2.28 percent. More recent studies completed have found that a RTOR maneuver relates to less than 1 percent of all reported pedestrian crashes. (Source 2, 5 and 15)
- Less than 0.1 percent of all pedestrian crashes implicating a RTOR results in a fatality. (Source 5 and 15)
- Studies have found that the probability of vehicle-pedestrian conflict or crash is greater with a right turn on green (RTOG) than a RTOR (Source 2, 10, 12 and 13).
- The allowance of RTOR provides significant capacity improvement. Although dependent on location, two studies found that approximately 26 to 39 percent of all right turn movements were made on red. (Source 9 and 13)

### *Driver Behavior*

- Allowing RTOR does result in an increase of vehicles not coming to a complete stop prior to proceeding. Approximately 35 to 56 percent of vehicles with the opportunity to turn right on red did not fully stop. (Source 9, 13 and 16). This is compared to 68 percent (Source 13) of vehicles not fully stopping at stop sign controlled intersections.
- Approximately 20 percent of motorists violate NTOR prohibitions when given the opportunity. (Source 13)
- The FHWA found RTOR to be more problematic for the older driving population. However, the study also found that the older population attempts to make a RTOR only 16 percent of the time compared to 83 percent of young/middle aged drivers. (Source 16).

### *Message Signs*

- When a NTOR is deemed appropriate, the “red ball” sign was found to be more effective than the standard black and white sign in terms of RTOR violations. (Source 6, 14 and 16)
- Part time NTOR restrictions were found effective in increasing driver compliance. (Source 3, 7 and 8)
- Blank-out NTOR signs were found most effective in increasing driver compliance at locations where NTOR is necessary for short time periods. (Source 1, 6 and 14)
- Message signs specifying NTOR “When Pedestrians are Present” were found ineffective in increasing driver compliance (Source 7). Source 14 found this sign effective only at locations with a low right turn volume.

## **7. Minneapolis Crash Database**

A cursory review of the overall crash type occurrences within the City of Minneapolis was completed. Table 1 summarizes the percent representation of right turn and pedestrian type crashes in comparison to the overall number of City wide crashes.

**Table 1. Percent of Overall Crashes by Crash Type**

Crash Type	Year			
	2002	2003	2004	2005*
Right Turn	1.9%	1.8%	1.5%	0.5%
Pedestrian	4.9%	3.8%	4.1%	5.1%

\* January 1 to March 31, 2005

The percentages illustrated in Table 1 include crashes occurring at signalized intersections, unsignalized intersections and mid-block roadway segments. In review of

Minneapolis current method of tracking crashes, the following considerations need to be made in assessing the statistics:

- Right turn related crash data does not differentiate whether the vehicle made a RTOR or RTOG. Individual crash reports may provide greater insight.
- Intersection characteristics, traffic control and existing RTOR prohibitions are not identified.
- Some right turn crash types may have been coded as a right angle type crash.
- A crash involving a pedestrian is coded as a “Pedestrian” type, regardless of the movement of the vehicle involved.

As shown, the overall percentage of right turn and pedestrian related crashes is quite low. If a detailed analysis was conducted further breaking down the right turn/pedestrian crashes; to signalized intersection locations, identifying crashes specifically as a result of a RTOR maneuver, and completing a cross-reference between pedestrian/right turn related crashes, the analysis would be expected to yield results similar to those illustrated in the reference sources. Therefore, a similar conclusion that the provision of NTOR signs result in a negligible pedestrian safety benefit is expected.

## **8. Proposed Guidelines**

The primary pedestrian safety concern relative to RTOR on red is the situation where a motorist is looking left for a gap in traffic and does not see a pedestrian crossing from the right. This situation has led to a perception of improved pedestrian safety with NTOR. As found, crash statistics and safety evaluations do not necessarily support this perception. Furthermore, this conflict is not unique to signalized intersections. There are a greater number of two-way stop controlled intersections versus signal controlled, where the same conflict issues exist.

In review of the NTOR studies and publications, several researchers have concluded that there is no clear safety benefit of the NTOR sign with respect to pedestrians. Due to the very small magnitude of vehicle-pedestrian conflicts resulting from a RTOR maneuver, any benefit that could be achieved from the NTOR sign is insignificant in comparison to the greater number of pedestrian and/or vehicle crash types. Furthermore, studies have found that the RTOG vehicle-pedestrian conflict is as much of a concern as RTOR. Whether RTOR or RTOG, the number of crosswalk conflict zones, requiring the vehicle to yield to pedestrians, is the same. However, vehicles passing through the second crosswalk (RTOG) are generally moving faster.

Based on the survey of other municipalities and the results of research completed on the NTOR subject, a NTOR sign should be installed or retained at only those locations where an engineering investigation deems it appropriate. It is recommended that Minneapolis adopt an approach consistent with the guidelines provided in the MMTUCD and the following situations:

1. On an approach where the sight distance is limited or obstructed and an engineering study determines the right turning vehicle cannot safely enter the traffic flow. As a rule of thumb, a sight distance less than 190 feet for a 30 mph speed (AASHTO Stopping Sight Distance) may be considered for a NTOR sign. All other reasonable measures (e.g. removing/relocating sight obstruction) to improve the sight distance should be addressed prior to installation of the sign.
2. Intersections consisting of unique geometrics (e.g., five leg intersection), where the right turning vehicle has multiple crossing conflicts or unexpected conflicts. A NTOR should be placed on only the approach or approaches, which these conditions apply.
3. On any approach where a crash analysis determines the RTOR maneuver directly results in an average of one crash per year (over three year study period). However, all other potential remedial measures or potential contributing factors should be addressed prior to installation of the NTOR.
4. Locations where an exclusive pedestrian scramble phase is in operation.
5. At signalized intersections where a designated school crosswalk and school crossing guard are present. Barring justification for a NTOR due to other factors listed, part-time prohibitions should be considered.
6. Locations where an active train or LRT vehicle traverses through the center of or near the intersection.
7. Where an active train or LRT track is adjacent to the intersection and the signal controller is preempted, a NTOR sign may be appropriate.

Other intersection characteristics, which may be considered for a NTOR sign, are as follows:

- Intersections where a protected left turn phase is in operation (e.g. southbound), but the opposing direction (e.g. northbound) is a permitted only left turn movement. In general, a NTOR should not be installed unless; the intersection consists of unique geometric characteristics (unique in comparison to all other locations with protected left turn operation) resulting in an unexpected conflict, a documented safety problem is found, or field visits consistently observe driver confusion or near miss conflicts.
- Intersections with multiple vehicle directions (e.g., one-way to two-way traffic flow). In general, a NTOR should not be installed unless; the intersection consists of unique geometric characteristics resulting in an unexpected conflict, a documented safety problem is found or field visits consistently observe driver confusion or near miss conflicts.

- Intersections where no single warrant is met (i.e., any of Guidelines 1 through 7), but an engineering investigation finds the pedestrian composition (percentage of blind, elderly or child pedestrians), or pedestrian activity to be unique in comparison to all other surrounding locations. In general, pedestrian volumes, pedestrian activity or other related pedestrian activities should not in itself warrant a NTOR sign. Alternative pedestrian treatments should be investigated first (e.g., “Yield to Pedestrian in Crosswalk” or “Watch for Turning Vehicle” signs); and if after proven unsuccessful trial of other alternative pedestrian treatments, a NTOR sign may be considered.

When an engineering investigation determines a NTOR is warranted for installation, the following shall apply:

- The NTOR sign should be installed only for the approach or approaches, which apply.
- The NTOR signs should be installed on the near and/or far side traffic signal pole and should be located to provide the maximum degree of visibility.

The proposed guidelines will provide Minneapolis with a NTOR standard that is consistent with other larger metropolitan municipalities, consistent with the surrounding Twin Cities Metro Region, will provide greater consistency in the use of NTOR signs throughout Minneapolis, will provide safe and efficient movement of vehicles, pedestrians and bicyclists and will better conform to the MMUTCD.

## 9. Other Recommendations

The following is intended to provide further guidance and establish recommended action items.

1. Officially adopt the proposed NTOR guidelines recommended in the previous section.
2. Implement a program and develop a schedule to systematically review all intersections where NTOR signs are currently provided. The purpose of the review would be to bring all intersections within the City of Minneapolis into compliance with the proposed NTOR guidelines. It is expected that many of the existing NTOR signs would be removed. Once completed, requests made for the installation or re-installation of NTOR signs would be evaluated on a case-by-case basis.
3. Minneapolis should adopt an official NTOR sign type. All NTOR signs justified for retention or installation should be of the same type. Currently, there are approximately 685 NTOR signs of three different varieties in use. The following summarizes the existing NTOR sign quantities:

- Text with Red Dot (old style): 484



- Black and White Text Only: 195



R10-11a  
600 x 750 mm  
24" x 30"



R10-11b  
600 x 600 mm  
24" x 24"

- Symbol with Black and White Text: 6



R10-11c  
600 x 750 mm  
24" x 30"

Research studies have found the NTOR sign with the “Red Dot” to be the most effective and easily understood sign. The MMUTCD no longer endorses the ‘old style’ NTOR sign with the centered “Red Dot.” Therefore, it is recommended that Minneapolis adopt the new “Red Dot” R10-11 sign as its standard. The proposed R10-11 sign is illustrated in Figure A-1. If a systematic review of NTOR signs is completed, many signs are expected to be removed. As such, the burden for updating the remaining NTOR signs to the recommended R10-11 sign is less. A NTOR sign costs approximately \$20.00 to \$25.00 each (material only).

4. Encourage police officers to begin documenting right turn on red related crashes in crash reports. Crash reports should identify whether a RTOR or RTOG movement was made, if pedestrian conflict was involved and whether or not the crash was the fault of the right turning vehicle. Contributing factors should also be noted.
5. Improve the coding of right turn related crashes into the City of Minneapolis crash database. Specific attention should be made in entry of right turn and pedestrian related crashes at intersections. The collection and provision of such crash details will support future evaluation of NTOR installations on the basis of

safety. In the long term, updated crash database and analysis software should be considered to provide better or more useful information.

6. Education and enforcement play a significant role in the benefits and safety of RTOR. When citizen requests are made for the NTOR sign to address pedestrian right of way violations, enforcement measures should be addressed prior to the installation of NTOR signs. The Minneapolis Police Department has set up plainclothes details (posing as pedestrians) in order to cite violators. Continual efforts and establishment of other similar programs should be pursued to help enforce pedestrian right of way laws, which at the same time, educates the driving public. Improved compliance and driver understanding in this area would likely reduce public demand for NTOR signs.
7. Consider implementing part-time NTOR prohibitions or the use of blank-out signs at designated school crossings as opposed to full time restrictions. Cost and materials required for blank-out signs would need to be further investigated. Coordination with the City of Minneapolis safe routes to school and school crosswalk program should be considered.
8. Explore alternative countermeasures and intersection treatments to improve pedestrian safety at crosswalks. Source 4, documented in Table A-2, provides several effective measures, which could be investigated prior to consideration of a NTOR. A few examples are listed below:
  - “Pedestrian Crossing” warning signs.
  - MMUTCD sign R1-6 (“Stop for Pedestrians or Yield to Pedestrians”).
  - Enhance ladder or cross-hatched crosswalk striping.
  - Far side bus stops.
  - Improve illumination.
  - Pedestrian countdown timer, adjusted pedestrian crossing intervals.
  - Reduce corner radii.
  - Intersection throating (i.e., bump-outs).

# **Appendix A**



R10-11

NO TURN ON RED

\*Series 2000 Standard Alphabets.

A	B	C	D	E	F	G	H	J	K	L
18	24	.375	.625	2.375	4 E	1.75	3 D	.75	5	3.742
24	30	.375	.625	2.75	5 E	2	4 D	1.5	6	4.681
36	48	.625	.875	4.75	8 E	3.5	6 D	1.5	10	7.491

**C**

M	N	P
4.806	6.972	1.5
6.41	9.299	1.5
9.616	13.950	2.25

COLORS: LEGEND — BLACK  
 SYMBOL — RED (RETROREFLECTIVE)  
 BACKGROUND — WHITE (RETROREFLECTIVE)

**Figure A-1. No Turn on Red Sign Type R10-11**

**Table A-1. No Turn on Red Policy Survey of Major Metropolitan Cities**

	City	Key Findings/Conclusions
1	Phoenix, Arizona	<p>The City of Phoenix has adopted a policy, which minimizes the use of No Turn on Red signs to unique situations. The Phoenix Traffic Operation Handbook provides the following circumstances for their installation:</p> <ul style="list-style-type: none"> <li>• Inadequate sight distance to vehicles approaching from the left.</li> <li>• Intersections with uncommon geometric or operational characteristics that might result in unexpected conflicts.</li> <li>• The existence of an exclusive pedestrian (i.e., pedestrian scramble) signal phase.</li> <li>• Excessive Right Turn on Red crashes.</li> <li>• Significant crossing activity by children, elderly, or handicapped. However, prohibiting Right Turn on Red may increase right turn on green conflicts, which are more often associated with pedestrian crashes.</li> </ul>
2	Calgary, Canada	<p>The following four items serve as a guideline when considering the installation of a No NTOR in the City of Calgary, Canada:</p> <ul style="list-style-type: none"> <li>• There is a poor observance of the correct method of making a turn after stopping against a red light.</li> <li>• A multiple phased traffic signal operation is used.</li> <li>• There is evidence of a relatively large number of vehicle-vehicle or pedestrian-vehicle crashes, which cannot be reduced by other methods.</li> <li>• Adequate visibility of oncoming vehicles is obstructed.</li> </ul>
3	Madison, Wisconsin	<p>The City of Madison attempts to minimize the use of NTOR signs to situations where turn on red presents considerably more conflict than turn on green. The following guidelines are followed when considering the installation of NTOR Signs in Madison, Wisconsin:</p> <ul style="list-style-type: none"> <li>• Intersections where an all walk phase is provided concurrent with an all red phase for vehicles (i.e., similar operations as currently provided at the Franklin Avenue/East River Road-27th Avenue intersection in Minneapolis).</li> <li>• Intersections where an advanced walk (leading pedestrian interval – LPI) is used. However, No Turn on Red signs are minimized at these locations as well.</li> <li>• The visibility of approaching conflicting traffic is severely limited.</li> <li>• Dual right turns are permitted. However, Madison uses special signing to permit the traffic in the right most right turn lane to turn on red.</li> <li>• Locations where the first crosswalk crossed by a vehicle making a turn on red is used by a significant number of elementary school children. However, this is considered only in locations where a school crossing guard is not provided.</li> <li>• Locations where there are unexpected vehicle-vehicle conflicts resulting from unusual intersection geometrics, high speeds or complex signal phasing.</li> <li>• There is a history of crashes involving turns on red.</li> </ul>
4	Denver, Colorado	<p>The City of Denver implements NTOR in accordance with the criteria provided in the MUTCD. Denver does not have any other written policy with respect to the implementation of these signs. In general, there are very few NTOR signs within Denver. However, they do use numerous "Turns on Red Yield to Pedestrians" in the downtown CBD. Primarily at locations where an exclusive pedestrian (scramble) phase is in operation.</p>
5	Atlanta, Georgia	<p>Atlanta does not have a written policy regulating the use of NTOR signs. NTOR are implemented on a case-by-case basis, where consistency is monitored by City Staff. In general, Atlanta's unwritten policy is that NTOR signs should be considered in the following situations:</p> <ul style="list-style-type: none"> <li>• Where right turn vehicles may obstruct crosswalks during hours of heavy pedestrian crossings.</li> <li>• The visibility of approaching conflicting traffic is severely limited.</li> <li>• Locations where there are unexpected vehicle-vehicle conflicts resulting from unusual intersection geometrics, high speeds or complex signal phasing.</li> </ul> <p>Atlanta uses blank out signs or signals to restrict right turn on reds at a few locations. Blank out signs are used to eliminate conflicts with left turning vehicles for a specific lane and to eliminate conflicts with pedestrians on an actuated crosswalk where the righting turning vehicle may have a visibility constraint.</p> <p>At this time Atlanta does not use time restricted NTOR signs. The basis for this decisions, is they feel this type of sign violates driver expectation and adds additional inconsistency.</p>
6	Omaha, Nebraska	<p>The City of Omaha implements NTOR in accordance with the criteria provided in the MUTCD. Omaha does not have any other written policy with respect to the implementation of these signs. In general, Omaha has very few NTOR signs, with exception to those installed due to visibility limitations. Omaha has installed a few NTOR signs with respect to the pedestrian guidelines provided in the MUTCD.</p>
7	Cincinnati, Ohio	No Response
8	Portland, Oregon	No Response

**Table A-1. No Turn on Red Policy Survey of Major Metropolitan Cities - Continued**

	<b>City</b>	<b>Key Findings/Conclusions</b>
9	Baltimore, Maryland	No Response
10	Rochester, Minnesota	<p>The City of Rochester does not have a written policy with respect to the implementation of NTOR signs. In general, Rochester implements NTOR on a case-by-case basis with the principal criteria as follows:</p> <ul style="list-style-type: none"> <li>• Adequate visibility of oncoming vehicles is obstructed.</li> <li>• History of crashes relevant to vehicles turning on red.</li> </ul> <p>Rochester had also installed a NTOR at the request of the PTA for a local school. Implementation was based on crash history, pedestrian volume conflicts, and traffic volumes. Subsequent to the school closing, the city removed the NTOR sign.</p>
11	St. Paul, Minnesota	<p>The City of St. Paul does not have a written policy with respect to the implementation of NTOR signs. Similar to Rochester, St. Paul implements NTOR on a case-by-case basis with the principal criteria as follows:</p> <ul style="list-style-type: none"> <li>• Adequate visibility of oncoming vehicles is obstructed.</li> <li>• History of crashes relevant to vehicles turning on red.</li> </ul> <p>St. Paul generally considers the needs of the vehicle (i.e., capacity of the intersection) as the first priority. However, unusual pedestrian-vehicle conflicts are considered in any determination. St. Paul did not provide any concrete guidelines for how they assess vehicle-pedestrian conflicts and at what threshold or criteria a NTOR sign would be justified. With respect to school areas, St. Paul does not automatically install NTOR. They have used a "NTOR When School Patrol is Present" sign in these instances.</p>
12	NCITE Pedestrian Committee Survey, 2002	<p>The North Central Institute of Transportation Engineers (NCITE) pedestrian committee conducted a survey in 2002 of perimeter and suburban cities in Minnesota in regards to their policies on NTOR signs. The following cities and their responses were made to the NCITE survey:</p> <p><b>City of Bloomington, Minnesota</b></p> <p>Under the Bloomington administration in 2002, when the NCITE survey was completed, Bloomington did and still does not use the NTOR sign on the basis of pedestrian safety. The installation of NTOR are implemented based on the criteria found in the MMUTCD, with the principal criteria being to address obstructed visibility issues.</p> <p>Installation of NTOR are completed on a case-by-case basis and guided by engineering personnel as to consistency. Bloomington believes that the NTOR is not applicable for a pedestrian safety warrant, because vehicles passing through the conflict zone on red, after stopping, is safer than passing through the same conflict zone on a green light without stopping. The stop for pedestrian obligation is the same either way.</p> <p><b>City of Plymouth, Eden Prairie, Richfield, Brooklyn Park and Maple Grove</b></p> <p>None of these cities have a written policy in regards to the installation of NTOR signs. NTOR are generally not used with respect to pedestrian safety. Each city installs NTOR on a case-by-case basis with the principal criteria considered are as outlined in the MMUTCD.</p>

**Table A-2. No Turn on Red Research Studies and Publications - Key Findings and Conclusions**

Source	Title	Author	Date	Key Findings/Conclusions
1	Update of the Guidelines for "Prohibition of Turns on Red" Recommended Practice	Institute of Transportation Engineers (ITE)	November 4, 2004	<ol style="list-style-type: none"> <li>Engineering Judgment. Considerations that might warrant NTOR totally or part-time include: <ul style="list-style-type: none"> <li>Limited sight distance</li> <li>A multiple leg-intersection (phasing or geometrics) where potential conflicts are not easily seen.</li> <li>Heavy volume of pedestrian crossings</li> <li>Exclusive pedestrian phase (pedestrian scramble)</li> <li>Request from disabled pedestrians using intersection.</li> <li>School crossings</li> <li>Railroad crossings</li> <li>Traffic signals with 3 or more phases</li> </ul> </li> <li>Part-time restrictions are discouraged but preferred to full-time where locations warrant only short time period.</li> <li>Less restrictive measures should be considered first (i.e., Use "When Pedestrians are Present" sign)</li> <li>Multi-phase signalized intersections. Most authorities do not perceive this need. However where found appropriate consideration should be given to right turn lane green arrow.</li> <li>Restrictions should be sensitive to special needs of peds and cyclists (i.e., children, elderly and disabled). Pedestrian volumes should be considered but not be the only criteria for prohibiting turns on red.</li> <li>Blank-out signs are found effective and encouraged where practical in lieu of full or part-time NTOR.</li> <li>LTOR follows same criteria as RTOR.</li> <li>Education plays significant role in benefits and safety of RTOR. Public needs to be educated. State driver manuals need to reflect current RTOR practices.</li> <li>Enforcement plays a significant role in reducing violations and educating public on proper execution of RTOR. Collaboration with law enforcement should be done when investigating methods to reduce violations and improve safety.</li> </ol>
2	Safety Evaluation of Right Turn on Red, ITE Journal	Jack L. Fleck, Bond M. Yee	June 2002	<ol style="list-style-type: none"> <li>The report references a study completed in San Francisco which found very low incidence of RTOR collisions, and also found that RTOR have a lower rate of collisions than RTOG.</li> <li>1994 to 1996, RTOR resulted in 0.45 percent of all crashes.</li> <li>From 1994 to 1998, pedestrian and RTOR collisions resulted in 0.8 percent of all pedestrian crashes.</li> <li>Pedestrian safety is not clearly improved with NTOR.</li> <li>RTOR results in increased RTOG collisions, which are intuitively more severe than RTOR.</li> <li>Author's conclude that California law and San Francisco's current policy (125 of 1,050 signalized intersections have NTOR. Prohibition at locations with limited sight distance and intersections with unusually high pedestrian/vehicle conflicts) of permitting RTOR is sound. It has a proven safety record and provides for posting of RTOR at appropriate locations.</li> </ol>
3	Field Evaluation of Two Methods for Restricting Right Turn on Red to Promote Pedestrian Safety, ITE Journal	Richard A. Retting, Marsha S. Nitzburg, Charles M. Farmer, Richard L. Knoblauch	January 2002	<ol style="list-style-type: none"> <li>Signs prohibiting RTOR during specified hours were found very effective at increasing driver compliance with stop lines, reducing number of RTOR without stopping and reducing number of pedestrians yielding to turning vehicles.</li> <li>Signs giving drivers discretion (i.e., "When Pedestrians are Present") were found to be not very effective.</li> <li>Where appropriate to install a NTOR to promote pedestrian safety, consideration should be given to installing signs tailored to times of pedestrian activity versus giving the driver discretion to determine if pedestrians are present.</li> </ol>
4	Pedestrian Safety at Intersections	FHWA, ITE	April 2004	<ol style="list-style-type: none"> <li>RTOR can potentially contribute to pedestrian crashes because it creates conflicts between pedestrians and motor vehicles</li> <li>Pedestrian Safety Countermeasures: <ul style="list-style-type: none"> <li>Use ladder or cross-hatched crosswalk, consider raised cross walk. In pavement lights, use "Pedestrian Crossing" warning sign, use MUTCD sign R1-6: "Stop for Pedestrians or Yield to Pedestrians", use MUTCD sign R1-5 "Yield here to Pedestrians".</li> <li>Install barriers to channelize pedestrians to appropriate crossing location, install bulb-outs to shorten crossing distance, provide refuge islands, reduce corner radii, pedestrian bridge.</li> <li>Consider longer ped crossing timing, NTOR restriction, far side bus stops, illumination.</li> <li>Pedestrian countdown timer, Animated eye pedestrian signal, pedestrian intervals and signal phases.</li> </ul> </li> <li>Pedestrian safety requires partnership between the driver, pedestrians, police department and traffic engineer.</li> <li>Ensure enforcement of motorist compliance with traffic control devices, speeds and pedestrian safety laws.</li> </ol>
5	Office of Program Development and Evaluation - Traffic Safety Programs (Statistical Safety Evaluation of RTOR)	Compton, Milton	1994	<p>Results of data analysis from four states (Illinois, Indiana, Maryland and Missouri - 1989-1992) are as follows:</p> <ol style="list-style-type: none"> <li>RTOR crashes represent a small proportion of the total crashes (0.05%). RTOR injury and fatal crashes represent a fraction of 1% of all fatal and injury crashes (0.06%).</li> <li>RTOR crashes represent a very small proportion of signalized intersection crashes (0.4%).</li> <li>The proportion of RTOR pedestrian and bicycles crashes to all RTOR crashes was 22%.</li> <li>93% of RTOR pedestrian or bicyclist crashes resulted in injury.</li> <li>Only 1% of RTOR pedestrian and bicyclist crashes resulted in fatal injury. However, only 0.2% of all fatal pedestrian and bicyclist crashes result from a RTOR vehicle maneuver.</li> <li>RTOR pedestrian crashes are 50/50 split between male and female. RTOR bicycle crashes consisted predominantly of males.</li> <li>Most RTOR crashes were found to occur between 6AM and 6PM.</li> <li>Study concludes by stating RTOR crashes have represented a very small percentage of all crashes, deaths and injuries; therefore, the impact on traffic safety has been small.</li> </ol>
6	The Effects of No Turn on Red / Yield to Peds Variable Message Signs on Motorist and Pedestrian Behavior	Herman Huang	November 2000	<ol style="list-style-type: none"> <li>Preusser et al (1981) found that right turn crashes comprised 1.47% of all pedestrian crashes prior to RTOR laws. The proportion increased to 2.28% of all pedestrian crashes after RTOR laws went into effect.</li> <li>Countermeasures found to be effective in reducing pedestrian risks related to RTOR related crashes include: illuminated NTOR signs, NTOR sign with a "red ball" and offset stop bars at intersections where RTOR is allowed.</li> <li>Motorists do not always yield to pedestrians during a RTOG movement. Countermeasures include: smaller corner radii, intersection bulb-outs, "Pedestrians Watch for Turning Vehicle" signs and "Yield to Pedestrians when Turning" signs.</li> </ol> <p>Comparison study of variable signs (displays "NTOR" during red phase and "Yield to Pedestrian" during green phase) at treatment sites versus intersections with no NTOR or yield to pedestrian signs (control sites). Results as follows:</p> <ol style="list-style-type: none"> <li>Variable message signs were found to be associated with significantly lower percentages of RTOR violations at treatment sites in comparison to control sites</li> <li>Motorists were much more likely to yield to groups than to single pedestrians at treatment sites, but not at the control sites.</li> <li>The signs did not have an effect on the number of pedestrians who exhibited normal crossing behavior.</li> </ol>

**Table A-2. No Turn on Red Research Studies and Publications - Key Findings and Conclusions - Continued**

Source	Title	Author	Date	Key Findings/Conclusions
7	8.2.1 Turn Prohibitions at Signalized Intersections	Unknown	Unknown	<p>1. RTOR should be prohibited when an engineering study finds that either (1) there is an exclusive pedestrian phase (i.e., pedestrian scramble), (2) the number of total RTOR related collisions is two or more for an approach in a 3-year period, or (3) the intersection is within 60 feet of a railroad crossing and the signal controller is preempted (the prohibition should only apply to the approach on which the right turn lane crosses the track).</p> <p>2. 5 or more approaches and substantial traffic exists on each approach, The NTOR would apply only to the critical approaches.</p> <p>3. The sight distance is limited and is less than the values shown in Table 8-2 (refer to reference material).</p> <p>4. Approaches with double right turn lanes. NTOR prohibited for both lanes or only the left lane.</p> <p>5. A total of 6 or more RTOR conflicts with pedestrians have occurred during the peak hour for an approach.</p> <p>6. Intersections within school zones</p> <p>7. At approaches with 250 or more pedestrians in the peak hour and there are 26 or more RTOR maneuvers per hour.</p> <p>8. The area has an unusually high number of elderly or mobility and visually impaired people.</p> <p>A study completed by the Insurance Institute for Highway Safety evaluated 2 methods of restricting RTOR to promote pedestrian safety. The results indicated that signs prohibiting RTOR during specified hours were moderately effective in increasing the percentage of drivers stopping at the limit line. Signs prohibiting RTOR when pedestrians were present were not effective. Signs prohibiting RTOR at all times were most effective.</p>
8	44. Right Turn on Red Restrictions ( <a href="http://safety.fhwa.dot.gov/saferjourney/Library/countermeasures/44.htm">http://safety.fhwa.dot.gov/saferjourney/Library/countermeasures/44.htm</a> )	Unknown	--	<p>1. One significant concern when RTOR is prohibited is that this leads to higher RTOG conflicts. A leading pedestrian interval (LPI) can be used to address this issue.</p> <p>2. NTOR should be done in areas where substantial pedestrian volumes exist and places where children cross.</p> <p>3. Part-time RTOR prohibitions during the busiest times may be sufficient to address the problem.</p> <p>4. Signs should be clearly visible to right turning vehicle stopped in the curb lane at crosswalk.</p>
9	Driver Behavior at Right Turn on Red Locations, ITE Journal	William D. Wagoner	April 1992	<p>1. The majority of drivers who execute a RTOR do so without conflicts imposed by pedestrians or cross-street traffic. (Pedestrian conflicts are experienced 4.6% of all RTOR movements)</p> <p>2. 28.6% of the pedestrians involved in a RTOR maneuver yielded to a right turning vehicle.</p> <p>3. 40.4% of RTOR vehicles did not come to a complete stop prior to proceeding on the RTOR.</p> <p>4. More than 95% of motorists provided with the opportunity to turn right on red, did so.</p> <p>5. Over 39.2% of all right turning movements were executed as RTOR. RTOR provided significant capacity increases for right turn movements</p>
10	Re-evaluation of Accidents Experience with Right Turn on Red, ITE Journal	Daniel Galin	January 1981	<p>1. Evaluation of Table 2 (See Reference Material) suggests that RTOR does not offer a greater degree of safety than RTOG. It rather suggests that RTOR offers less safety than RTOG.</p> <p>2. A California survey found the probability of having a crash on RTOR is 45% less than when making a RTOG. The probability of a pedestrian crash in RTOR is 28.6% less than in RTOG. However, injury crashes with RTOR were found to be 20% higher than on RTOG.</p> <p>3. 27% to 36% of drivers surveyed considered RTOR to be dangerous to pedestrians.</p> <p>4. 43% of pedestrians surveyed considered RTOR to be dangerous to pedestrians.</p> <p>3. The article concludes with saying the analysis of ROTR crash experience presented suggests a deterioration of safety at signalized intersections as a result of RTOR.</p>
11	Guidelines for Prohibiting Right Turn on Red at Signalized Intersections, Transportation Engineering	Hugh W. McGee	January 1978	<p>The article sites 19 factors used by states for prohibiting RTOR: Five or more approaches, Restrictive geometrics, Inadequate sight distance, Significant pedestrian volumes, High speeds through intersection, Exclusive ped-phase, RTOR conflicts with other vehicle movements, Signals under school crossing warrant, Vehicle conflict serious, Dual right turn lanes, History of RTOR crashes, Complex signal phasing, Signed school crossing, No appreciable right turns, Short red interval, Pedestrian signal, Fully actuated signals, Capacity problems for acceptance lanes, Railroad crossing interconnection.</p> <p>Discussion is provided for each factor. Based on the evaluation, the article suggests the following factors where RTOR should be prohibited:</p> <ol style="list-style-type: none"> <li>1. Sight distance of vehicles approaching from the left is less than a minimum criteria.</li> <li>2. Intersection has more than 4 approaches (Restriction applies only to those approaches which have multiple potential conflicts).</li> <li>3. Exclusive pedestrian phase (i.e., pedestrian scramble).</li> <li>4. The intersection is within 200 feet of a railroad crossing and the signal controller is preempted.</li> </ol> <p>RTOR may be prohibited where:</p> <ol style="list-style-type: none"> <li>1. Significant pedestrian conflicts are resulting from RTOR maneuvers.</li> <li>2. More than 1 RTOR crash per year has been identified a particular approach.</li> <li>3. There is an unusual movement, that would not be anticipated by the RTOR driver.</li> <li>4. There are school crossings or large numbers of children or elderly expected.</li> </ol>
12	An Emerging National Policy on Right Turn on Red, Traffic Engineering	Gerald Love, Justin True	November 1976	<ol style="list-style-type: none"> <li>1. Crashes involving the RTOR maneuver comprise 0.61% of all crashes at intersections where RTOR is allowed.</li> <li>2. The number of pedestrians in RTOR crashes is very small. This ranged from zero (Denver, Dallas and Virginia at 1,059, 1,000 and 29 intersections) over 1 year period to 54 (Los Angeles) over 2 year period at 3,235 intersections.</li> <li>3. Based on exposure, RTOR crashes occur equally or less frequently than RTOG crashes.</li> <li>4. RTOR usage (RTOR volume/total right turn volume) was 12% in CBD, 18% in non-CBD and 28% at rural</li> <li>5. Intersections approaches with a right turn pocket, the RTOR usage was 28% and only 13% on approaches without a right turn pocket.</li> <li>6. RTOR delay savings range from 9 to 39%.</li> <li>7. 50% of pedestrians interviewed did not think RTOR was dangerous, 38% felt RTOR was dangerous and 12% were undecided.</li> <li>8. A survey of law enforcement officials resulted in an overall view that RTOR is a positive traffic control feature, they did not feel RTOR was a major problem.</li> <li>9. The study recommendations were the exact same as listed in the above 1978 Hugh McGee Report</li> </ol>

**Table A-2. No Turn on Red Research Studies and Publications - Key Findings and Conclusions - Continued**

Source	Title	Author	Date	Key Findings/Conclusions
13	Determination of Motorist Violations and Pedestrian-Related Countermeasures Related to Right Turn on Red (Transportation Research Record 1010)	Charles V. Zegeer, Michael J. Cynecki	Unknown (Approx. Mid 1980's)	<ol style="list-style-type: none"> <li>Only 3.7% of vehicles violate the RTOR prohibition. However, of those motorists given the opportunity to commit a RTOR violation, 20% do so.</li> <li>Of drivers committing a RTOR violation, 23.4% result in conflicts with a pedestrian. However, less than 1% of the total right turn vehicles is involved in a RTOR-related conflict.</li> <li>14.2% of RTOR maneuver resulted in a conflict to pedestrians, compared with 19.5% RTOG maneuvers that involve a pedestrian conflict.</li> <li>Of 29 intersection approaches allowing RTOR, 26.2% of right turning vehicles turned right on red. Of the RTOR vehicles, 56.9% did not come to a complete stop.</li> <li>The overall percent not stopping at stop sign approaches is 68.2%. 11% greater than RTOR. However, author comments this due in part to greater opportunity for a rolling stop (i.e., less volume).</li> <li>Site characteristics related to high RTOR violations include: confusing or inappropriate part time prohibitions, inconspicuous NTOR, long cycle length, confusing multi-leg intersection, unjustified NTOR prohibition, signal split-phased, low pedestrian volume.</li> </ol>
14	Evaluation of Countermeasures Related to RTOR Accidents That Involve Pedestrians (Transportation Research Record 1059)	Charles V. Zegeer, Michael J. Cynecki	Unknown (Approx. Mid 1980's)	<ol style="list-style-type: none"> <li>The red ball NTOR sign was found to be more effective than the standard black and white NTOR in terms of RTOR violations and pedestrian conflicts.</li> <li>The NTOR with supplementary "When Pedestrians are Present" message was effective at sites where right turning vehicle volumes were low to moderate, but less effective when RTOR volumes were high.</li> <li>The offset stop bar was tested to provide better sight distance. It was effective in reducing RTOR conflicts with cross-street traffic and resulted in greater RTOR stop compliance.</li> <li>The "Look for Turning Vehicles" pavement marking was effective in reducing RTOR pedestrian-vehicle conflicts at several sites, but was not effective at others.</li> <li>The electronic NTOR blank-out sign was found to be slightly better than the standard NTOR sign in terms of violations.</li> </ol>
15	Synthesis on the Safety of Right Turn on Red in the United States and Canada	Dominique Lord	November 2002	<ol style="list-style-type: none"> <li>Between 5% and 20% of crashes at signalized intersections involve a pedestrian.</li> <li>Between 5% and 15% of pedestrian crashes at signalized intersection implicate a RTOR.</li> <li>Pedestrian crashes involving a RTOR account for less than 1% of all reported crashes in the US and Canada.</li> <li>Less than 4% of multi-vehicular crashes at signalized intersections involve a RTOR</li> <li>Similar to pedestrian crashes, the proportion of RTOR crashes is below 0.5% of all reported crashes.</li> <li>RTOR is rarely fatal with less than 0.05% of all reported crashes.</li> <li>The proportion of RTOR-related crashes involving a bicycle is slightly higher than the proportion of pedestrian crashes.</li> <li>The results of interviews found that most of the interviewees were in favor of RTOR. Although the feedback was positive towards RTOR, all agreed RTOR should be prohibited at intersection approaches where it is justified to do so.</li> </ol>
16	Highway Design Handbook, Publication No. FHWA-RD-01-103  I. Design Element: Traffic Control for Right-Turn/RTOR Movements at Signalized Intersections  (www.fhrc.gov/humanfac/01103/ch1.htm)	FHWA	May 2001	<ol style="list-style-type: none"> <li>Researchers have identified that the right turn maneuver is more problematic for older drivers compared with young or middle-aged drivers.</li> <li>Staplin et al. (1997) found that significantly fewer drivers in the old-old driver group attempted to make a RTOR (16%), compared with young/middle-aged drivers (83%) and young-old drivers (45%).</li> <li>Drivers made significantly fewer RTOR's at the skewed channelized intersection than other locations.</li> <li>Young/middle aged drivers made a RTOR without a complete stop nearly 35% of the time, compared to 25% for young-old and 3% for old-old drivers.</li> <li>Channelized intersections with or without exclusive acceleration lanes encouraged making a RTOR without a complete stop. Nonchannelized and skewed intersection locations showed the lowest percentage of RTOR's without a complete stop.</li> <li>Zegeer and Cynecki (1986) found that offsetting the stop line - moving stop line of adjacent stopped vehicles back from the intersection (6 to 10 feet) - was effective in providing better sight distance and resulted in an increase of vehicles making a full stop.</li> <li>Zegeer and Cynecki (1986) also found that a NTOR (with Red Circle symbol) was more effective than the standard black and white NTOR text only sign. An overall reduction in NTOR violations was found. In addition the larger (30" x 36") sign was found more effective than the standard (24" x 30") sign.</li> </ol>