NO TURN ON RED (NTOR) REPORT

CONNECTICUT DEPARTMENT OF TRANSPORTATION

PURSUANT TO PUBLIC ACT NO. 23-116

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EXECUTIVE SUMMARY

As part of Public Act No. 23-116, "An Act Implementing the Recommendations of the Vision Zero Council," the Connecticut Department of Transportation (CTDOT) was tasked with performing a research review to determine the effect of implementing a blanket no turn on red (NTOR) policy for all signalized intersections in the State of Connecticut. Crashes involving pedestrians at signalized intersections have increased in the past three years. Of particular concern are fatal and serious injury crashes, which the Connecticut Vision Zero Council looks to eliminate through statewide policies. Many traffic safety treatments, including NTOR, are being considered for wider adoption to address these crashes.

To help inform CTDOT's use of right turn restrictions at signalized intersections, multiple factors including engineering, enforcement, and policies other jurisdictions have used, or plan on using, were reviewed. This was to determine the effectiveness of NTOR in reducing crashes and examine other possible benefits and disadvantages.

The conclusion of this study is that the effects of restricting right turn on red (RTOR) movements vary widely depending on the intersection type, pedestrian, and cyclist volumes, surrounding land uses, and other factors. It is recommended that a general prohibition on RTOR not be adopted but that other steps be taken to leverage right turn restrictions for safety benefits. For example, its recommended that the CTDOT guidelines for implementing NTOR be revised to explicitly include a greater emphasis on vulnerable road user safety. It is also recommended that dynamic right turn message signs be adopted as standard for all new traffic signals

where right turn on red is permitted and pedestrian activity can be expected. Details for the use of dynamic turn message signs should also be added to the CTDOT guidelines on RTOR restrictions.

Problem Statement

The Connecticut Vision Zero Council has set a goal to eliminate fatal and serious injury crashes in the State. With the recent rise in crashes, especially those involving vulnerable road users, CTDOT has an interest in investigating the current state of RTOR in Connecticut and the potential safety benefits of expanded NTOR policies in the State at signalized intersections. This includes determining what engineering, enforcement, procedures, and policies other jurisdictions have used regarding RTOR maneuvers and their effectiveness in reducing crashes.

Existing RTOR Conditions in CT

Connecticut passed a law permitting RTOR in 1975. This followed a federal conservation law that tied permitting right turns to federal funding to reduce vehicle delay and fuel consumption. At first, RTOR was permitted only in Connecticut at intersections where RTOR was specifically signed. A 1978 State law changed this to establish RTOR everywhere in the State unless an approach was specifically signed for NTOR. As a result of that law, Connecticut is similar to all states in that RTOR is allowed, but individual agencies or jurisdictions within the states can have their own guidance or procedures for prohibiting RTOR at intersections.

The criteria for establishing NTOR at an intersection can be general and many states and cities rely on engineering judgement based on observations, crash history, and other factors to decide where to prohibit RTOR, rather than a strict set of standards. Even in cities that largely ban RTOR, there are intersections that are excepted. Strict criteria in one jurisdiction may be optional in another, for example some places ban RTOR at intersections near school crosswalks, while others do not or establish part-time NTOR. This is discussed in detail in the Literature Review section of this report.

Connecticut is similar to the rest of the country in that CTDOT, cities, and towns may approach RTOR restrictions differently, but that implementing NTOR is based on judgement, observations, and other specific factors. The existing ROTR conditions, crash data, and NTOR implementation criteria in Connecticut are discussed below.

<u>NTOR at State Signals</u>

- Number of State Traffic Signals: 2,560
- Number of State Traffic Signals with NTOR on at least one approach: 1,021

<u>NTOR at Municipal Signals</u>

- Number of Municipal Traffic Signals: 1,394
- Number of Municipal Traffic Signals with NTOR on at least one approach: 678

CRASH DATA FROM CONNECTICUT

To determine the vulnerable road user crash patterns occurring at signalized intersections, pedestrian involved crash data from the Connecticut Crash Data Repository was analyzed by crash characteristics and location. Crash analyses typically consider the last three years of data to provide a significant recent sample size, and this analysis was performed in September 2023. This analysis showed 3,662 crashes involving pedestrians occurred in the last three years, as seen in **Table 1**. There were 381 pedestrians involved crashes at traditional traffic signals in Connecticut. 72 of those crashes occurred during a right turn maneuver with 5 of those resulting in serious injury or a fatality. These right turn crashes could have occurred on the green, yellow, or red phase of the signal. Looking at right turn crashes on red phase specifically, there was only one confirmed fatal or serious injury pedestrian crash in the last three years. In that case, the motorist violated an existing NTOR sign, leading to a serious pedestrian injury.

Pedestrian Involved Crashes in CT Last 3 Years

	All	Serious or Fatal
Total Crashes (all locations)	3,662	754
All crashes at Signals	381	73
All turn crashes at Signals	202	23
Right turn crashes at Signals	72	5

Table 1: Pedestrian Crashes from Sept 1, 2020 to Aug 31, 2023

Research on RTOR, discussed below in this report, indicates that right turn signal crashes skew toward minor and property damage only and in the Connecticut three-year crash data, this pattern holds. 754 of the total 3,662 pedestrian crashes that occurred in the state resulted in serious injury or a fatality, which is 21% of those crashes. By contrast, of the right turn signal crashes only 7% were serious injury or fatal.

Since right turn signal crashes are so rare, an analysis was also done of historical Connecticut crash data to look for patterns. Detailed crash reports started in 2015, giving 8 years of historical crash data, **seen in Figure 1**. The historical data showed similar patterns to the three-year data. Since 2015, there have been nearly 12,000 pedestrian involved crashes and 19% of those crashes resulted in a serious injury or fatality. For right turn crashes at signals, on all signal phases, there have been 227 crashes since 2015 and 5% of those were fatal or serious. Right turn crashes at signalized intersections made up just 0.6% of all fatal and serious injury pedestrian crashes and 2% of minor injury and property damage crashes. A UConn analysis of the crash reports since 2015 estimates that approximately one third of these right turn signal crashes occurred on a red phase, another third on the green or yellow phase. The remaining third of pedestrian crashes occurred on an unknown phase that could not be determined by the reporting officer or through the crash report. It is currently unknown how many of these 227 right turn crashes occurred on an approach with an existing NTOR sign, but the UConn analysis determined 30% of the crashes occurred at signals with a RTOR restriction on at least one approach.

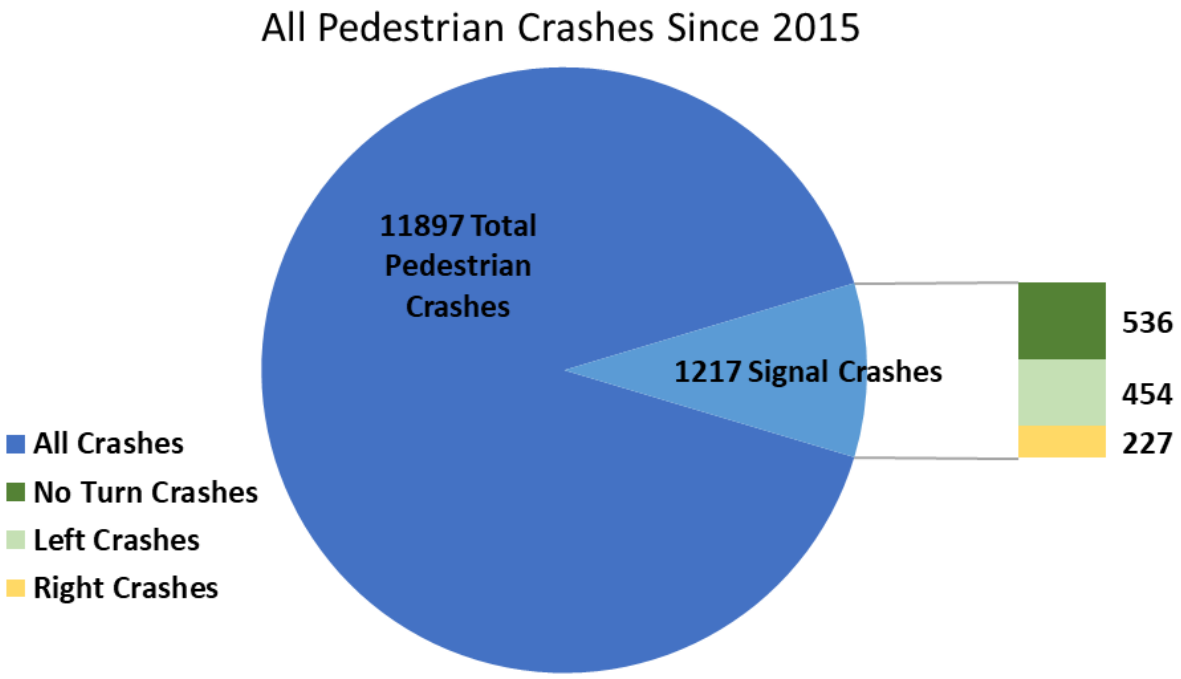

Figure 1: All Pedestrian Crashes in Connecticut Jan 1, 2015 to Aug 31, 2023

The Connecticut Vision Zero Council is focused on reducing serious injury and fatal crashes, so further analysis was performed on the serious injury and fatal right turn signal crashes in the historical data. As shown in **Figure 2** and **Table 2**, there have been 14 serious injury or fatal pedestrian crashes involving right turns at signals since 2015. Four of the crashes were fatal and 10 were serious injury. The four fatal crashes occurred on a green or unknown signal phase.

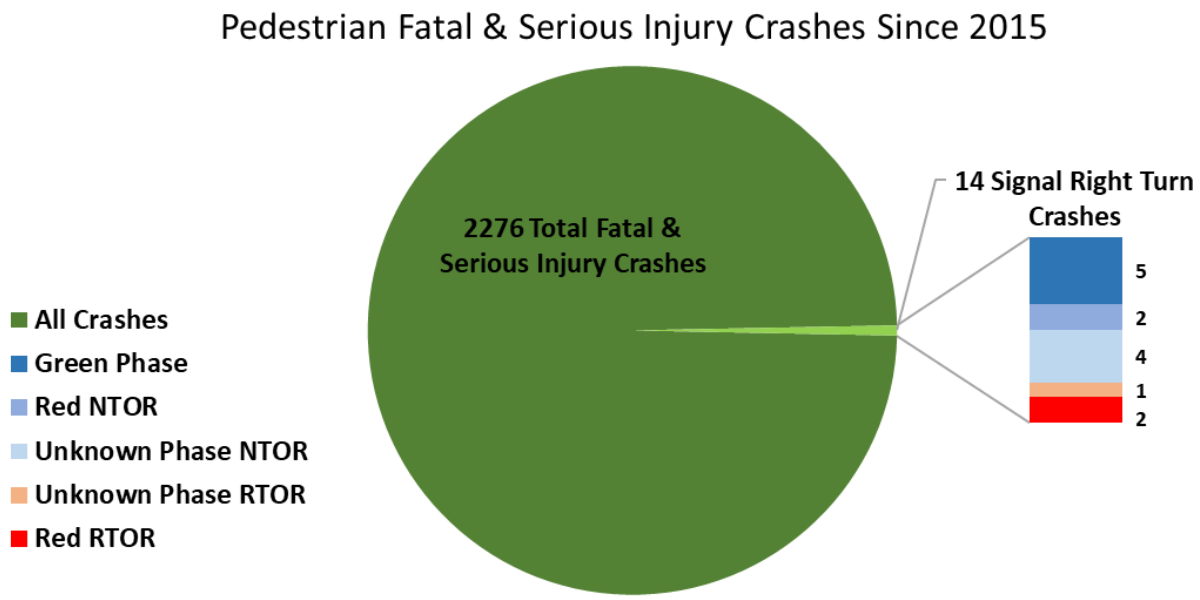

Figure 2: Fatal & Serious Injury Pedestrian Crashes in CT from Jan 1, 2015 to Aug 31, 2023

There were existing NTOR restrictions at approximately half of the approaches where serious or fatal crashes occurred. This is not necessarily surprising since RTOR is already restricted at many intersections in the State and as will be discussed below, is implemented in locations where crashes are more likely to occur. Two of the crashes occurring on a red phase were at locations with existing NTOR signs, meaning the motorist violated a RTOR restriction.

Pedestrian Serious or Fatal Crashes in CT since 2015		
	Total	**Existing NTOR**
All Right Turn Signal Crashes	14	8
Crashes on Green Phase	5	2
Crashes on Red Phase	4	2
Crashes on Unknown Phase	5	4

Table 2: Right Turn Fatal & Serious Injury Crashes at Signals from Jan 1, 2015 to Aug 31, 2023

The analysis of Connecticut crash data shows that right turn crashes make up a small portion of overall pedestrian crashes, especially the fatal and serious injury crashes. The literature review below suggests the same trend occurs in other jurisdictions, where fatal and serious injury pedestrian-vehicle and vehicle-vehicle crashes are generally rare for right turns at signals, particularly serious red phase crash types. The data also suggests that compliance and enforcement of existing NTOR is important to preventing crashes, since crashes are occurring in locations with existing RTOR restrictions.

CTDOT TRAFFIC GUIDELINES

CTDOT's internal traffic guidelines list factors that should be considered when determining whether RTOR should be prohibited at an intersection on a state road. Similar to many jurisdictions across the country, including other states, counties, and cities, each intersection is considered individually and NTOR criteria are provided as guidelines rather than strict standards. The conditions for establishing NTOR in the CTDOT Traffic Guidelines include:

- Proximity to railroad tracks
- Pedestrian volume, especially near school crossings or locations with many children, elderly, or people with disabilities
- Sight distance restrictions
- Intersection geometries or phasing that could lead to unexpected conflicts
- Crash history

Currently, implementing NTOR at an existing signalized intersection on a state road typically begins with a request from a municipality's Local Traffic Authority (LTA), who has first-hand local experience with the pedestrian activity in that municipality. Upon receipt of an NTOR restriction request, the CTDOT Traffic Division conducts an engineering study, including the factors listed above. An operational analysis is also performed for the intersection, using traffic flow modeling software, such as Synchro, to see the effects of restricting RTOR on delay and the potential collateral impacts on safety, like extended queues. The results of the engineering study are shared with LTA prior to deciding about NTOR at the intersection.

For new or substantially revised signalized intersections, CTDOT's internal design process includes an evaluation of site conditions as they relate to NTOR. Findings of these analyses are shared with the LTA for concurrence.

CT MUNICIPALITY NTOR IMPLEMENTATION REQUEST

If a municipality would like to implement NTOR at an intersection approach, on either a state or local road, the LTA must first make a request to CTDOT. The

process for a state road intersection request was discussed above and involves the CTDOT Traffic Division. For a local road, the LTA makes a request to the Office of State Traffic Administration (OSTA) who reviews the request. The LTA must justify the NTOR implementation based on guidance from the Manual on Uniform Traffic Control Devices (MUTCD) and submit an updated signal plan with the NTOR sign placement. OSTA typically approves these requests as long as the required justification is included.

The process for CTDOT regulatory requests, such as NTOR implementation at state and local intersections, are covered in the new mandatory LTA training administered by the UConn Training and Technical Assistance Center.

Connecticut Cities and NTOR

CTDOT reached out to several municipalities who own and operate their own traffic signals regarding NTOR policies on city and town roads. The City of Norwalk considers pedestrian volumes, traffic volumes, and intersection geometry to determine where to implement NTOR. The City of Stamford does not have an explicit NTOR policy but does evaluate intersections for RTOR restrictions, particularly in the downtown area at intersections with high pedestrian volume. Sightline issues and the potential for pedestrian conflicts are the two main reasons that NTOR is considered for an intersection in Stamford. Before NTOR is implemented at an intersection, an analysis is done on the impact to operation and capacity.

The Town of Manchester also uses engineering judgement and evaluates each intersection on a case-by-case basis for implementing NTOR. Factors like sightlines,

intersection geometry, signal phasing, and pedestrian and school crossing considerations all factor into whether RTOR will be prohibited. NTOR evaluations by the Town often begin with a request or complaint. The Town is judicious in their use of RTOR restrictions because implementing NTOR can be unpopular with drivers and compliance can be an issue.

Use Of Dynamic RTOR Signs by Towns in Connecticut

The municipalities contacted for this study have all utilized dynamic LED RTOR signs at one or more local intersections (**Figure 3**). These can be "blank out" signs which show no message until a pedestrian activates the crosswalk signal, at which time a NTOR message is displayed. These signs can also be at intersections with complex phasing to prevent vehicle conflicts. The sign message can be conditional and change depending on the pedestrian phase, displaying either a NTOR message or another message like "turning vehicles yield to pedestrians".

Figure 3: A Dynamic RTOR Message Sign in Manchester

CTDOT does not currently have wide-spread adoption of dynamic signs for RTOR messages so the municipalities' feedback was appreciated. Of the municipalities contacted, Norwalk and Stamford have installed the greatest number of dynamic signs. These cities report that locations which are transitioning to concurrent pedestrian phasing or have high pedestrian volume (mostly in downtown areas) are being prioritized for dynamic RTOR message signs. The municipalities generally report a positive response from residents and businesses. They have observed a

reduction in crashes at intersections where dynamic signs were installed while also seeing minimal increases in motor vehicles delays.

Implementing Dynamic NTOR on State Roads

As municipalities in Connecticut have expanded their use of dynamic message signs at local intersections, CTDOT plans to install more dynamic signs on state road signals as part of the Complete Streets Directive. The dynamic RTOR message sign is one of several emerging technologies that can provide an increased measure of safety for vulnerable road users. As discussed above, the signs can prohibit RTOR movements while pedestrians are in a conflicting crosswalk phase of a signalized intersection, while simultaneously maximizing vehicular efficiency and avoiding secondary safety concerns when a pedestrian conflict risk is not present.

For state roads, it is currently estimated that CTDOT can install dynamic message signs at approximately 80 locations per year as part of District and Computerized Traffic Signal System replacement projects. The total number of installations is anticipated to be higher with the inclusion of traffic signal upgrades in other CTDOT projects, such as highway and bridge projects. A systemic analysis of signalized intersections can be used to prioritize intersections for the installation of dynamic signs.

Dynamic message signs will be installed:

- For approaches where permissive right turns are currently allowed that will cross a marked crosswalk.
- Not in locations where RTOR is always prohibited. In those locations, a static sign will continue to be used.

The operation of the signs and the messages they display will depend on the type of pedestrian phasing at each intersection, such as exclusive, concurrent, and leading pedestrian interval phasing, with guidelines currently being developed.

Enforcement of NTOR

Enforcement of NTOR in Connecticut falls to police departments. Usually, complaints about RTOR behavior trigger a police presence near a particular intersection. In Connecticut, police can cite drivers for a violation of state statute 14-299 if they make a prohibited RTOR movement. Unfortunately, this statute covers multiple violation types so unless the violation came as a result of a recorded crash, it is difficult to know how many citations are given out each year in Connecticut specifically for violating NTOR.

In some jurisdictions outside Connecticut, enforcement cameras are used. However, due to the low compliance with NTOR during off-peak times and at locations with good sight lines, the use of these cameras to enforce strict NTOR rules has been sometimes criticized as more about revenue generation than safety. Agencies have tried to address these concerns in a variety of ways, including through public information campaigns, transparency, and stakeholder buy-in. In Wilmington, Delaware automatic enforcement parameters were relaxed, for example rolling RTOR movements were no longer fined if RTOR were permitted at an intersection.

LITERATURE REVIEW

CTDOT reviewed the studies and resources in the references of this report to determine the benefits and disadvantages seen with implementing NTOR as well the approaches taken to restrict RTOR movements in other jurisdictions.

Benefits of Right Turn on Red Restrictions and No Turn on Red Movements

Restricting RTOR movements at signalized intersections typically has a positive outcome for crashes, reducing crashes associated with right turn maneuvers, particularly those involving pedestrians and cyclists. The Crash Modification Factor (CMF) Clearinghouse is a database of studies which examine the effect of implementing countermeasures on crash rate and it references several studies regarding RTOR movements (see Appendix). According to studies in the CMF Clearinghouse, at locations with high pedestrian and cyclist volume, restricting RTOR can decrease right turn crashes involving pedestrians and cyclists by 50% or more. Apart from the safety benefits, NTOR could also help pedestrians feel more comfortable crossing the street if they feel confident that drivers will comply with RTOR restrictions. The effect of introducing NTOR on vehicle crashes is less profound but still generally results in fewer right turn crashes.

The positive effect of NTOR on crashes has caveats. Right turn crashes make up a small proportion of total intersection or system crashes, so that the effect of implementing NTOR on vehicle-vehicle crashes is sometimes statistically insignificant. Also, these crashes typically occur at slower speeds and are less severe than other crash types, as seen in the Connecticut crash data. Also, due to

the infrequency of right turn crashes, it is difficult to quantify if NTOR leads to any more crashes during right turn on green movements.

Further, the reduction in pedestrian and bicycle involved crashes due to RTOR restrictions is highly dependent on the location. In areas with little existing pedestrian or bicycle volume, there is much less crash reduction benefit. Similar to vehicle-vehicle crashes, pedestrian and cyclist involved RTOR crashes make up a small number of the total pedestrian and cyclist crashes at intersections and are generally less severe than other types of crashes.

Disadvantages of Right Turn on Red Restrictions

The biggest disadvantage of RTOR restrictions is the impact on vehicular traffic operations. Depending on the intersection geometry, turning volumes, and conflicting volumes, implementing NTOR can have a severe impact on intersection delay and queue lengths, increasing driver frustration and encouraging more aggressive and risky driving behaviors. The resulting extended queue lengths and increase in right turn on green movements, which occur at faster speeds than NTOR movements, can also result in secondary safety risks that should be evaluated. Implementing NTOR at an intersection may necessitate the addition of an exclusive right turn lane to maintain operations, which extends the crossing distance for pedestrians. Before NTOR can be implemented, it is also likely that signal timings and detection will have to be updated, particularly if there is an exclusive right turn lane. For these reasons, an operational analysis of an intersection should occur before RTOR restrictions are applied.

Further disadvantages of RTOR restrictions can include increased fuel consumption and emissions as well as a reduced compliance of the regulatory NTOR restriction, creating expectancy issues that could result in safety concerns for pedestrians and cyclists. These impacts of NTOR have not been studied in detail recently, possibly because studies on safety, fuel consumption, and other intersection performance measures typically look at optimizing all turning movements, not just specifically right turns. To help fill this gap in the literature, some traffic signal simulations and case studies from Connecticut are included in this report in the Operational Impact section below.

Intersection Factors That Impact NTOR/RTOR Effectiveness

The safety impact of implementing NTOR is highly dependent on the local pedestrian and cyclist volume. Allowing RTOR impacts pedestrian and cyclist crashes the most since drivers making a right turn generally look for conflicting vehicle movements rather than other road users. Intersections with significant pedestrian volume can see a decrease in pedestrian-vehicle conflicts with NTOR. However, since RTOR crashes are such a small proportion of intersection crashes, if there are few pedestrians crossing the intersection, the benefits of NTOR greatly diminish.

Intersection geometry has an impact on the effectiveness of RTOR policies. Intersections with limited sight distance due to horizontal or vertical curves, angled approaches, or other obstructions, could benefit from implementing NTOR. Sight distance measurements, crash history, and local observations as part of an engineering study can determine if NTOR would be appropriate. The characteristics

of each intersection approach effect the impact of NTOR. For example, NTOR may be beneficial in locations with a long pedestrian crossing distance as pedestrians spend more time in the vehicle path. Also, if the approaches do not include an exclusive right turn lane or wide shoulders then benefits of allowing RTOR diminish. This is because vehicles turning right would share a lane with vehicles making other movements and could get “stuck” behind a vehicle waiting to go straight through or make a left turn. The storage length of an exclusive right turn lane is also a factor. Intersections with shorter right turn storage lengths benefit more from allowing RTOR as otherwise right turning vehicles would have a larger effect on the delay of other turning movements. Intersections with unobstructed approaches at nearly right angles and with room for vehicles to make exclusive right turning maneuvers would benefit the least from RTOR restrictions and have the highest operational impact if NTOR was implemented.

The impact of NTOR on operations is also dependent on the conflicting vehicle movements. Drivers looking to make a RTOR need to wait for a gap in the flow of conflicting vehicles. Therefore, the signal phasing and the turning volumes all impact how much delay NTOR introduces into an intersection or corridor. At some intersections, allowing RTOR can have a profound positive effect on capacity, at others it may be less pronounced if conflicting traffic and signal timing does not allow for frequent gaps to make a RTOR maneuver.

A jurisdiction with a well-known and long standing NTOR restriction is New York City. The law prohibiting right turns on red throughout New York City, recognizes the site-specific nature of such a restriction, exempting 336 locations in the City. The intersections where turning on red is permitted has been done methodically

with engineering studies and has been reported to have resulted in no significant increases in crashes at the newly permitted intersections. This reinforces that the impact of RTOR restrictions is highly dependent on individual intersection characteristics.

[1]There Are Hundreds of NYC Streets That Allow Rights on Red (ny1.com)

No Turn on Red Compliance

While they are limited, studies indicate that compliance with NTOR policies depends on the conflicting vehicle and pedestrian movements, so compliance can vary widely. The more safe or comfortable a driver feels making a RTOR at an intersection, the more likely they are to violate a RTOR restriction. Compliance with RTOR restrictions also increases with better signing and with dynamic LED signs. Enforcement camera data from Wilmington, Delaware shows generally low compliance with NTOR in situations where there are few conflicting vehicles and that these illegal maneuvers result in very few crashes. Speed camera enforcement is discussed in more detail earlier in this report.

National NTOR Policies Findings

In the absence of a single national NTOR policy, the MUTCD, Highway Capacity Manual (HCM) and other guidance documents provide some criteria for implementation of NTOR. As an example, the MUTCD criteria is discussed below.

Like other national guidelines, the 11th edition of the MUTCD offers guidance but no mandatory conditions for prohibiting RTOR. Section 2B.60 states that NTOR should be considered when one of the following conditions exist:

- Sight distance issues
- Geometries or phasing/timing that might result in unexpected conflicts for motorists
- The use of exclusive pedestrian or bicycle phase
- Unacceptable number of pedestrian conflicts with RTOR maneuvers, especially involving children, older people, or people with disabilities
- More than three RTOR crashes reported in a 12-month period for a particular approach
- Approach angles that impact visibility of conflicting traffic.

Guidance documents from the National Association of City Transportation Officials (NACTO) include implementing NTOR where they provide a safety benefit. For example, NACTO's Urban Steet Design Guide and Transit Street Design Guide include NTOR restrictions as one of many possible safety measures for vulnerable road users. Other measures include shortening crossing distances, traffic calming, phasing adjustments, protecting bike paths, and dedicated bus stop facilities.

Outside of Connecticut, other states and cities have a patchwork of RTOR policies. Common elements of these policies are consideration of the factors discussed above and the flexibility to evaluate each intersection individually. According to an Institute of Transportation Engineer (ITE) survey of traffic engineers across the country, the most likely factors to trigger an automatic RTOR prohibition are proximity to school crossings, intersection geometry and phasing characteristics, political direction, and wider policy goals like Vision Zero and establishing bike corridors.

All states allow RTOR as a default but usually provide that NTOR can be implemented where necessary. Some states impose RTOR restrictions at limited locations. For example, Washington is considering banning RTOR within 1,000 feet of facilities considered to have large pedestrian volumes. New York prohibits RTOR in cities with more than 1 million residents, unless otherwise signed. These types of statewide restrictions are uncommon, however, and specific RTOR policies are generally left to the judgment of traffic engineers. State DOTs generally develop their own in-house guidelines for where RTOR restrictions should be considered. These guidelines usually consider the factors mentioned above. They may be more specific than the MUTCD criteria but generally consider each intersection on a case-by-case basis.

Cities are much more likely than states to have statutes that specifically prohibit RTOR. City traffic policies are also more specific and restrictive regarding RTOR than state policies. Some cities, such as Raleigh and Boston have designated all intersections within specific blocks as RTOR prohibited, such as in downtown areas. The cities of Washington D.C., Baltimore, and Seattle are working to severely limit RTOR throughout the city extents, to reduce vehicle-pedestrian conflicts. However, similar to New York City, RTOR is still allowed at specific intersections in these cities and the RTOR allowances are handled on a case-by-case basis. Many jurisdictions have had success with part-time NTOR at intersections, for example when schools are in session.

OPERATIONAL IMPACTS IN THE STATE

While the safety impacts and crash history regarding right turns was discussed above, the operational impact of prohibiting RTOR can be harder to quantify since it can vary greatly by intersection. To demonstrate this, traffic modeling simulations with and without NTOR were run on five locations within Connecticut covering 18 intersections. These intersections showed the varied cost that implementing NTOR can have. Further, two case studies of NTOR implementation requests are discussed to demonstrate the importance of operational analysis prior to prohibiting RTOR at intersections.

Operational Analysis

18 intersections at 5 locations in Connecticut were simulated using software for NTOR implementation (See Appendix for full results). These locations were chosen as they were part of recent Major Traffic Generator (MTG) analysis so turning movement counts and traffic conditions had been previously verified for the simulation. **Table 3** shows the impact of implementing NTOR at 6 intersections on one example corridor.

Route 81 Clinton NTOR Operational Analysis										
Intersection		**Delay (Sec)**				**Fuel Used (Gal/Hr)**			**Sum of Queue Lengths (ft)**		
		Exist.	NTOR	% Change		Exist.	NTOR	% Change	Exist.	NTOR	% Change
Clinton Crossing Driveway		6.5	10.4	60%		11	13	18%	362	494	36%
Library Driveway		3	4.7	57%		7	8	14%	173	257	49%
Clinton Crossing Exit		16.9	21.7	28%		17	21	24%	694	1051	51%
I-95 SB Ramps		12.8	14.2	11%		16	17	6%	547	761	39%
Glenwood Road		15.3	16.5	8%		15	16	7%	728	841	16%
I-95 NB On Ramp/N High St		18	18.2	1%		6	6	0%	236	236	0%

Table 3: Example Synchro Traffic Simulation Software Results with and without NTOR

The simulation showed that the operational and emissions impact of implementing NTOR varies widely between intersections, even those in the same corridor. This is one reason why prohibiting RTOR has traditionally been done on a case-by-case basis, since the impacts can vary widely. These impacts include time delays, and cost to residents and the environment in additional fuel consumption. To accommodate the longer queues associated with NTOR, intersection geometry, timing, and detection may have to be updated, so operational analysis is crucial prior to NTOR implementation.

CASE STUDIES

Two case studies of NTOR requests in Connecticut are presented here to demonstrate the importance of studying operational impacts prior to prohibiting RTOR at intersections.

In 2009, there was a town request for implementing NTOR on Route 160 (New Britain Avenue) eastbound approach to Route 3 in Rocky Hill. Residents had concerns about pedestrian safety at the intersection which had an exclusive pedestrian walk phase but allowed vehicles to still turn right on red. Operational analysis indicated that implementing NTOR on that approach could significantly affect the right turn delays and queues, blocking commercial driveways (Traffic Investigation Report 118-0910-02). NTOR was implemented as the town wanted to prohibit RTOR for the safety concerns regardless of the potential for backups. After a NTOR sign was installed at that approach, large queues did occur, and the State Legislators for Rocky Hill requested that RTOR be permitted again. Because of the

nature of the initial NTOR request, Legislators had to be involved in the removal of the restriction, which occurred in 2011. A full-time blanket ban on all right turns on that approach was not a viable long-term solution. Had this request been made today, implementing dynamic NTOR signs, concurrent pedestrian phasing, and/or leading pedestrian interval at the intersection may have been suggestions to improve safety while minimizing traffic impacts.

The second case study involves a more recent request for NTOR implementation on Main Street, Glastonbury to Route 17. This request was part of an encroachment permit to install a crosswalk and other pedestrian facilities at the intersection. Operational analysis showed that NTOR on Main Street would cause significant delays, which were unacceptable to the town. The solution was to instead install a dynamic NTOR message sign that would activate with the pedestrian phase. Installation was completed in 2023. The dynamic message sign allowed for both safety and operational needs to be met. The operational analysis was valuable in this case as it identified the issues with a complete RTOR ban at the intersection, which would have been costly to remove after installation.

The case studies and traffic simulations demonstrate the important role that operational analysis plays in determining the best RTOR treatments at each intersection. Studying intersections on a case-by-case basis remains an important part of maintaining safety and operations at intersections with regard to NTOR. Blanket RTOR bans without operational considerations have an associated time and fuel cost and can create public pushback and other unforeseen consequences.

Findings

Prohibiting RTOR movements systematically has a small impact on both average total crashes and operational delay for the overall system. However, the impacts of implementing NTOR on a particular intersection varies widely depending on local factors so few if no jurisdictions impose a universal ban or allowance of ROTR. The jurisdictions that were examined generally allow RTOR unless there is specific reason to prohibit it at a particular intersection. Even places that ban ROTR in most locations, like New York City, exempt particular intersections and allow RTOR. This is because, depending on the intersection, prohibiting RTOR may not reduce fatal and serious crashes but could have a significant operational impact. Without strong research or national guidelines in place regarding the impact of NTOR, in most places, implementing NTOR is often a policy decision. Jurisdictions determine their own NTOR guidance based on local or individual intersection characteristics, or they implement NTOR in reaction to complaints or crashes at a particular location.

The crash patterns and operational concerns seen in the literature review were reflected in the data and case studies from Connecticut. It seems a case-by-case approach to implementing NTOR, including a safety and operational analysis, is still the best method for Connecticut. However, NTOR remains an important safety countermeasure at particular intersections and neighborhoods and local knowledge is invaluable when implementing NTOR. Dynamic right turn message signs could offer further safety and operational benefits and are being positively received in Connecticut and around the country.

RECOMMENDATIONS

For the reasons outlined above, a blanket ban of ROTR is not recommended. Crash reductions, particularly for serious injury and fatal crashes, from a systemic ROTR prohibition would be small compared to overall crashes. The operational impacts of universal full-time NTOR, and the resulting secondary safety concerns, at some intersections could be substantial with significant increased delay and fuel consumption. With input from local municipal partners, CTDOT should retain the ability to implement NTOR at particular intersections. Individual intersection characteristics, such as pedestrian volume, proximity to schools or care facilities, geometry, and phasing should be used to determine whether NTOR should be implemented at specific locations.

That said, there are steps that are currently being taken and could be taken in the future to address concerns about crashes involving right turn movements at signalized intersections.

It is recommended that CTDOT advance the following action items:

- Conduct a systemic analysis of signalized intersections to determine if restricting right turns on red at specific intersections, either through static or dynamic signage, would be appropriate based on local conditions. A variety of tools can be used to accomplish this including GIS analysis of the intersections' proximity to areas with vulnerable road users, zero-car households, multi-use trails, etc. There is a current CTDOT NTOR planning study, project number 0170-3696, that has begun to look at right turn pedestrian crash patterns, which provided the crash analysis for this report.

- Incorporate dynamic NTOR/Yield to Pedestrian message signs at signalized intersections on State roads as part of CTDOT's Complete Streets Directive. This will be done as part of signal upgrade, highway, and other projects, as well as through encroachment permits. This effort is already underway and is described in further detail earlier in this report.
- Encourage municipalities to expand the use of dynamic right turn signing on local intersections, including in LOTCIP and LRSP (previously LRARP) projects.
- Enhance CTDOT's internal Traffic Guidelines section on NTOR to include a greater emphasis on vulnerable road user safety and provide detail on the use of dynamic turn restriction signs.
- Consider allowing red-light safety cameras to enforce RTOR restrictions.
- Conduct an education campaign to reinforce RTOR AFTER stop

REFERENCES

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APPENDIX

Crash Modification Factors

https://www.cmfclearinghouse.org/index.php

CMF ID	Countermeasure	CMF	CRF	Crash Type	KABCO Crash Severity
376	Permit RTOR	1.6	-60	Right turn only	A, B, C
377	Permit RTOR	1.1	-10	Right turn only	PDO
5194	Prohibit RTOR	0.98^n	100 X $(1- 0.98^n)$	All crashes except bike/ped	All

n = number of NTOR approaches

Full Operational Analysis Results

Synchro traffic simulation of 18 intersections at 5 locations

Route 81 Clinton (Evening Peak)										
Intersection	**Delay (Sec)**			**Fuel Used (Gal/Hr)**			**Sum of Queue Lengths (ft)**			
	Exist.	NTOR	% Change	Exist.	NTOR	% Change	Exist.	NTOR	% Change	
Clinton Crossing Driveway	6.5	10.4	60%	11	13	18%	362	494	36%	
Library Driveway	3	4.7	57%	7	8	14%	173	257	49%	
Clinton Crossing Exit	16.9	21.7	28%	17	21	24%	694	1051	51%	
I-95 SB Ramps	12.8	14.2	11%	16	17	6%	547	761	39%	
Glenwood Road	15.3	16.5	8%	15	16	7%	728	841	16%	
I-95 NB On Ramp/N High St	18	18.2	1%	6	6	0%	236	236	0%	

Cheshire Route 10 (Morning Peak)										
Intersection	**Delay (Sec)**			**Fuel Used (Gal/Hr)**			**Sum of Queue Lengths (ft)**			
	Exist.	NTOR	% Change	Exist.	NTOR	% Change	Exist.	NTOR	% Change	
Johnson Ave	13.3	16.4	23%	13	15	15%	488	631	29%	
I-691 EB Ramps	23.8	28.2	18%	29	34	17%	1081	1255	16%	
I-691 WB Ramps	21.1	51.6	145%	44	61	39%	1246	1529	23%	
Park & Ride Driveway	28.6	33.4	17%	53	56	6%	1382	1542	12%	

Norwalk Route 1 (Saturday Peak)										
Intersection	**Delay (Sec)**			**Fuel Used (Gal/Hr)**			**Sum of Queue Lengths (ft)**			
	Exist.	NTOR	% Change	Exist.	NTOR	% Change	Exist.	NTOR	% Change	
Costco Driveway	18.3	20.6	13%	34	36	6%	1055	1176	11%	
Richards Ave	31.5	36	14%	46	51	11%	2135	2431	14%	
Walmart & Urgent Care Driveway	13.3	14.4	8%	22	28	27%	644	729	13%	
Walmart & Liquidators Driveway	28.2	33.3	18%	48	56	17%	1133	1266	12%	
Keeler Ave	12.7	13	2%	29	29	0%	908	924	2%	

Vernon Route 30 (Evening Peak)										
Intersection	**Delay (Sec)**			**Fuel Used (Gal/Hr)**			**Sum of Queue Lengths (ft)**			
	Exist.	NTOR	% Change	Exist.	NTOR	% Change	Exist.	NTOR	% Change	
Dobson Rd	19.2	25.7	34%	26	32	23%	997	1407	41%	

Fairfield Route 130 (Evening Peak)										
Intersection	**Delay (Sec)**			**Fuel Used (Gal/Hr)**			**Sum of Queue Lengths (ft)**			
	Exist.	NTOR	% Change	Exist.	NTOR	% Change	Exist.	NTOR	% Change	
Grasmere Ave	16.8	18.3	9%	13	14	8%	675	726	8%	
Riverside Dr	21.8	23.7	9%	17	18	6%	663	713	8%	

Abbreviations

CTDOT – The Connecticut Department of Transportation

LOTCIP – Local Transportation Capital Improvement Program. A State-funded program providing funds to eligible municipalities for transportation infrastructure improvements.

LRSP – Local Road Safety Program. A federally funded program that provides funds to municipalities for safety related projects on local roads, formerly named the Local Road Accident Reduction Program (LRARP)

LTA – Local Traffic Authority. By State law, each municipality has a designated LTA who is typically an elected official, a member of Police Department, or an administrator or manager in the municipality.

MUTCD – Manual on Uniform Traffic Control Devices. Published by the Federal Highway Administration, the MUTCD establishes national criteria for the use of signs, signals, pavement markings, and other traffic control devices.

NTOR – No Turn on Red. A static or dynamic sign on an intersection approach indicates to motorists that right turns are restricted to the green signal phase only.

RTOR – Right Turn on Red. In Connecticut, right turns after stopping are allowed on the red phase of a signal, as long as there is not a posted restriction.

Definitions

Exclusive Pedestrian Phasing: A type of signal phasing where all vehicle approaches have a red during the pedestrian walk (walking person symbol) and clearance (upraised hand) signal phases. In this phasing, pedestrian and vehicle conflicts can be minimized at the cost of pedestrian and vehicle delay.

Concurrent Pedestrian Phasing: A type of signal phasing where the vehicle approaches parallel to a crosswalk have a green during pedestrian phase. With this phasing, turning vehicles yield to pedestrians in the crosswalk. This type of phasing reduces pedestrian and vehicle delay.

Leading Pedestrian Interval: A type of signal phase where the pedestrian walk phase begins before a concurrent vehicle green phase. This means that when the vehicle green phase begins, pedestrians are already walking and visible in the crosswalk, which has been shown to reduce pedestrian crashes.

Dynamic Right Turn Signs: Variable message signs at traffic signals that indicate which right turn movements are allowed. Example messages include “No turn on Red,” and “Yield to Pedestrians,” or the signs can be blank and unilluminated when no message is required. Sometimes referred to as “blank-out” signs.

Synchro: A vehicle traffic modeling software that allows for simulations of intersections with a variety of control types. This software is used in traffic design and planning to model different signal timings, intersection geometries, and control types to determine the effects on intersection operation.