TECHBRIEF

U.S. Department of Transportation
Federal Highway Administration

Turner-Fairbank
Highway Research Center

Research, Development,
and Technology
Turner-Fairbank Highway
Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

https://highways.dot.gov/research

Field Evaluation of At-Grade Alternative Intersection Designs, Volume I—Operations Report

FHWA Publication No.: FHWA-HRT-24-125

FHWA Contact: Wei Zhang (ORCID: 0000-0002-5175-7527), HRSO-10, (202) 493-3317, wei.zhang@dot.gov

This document is a technical summary of the Federal Highway Administration report *Field Evaluation of At-Grade Alterative Intersection Designs, Volume I—Operations Report* (FHWA-HRT-24-126).

INTRODUCTION

In their simplest forms, intersections are locations where two or more roads cross, creating a shared conflict point for road users. Therefore, the intersection is a critical roadway element at which it is essential to facilitate smooth and safe traffic flow. Whenever traffic volume levels increase on one or both intersecting roadways, there may be a point when the road cannot accommodate the increasing traffic density due to unique site characteristics such as increased left-turn traffic or safety concerns. When one or more issues occur, the agency maintaining the intersection may ultimately consider implementing a unique alternative or innovative intersection.

In the last decade, transportation agencies have faced increasingly congested traditional intersections and have sought innovative geometric solutions. One solution uses indirect movements to improve capacity and safety for the entire intersection. These alternative intersections create strategic micronetworks around the central intersection to potentially orchestrate traffic movements more efficiently while also reducing and dispersing conflict points for potential safety benefits. At some signalized locations, these changes often accommodate fewer traffic signal phases, resulting in less system delay.

Currently, the number of alternative intersections in the United States is limited. One of the most widely constructed alternative configurations is an adaptation that features median U-turn (MUT) intersections to facilitate indirect left-turn movements.(1) These intersections are generally referred to as reduced conflict intersections or reduced left-turn conflict intersections (RLTCI). MUT and restricted crossing U-turn (RCUT) designs are the most common types of reduced conflict intersections.(2) The Federal Highway Administration's (FHWA's) proven safety countermeasures featured these designs as RLTCI.(3) Other alternative intersections include displaced left-turn (DLT) designs and quadrant roadway intersections.(4,5)

STUDY OBJECTIVE

Traffic professionals need to consistently evaluate all alternative intersection configurations and document intersection operational benefits. This information is vital to roadway designers who need to make informed decisions on whether to select a traditional or alternative intersection design and potentially choose among competing alternative intersection designs. The relatively limited number of alternative intersection forms means that the geometrics of each alternative intersection are evolving with every new intersection constructed. Knowing what works and what does not work from past designs will help roadway designers improve future designs.

Therefore, this study's objective was to identify and assess proposed alternative intersection installations and their operational performance before construction was started (before period) and contrast traffic operations to conditions following the completion of construction (after period). For the purposes of this study, before was defined as a candidate location that did not exhibit any sign of the upcoming construction (i.e., barrels, work zone signs, etc.). This information can then be used to assess the performance of various alternative intersection features.

SITE IDENTIFICATION

The research team identified potential alternative intersection study sites based on feedback from regional and national transportation agencies. In addition, the research team worked with FHWA to establish the following criteria for the selected sites:

- No sign of construction evident at the site (includes construction signs, barrels, or companion utility work).
- Data collection on weekdays at times when no special events are occurring.
- Support by the stakeholder agencies.
- Construction schedule to begin shortly after the completion of the preliminary before data collection and end at least 2 yr before the proposed after data collection. The research team did not have direct control of this final criteria, and ultimately three Texas sites did not complete construction by the conclusion of this study. These sites are designated as future RCUTs.

The study included the following locations and intersection types:

- Tucson, AZ:
    - Grant Road East at First Avenue North—MUT.
    - Grant Road West at Oracle Road North—MUT.
    - Grant Road (transition from East to West) at Stone Avenue North—MUT.
    - Valencia Road East at Kolb Road South—Signalized hybrid with quadrant and MUTs.
- Ham Lake, MN:
    - MN–65 at 157th Avenue Northeast at signalized RCUT.
    - MN–65 at 181st Avenue Northeast RCUT.
- East Bethel, MN:
    - MN–65 at 187th Lane Northeast—Unsignalized RCUT.
    - MN–65 at 209th Avenue Northeast—Traditional two-way, stop-controlled intersection (included as a comparison site).
    - MN–65 at Viking Boulevard Northeast Signalized RCUT.
- College Station, TX:
    - FM–2818 at George Bush Drive West—Future RCUT.
    - FM–2818 at Luther Street West—Future RCUT.
    - FM–2818 at Holleman Drive South—Future RCUT.
- San Antonio, TX: SH–16 (Bandera Road) at Loop 1604 Access Road West—Signalized DLT interchange.
- Norfolk, VA: Military Highway at Northampton Boulevard (U.S. 13 at SR–165)—Signalized intersection with DLT on north and south approaches.
- Virginia Beach, VA: Indian River Road at Kempsville Road—Signalized hybrid intersection (DLT on two approaches and MUT on two approaches).

Figure 1 shows the start of the DLT in Virginia on Military Highway at the approach to Northampton Boulevard.

DATA COLLECTION

The research team compiled information for the before and after periods about physical site characteristics to use for general roadway analysis (table 1) and targeted operation analysis (table 2).

Figure 1. Photo. Entrance to the DLT (left two lanes).

Source: FHWA.

Table 1. Physical site information for general analysis.

Data Measure	Data Collection Method
Intersection geometry (e.g., angle of intersection, distance to nearby intersections)	Aerial photos and site inspection
Cross-sectional geometry (e.g., number, width, configuration of lanes)	Aerial photos or transportation agencies' databases
Horizontal geometry (e.g., left-turn lane length, spacing between movements)	Aerial photos or plan or profile sheets
Traffic control devices (e.g., signs, signals, markings), including posted speed limit	Aerial photos, Google® Street View™, or site inspection[6]
Roadside development, including pedestrian and bicycle accommodations and driveways	Google Street View or site inspection[6]

Table 2. Physical site information for operational analysis.

Data Measure	Data Collection Method
Travel time (preselected origin-destination pairs), also useful for evaluating delay	Driving test vehicle (recording start and end time or recording second-by-second position)
Queue length	Video, onsite visual data collection supplemented with video review
U-turning vehicles or other operations that could affect the data measures	Video
Pedestrian path trips through the intersection (at locations with full development and pedestrians present)	Field-walking studies

ANALYSIS APPROACH

The research team conducted an operational analysis to determine if implementing an alternative intersection positively or negatively impacted various observed metrics. Where applicable, this evaluation focused on traffic volumes, vehicle queues, travel times, and pedestrian walking paths.

Traffic Volumes

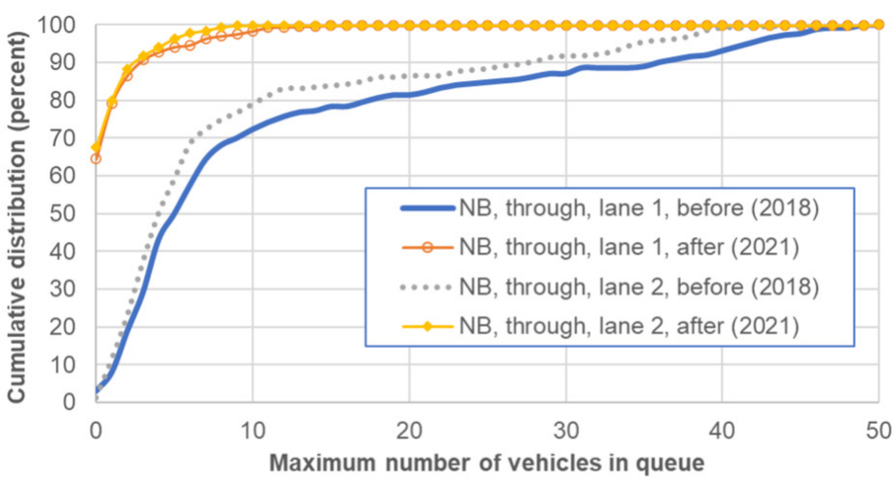
To acquire the traffic volume data, the research team mounted cameras at each study site along various approaches of the intersection. Depending on the configuration of each intersection and the height of the cameras, data were collected from 8 to 22 cameras. The cameras recorded field volume data for more than 12 h to cover both the a.m. peak period and p.m. peak period. The team's goal was to summarize the traffic volume for the period from 7:00 a.m. to 7:00 p.m. at each site. After obtaining the data, the research team counted individual vehicles, recorded the reduced data based on the specific time observed, and eventually aggregated the data to 15-min intervals.

Vehicle Queues

The research team used the recorded video data to measure the queue length for each lane for various movements at the study intersections. The team measured two types of queues:

- For unsignalized intersections, per-minute queues: The team counted the maximum number of vehicles in the queue per lane and per movement for each 1-min interval in the a.m. peak and p.m. peak periods.
- For signalized intersections, cycle queues: The team counted the maximum queue for each signal cycle for each lane of each movement. Documenting the maximum number of vehicles in the queues for each signal cycle for the 12-h study period allows the generation of cumulative distribution curves. These curves can be used to identify the percentage of the observations that reflect that length of queue (in number of vehicles) or fewer. The curves can be compared between the before period and the after period (example in figure 2). The team anticipates that long queues will be less likely in the after period compared to the before period, and that installing the alternative intersection design will result in shorter queues. The advantage of having data for a 12-h period, compared to only having data for the peak hour, is that this approach captures situations when long queues exist for more than just a single hour.

Figure 2. Graph. Distribution of maximum queue length for MN–65 at Viking Boulevard NE northbound through (major road) by period and lane.



Source: FHWA.

The research team evaluated the before and after configuration for the study sites, where the before condition typically included traditional intersections and the after condition represented alternative intersection configurations. Figure 3 shows an example of the plan view layout of the after configuration for the northbound movements for MN–65 at Viking Boulevard NE.

Travel Times

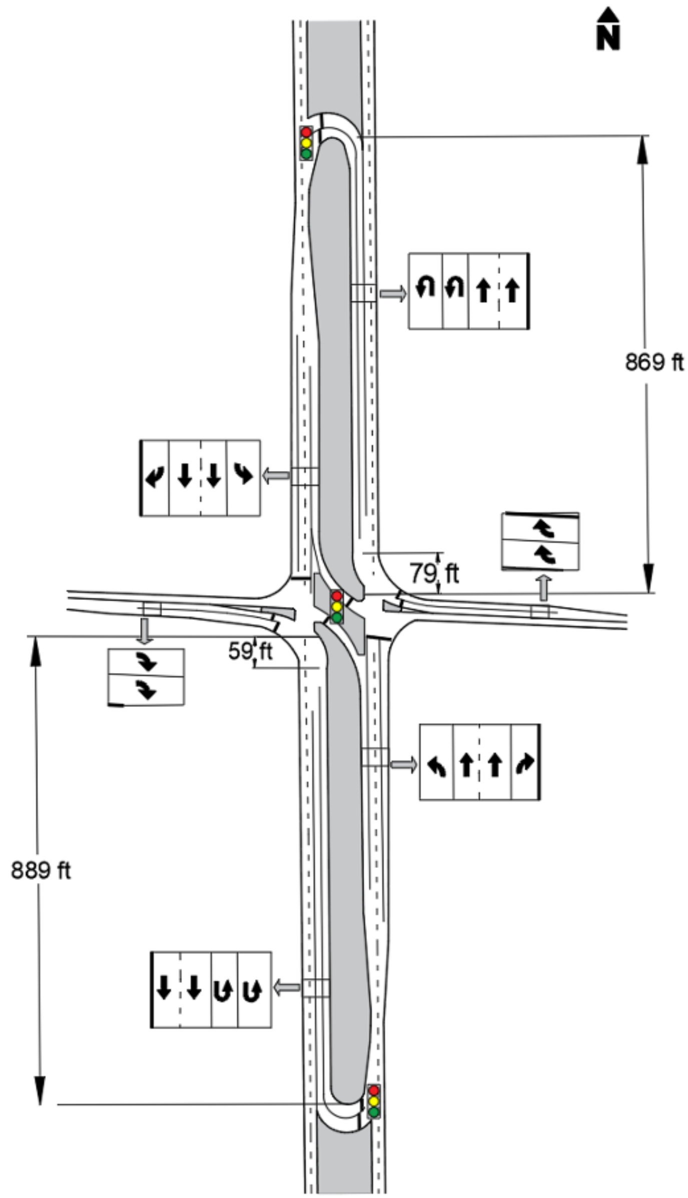
To assess the travel time performance of the intersection, the research team conducted field-measured, travel-time studies with a primary focus on the through and left-turn maneuvers for locations with modified left-turn operations. To collect the travel-time data, the research team used the floating car method, along with a Global Positioning System unit. The floating car method is when one team member drives a vehicle and the other team member marks the predefined start point and end point.

In many cases, the study sites included substantial congestion (particularly during the before period). The data collection team sat in long queues when this constrained operational condition occurred, which restricted the number of travel time runs. As an alternative approach, the research team used the individual videos to track vehicles through the intersection and develop a travel time.

Pedestrian Walking Path

One of the research team's objectives was determining how the alternative intersections affected pedestrians. To make this comparison, the team measured pedestrian travel times for before and after periods. The team defined origin and destination points for each approach at the intersections. To consider various walking speeds, two different team members were involved in the pedestrian travel time measurement. The team members measured the distance over which they were exposed and not exposed to the traffic, as well as the total travel time from an origin to a destination and measured each movement multiple times to calculate and present the average pedestrian travel time values. For rural locations, like the Minnesota sites, the team did not measure the walking path due to the high-speed conditions and lack of appropriate bicycle and pedestrian facilities.

Figure 3. Illustration. Signalized RCUT schematic for MN–65 at Viking Boulevard NE.



Source: FHWA.

FINDINGS

The key findings by intersection form are as follows:

- The MUTs in Arizona require the major road drivers who want to turn left to go straight at the main signalized intersection and then use a U-turn (also signalized) to return to the main intersection, where drivers then turn right to complete their left turn. For the two sites included in the before-after analysis, the queues and travel times for the major road through movements were reduced in the after period, even with an increase in volume.
- Another intersection studied in Arizona added a quadrant road along with MUTs to a previously traditional intersection design. Even with volume increasing by 13 percent in the after period, the travel times improved, and queue lengths were reduced for most movements.
- Two unsignalized intersections in Minnesota were converted to unsignalized RCUTs. The queues along the minor road (all movements) and the major road left turns were similar in length between the before and after periods. Travel time along the minor road increased for most of the minor road movements. In other words, the unsignalized RCUTs in Minnesota overall did not show operational benefits in this study.
- The Minnesota signalized RCUT did experience notable improvements in operations. The team measured large reductions in queues for all movements on the minor road and for the major road left and through movements. Travel times on both the major and minor road were reduced for most movements.
- The DLT installed in Texas resulted in shorter queues, but the travel time results were mixed. In some cases, the travel time was reduced, but in others the travel time increased.
- The Norfolk, VA, site had a DLT that improved (reduced) both queues and travel times.
- The Virginia Beach, VA, site is a hybrid intersection with DLTs on the north and south approaches and MUTs on the east and west approaches. Both left-turn queues and travel times improved (reduced).

CONCLUSIONS

Overall, converting traditional intersections to innovative intersections did improve operations. The data demonstrate a general reduction in travel time for most intersection legs. The findings also show that queue lengths are shorter, and the queues tend to disperse more quickly.

The innovative intersection treatments identified for this study resulted in significant vehicular operational benefits, with the exception of the unsignalized RCUT sites that did not experience heavy volume conditions. The research for the DLT in San Antonio, TX, the hybrid in Arizona, and the signalized RCUT in Minnesota identified concerns for pedestrian walkability, such as creating a longer walking path or additional conflicts for pedestrians. Therefore, further assessment of how bicycles and pedestrians can be safely serviced at these types of designs is needed. The noted concern about adverse walkability at a few sites is important and emphasizes that pedestrian and bicyclist needs must be considered early in the design process.

REFERENCES

1. Reid, J., L. Sutherland, B. Ray, A. Daleiden, P. Jenior, and J. Knudsen. 2014. *Median U-Turn Intersection Informational Guide*. Report No. FHWA-SA-14-069. Washington, DC: Federal Highway Administration. https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa14069.pdf, last accessed October 22, 2022.

2. Hummer, J., B. Ray, A. Daleiden, P. Jenior, and J. Knudsen. 2014. *Restricted Crossing U-Turn Intersection Informational Guide*. Report No. FHWA-SA-14-070. Washington, DC: Federal Highway Administration. https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa14070.pdf, last accessed October 22, 2022.

3. FHWA. 2022. “Proven Safety Countermeasures” (web page). https://highways.dot.gov/safety/proven-safety-countermeasures, last accessed October 22, 2022.

4. Steyn, H., Z. Bugg, B. Ray, A. Daleiden, P. Jenior, and J. Knudsen. 2014. *Displaced Left Turn Intersection Informational Guide*. Report No. FHWA-SA-14-068. Washington, DC: Federal Highway Administration. https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/fhwasa14068.pdf, last accessed October 22, 2022.

5. Reid, J., and J. E. Hummer. 2020. *Quadrant Roadway Intersection Informational Guide*. Report No. FHWA-SA-19-029. Washington, DC: Federal Highway Administration. https://safety.fhwa.dot.gov/intersection/other/fhwasa19029.pdf, last accessed October 22, 2022.

6. Google. n.d. "Street View" (web page). https://www.google.com/streetview/, last accessed February 13, 2024.

Researchers—This study was conducted by Principal Investigator Karen Dixon (ORCID: 0000-0002-8431-9304), along with co–Principal Investigator Kay Fitzpatrick (ORCID: 0000-0002-1863-5106) and Researcher Maryam Mousavi Seyedeh (ORCID: 0000-0001-8188-4466). All three researchers work for the Texas A&M Transportation Institute under contract DTFH6115C00005.

Distribution—This TechBrief is being distributed according to a standard distribution. Direct distribution is being made to the divisions and Resource Center.

Availability—This TechBrief may be obtained at https://highways.dot.gov/research.

Key Words—Alternative intersection, left-turn conflict, restricted crossing U-turn intersection, median U-turn intersection.

MAY 2024

Recommended citation: Federal Highway Administration, *Field Evaluation of At-Grade Alternative Intersection Designs, Volume I—Operations Report* (Washington, DC: 2024) https://doi.org/10.21949/1521568

FHWA-HRT-24-125
HRSO-10/05-24(WEB)E