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Field Evaluation of At-Grade Alternative Intersection Designs, Volume II—Safety Report

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This document is a technical summary of the Federal Highway Administration report *Field Evaluation of At-Grade Alternative Intersection Designs, Volume II—Safety Report* (FHWA HRT-24-155).

INTRODUCTION

The research team conducted a multiyear research project for the Federal Highway Administration (FHWA) focused on evaluating how converting from conventional intersections to alternative intersections affects safety and operational performance. This research may be of interest to transportation practitioners involved in transportation design, safety, and operations.

This study's findings are in two report volumes. Volume I reviews site identification, data collection, and traffic operations at sites in Arizona, Minnesota, Texas, and Virginia.(1) Volume II reviews the safety effects for the same set of Volume I study sites to better understand the safety performance of converting conventional to unique alternative intersection configurations.(2) The findings are also summarized in a safety Tech Brief (this document) and an operations Tech Brief.(3)

The study included median U-turn (MUT), restricted crossing U-turn (RCUT), and displaced left turn (DLT) alternative intersections. The study also includes locations that contain two or more of those alternative intersection elements (referred to as hybrid intersections). FHWA's proven safety countermeasures feature these designs.(4) Where applicable, the analysis included bicycle and pedestrian safety performance for these study locations.(5)

STUDY OBJECTIVE

For all alternative intersection configurations, transportation professionals need to understand the safety and operational benefits associated with converting conventional intersections to alternative intersections. This information is vital to designers who need to make informed decisions regarding the most effective intersection alternative to use for a candidate intersection location. This knowledge can then be useful for a transportation agency considering whether to select a conventional or alternative intersection design and determining how to choose the best configuration for the site of interest. As an increasing number of alternative intersections are constructed, transportation professionals need to understand how the individual roadway features influence overall intersection safety performance. Understanding the performance of individual alternative intersection applications helps the transportation agencies improve future designs and select the best configurations for a specific application.

This study's objective, as described in Volume II of this report, is to identify proposed alternative intersection installations before their construction and acquire preconstruction (before) and postconstruction (after) field data that transportation professionals can use to assess the safety performance of various alternative intersection features.[2] Volume I summarizes the corresponding operational performance.[1]

SITE IDENTIFICATION

Volume I of this report describes the sites that the research team selected for analysis.[1] These sites include intersections located in Arizona, Minnesota, Texas, and Virginia. The research team worked with the State departments of transportation and local cities to identify project locations for each site where construction had not yet started but was scheduled to begin in the immediate future. The initial plan was to identify 12 locations for this before-after analysis. However, due to the coronavirus (COVID-19) pandemic, construction on three of the sites was delayed (these sites were still under construction at the time of this report). Consequently, the team identified one additional site in Arizona and two additional sites in Minnesota to use for comparison. Volume I provides additional information about the selected sites.

The targeted intersections are as follows:

- Three MUT locations in Arizona (one used for comparison purposes).
- One hybrid intersection in Arizona.
- Three unsignalized RCUT locations in Minnesota (one used for comparison purposes).
- One signalized RCUT location in Minnesota.
- One unsignalized conventional location in Minnesota (used for comparison purposes).
- One DLT signalized interchange in Texas (with before data acquired for three future RCUT intersection locations).
- One continuous flow intersection (CFI) location in Virginia.
- One hybrid CFI and MUT location in Virginia.

The researchers selected 12 sites for near-term evaluation and 3 sites with only before data for comparison. At some future date when the three incomplete Texas project sites have been finished and in operation for a sufficient period, researchers may be able to conduct a postconstruction operations and safety analysis.

DATA COLLECTION

As part of the general roadway and operational analysis documented in Volume I, the team compiled before and after data documenting the physical site characteristics.[1] In addition to these roadway characteristics, team members worked with the local transportation agencies to acquire crash data. These data included the physical location of crashes and the boundaries of the crash data relative to the primary intersection. The research team also documented the crash severity (table 1) and the crash type (table 2). The after periods in these tables do not include crashes that occurred in the COVID-19 year of 2020. To graphically depict this crash information, the team developed site schematics (figure 1 is an example).

ANALYSIS APPROACH

The research team conducted a safety analysis to determine the variation in the number and type of crashes for the conversions from conventional intersections to alternative intersections. This analysis included summary information for crash counts and crash types. In addition, the analysis extended to the individual intersection types. For the safety assessment, post-construction data analysis periods varied and in some cases were much shorter than originally planned because of the disruption in traffic patterns during the COVID-19 pandemic year of 2020. Where appropriate, the analysis extended to the safety impacts of pedestrian walking paths.

Crash Counts and Severity Levels

The research team identified crashes within approximately 250 ft of the intersection influence area. The crash count analysis included a summary of the number of crashes per crash period per site, the number of crashes per study period by severity level, the average number of total and injury crashes per year, and the percent distribution of crashes by severity level by intersection and period. Table 1 presents the observed distribution of KABCO crashes for before to after conditions. KABCO codes represent fatal (K), severe injury (A), injury (B), possible injury (C), and property damage-only (O) severity levels. In general, the percentage of KABC crashes decreased while the property damage-only and total crashes increased. In a few cases, such as the Arizona Valencia Road and Kolb Road site, the regional traffic substantially increased during the construction period, resulting in a disproportionate increase in crashes.

State	Intersection	Period	K (%)	A (%)	B (%)	C (%)	O (%)	Change in KABC Crashes (%)
AZ	Grant Road at First Avenue	Before	1	8	25	26	40	NA
AZ	Grant Road at First Avenue	After	0	0	19	11	70	−30
AZ	Grant Road at Oracle Road North	Compare-Before	0	7	16	35	42	NA
AZ	Grant Road at Oracle Road North	Compare-After	0	2	18	22	57	−15
AZ	Grant Road at Stone Avenue	Before	0	0	28	28	45	NA
AZ	Grant Road at Stone Avenue	After	3	3	29	12	53	−8
AZ	Valencia Road at Kolb Road	Before	0	0	50	0	50	NA
AZ	Valencia Road at Kolb Road	After	2	6	28	7	57	−7
MN	MN–65 at 157th Avenue Northeast	Before	6	6	11	33	44	NA
MN	MN–65 at 157th Avenue Northeast	After	0	0	0	20	80	−36
MN	MN–65 at 181st Avenue Northeast	Before	17	0	33	0	50	NA
MN	MN–65 at 181st Avenue Northeast	After	0	33	0	33	33	17
MN	MN–65 at 187th Northeast	Before	8	0	25	8	58	NA
MN	MN–65 at 187th Northeast	After	0	14	0	14	71	−13
MN	MN–65 at 209th Avenue Northeast	Compare-Before	0	0	33	0	67	NA
MN	MN–65 at 209th Avenue Northeast	Compare-After	0	33	0	0	67	0
MN	MN–65 at Viking Boulevard Northeast	Before	0	0	17	41	41	NA
MN	MN–65 at Viking Boulevard Northeast	After	17	0	33	0	50	−9
TX	SH–16 at West Loop 1604 Access Road	Before	0	1	7	22	70	NA
TX	SH–16 at West Loop 1604 Access Road	After	0	1	9	19	70	0
VA	Indian River Road at Kempsville Road	Before	0	1	25	4	70	NA
VA	Indian River Road at Kempsville Road	After	0	4	27	0	69	1
VA	Military Highway at Northampton Boulevard	Before	0	9	5	37	49	NA
VA	Military Highway at Northampton Boulevard	After	0	2	20	4	74	−25

Table 1. Percent distribution of crashes by severity level, intersection, and period.

NA = the comparison is only applicable for the after period.

Table 2. Distribution of crash type by intersection and before and after periods.

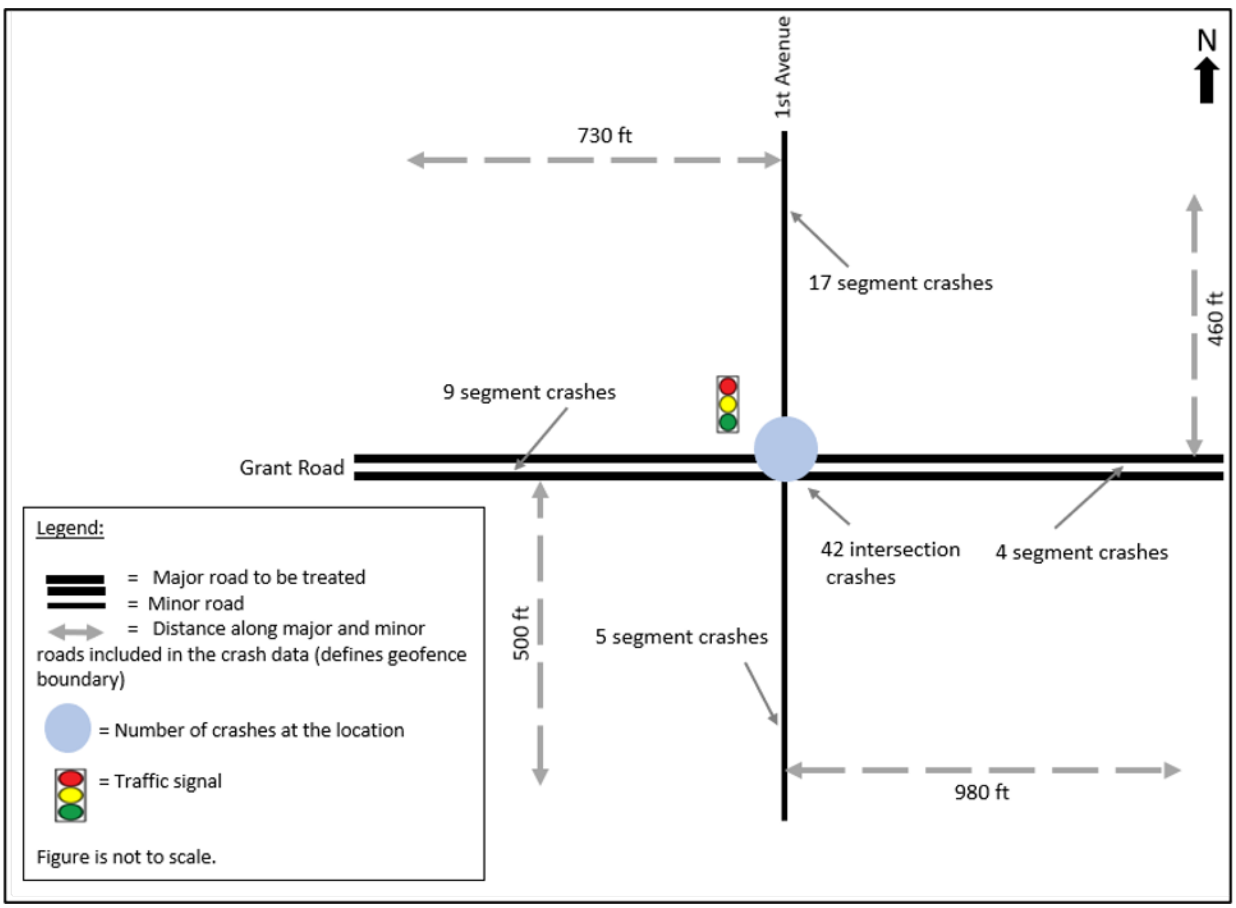
State	Intersection	Period	RE (%)	Angle (%)	LT (%)	SS (%)	HO (%)	Veh PorB (%)	ROR SV (%)	Other (%)
AZ	Grant Road at First Avenue	Before	30	13	34	3	3	13	4	1
AZ	Grant Road at First Avenue	After	24	19	50	2	0	2	2	2
AZ	Grant Road at Oracle Road North	Compare-Before	28	9	23	16	2	9	12	0
AZ	Grant Road at Oracle Road North	Compare-After	22	14	35	8	0	16	4	0
AZ	Grant Road at Stone Avenue	Before	22	14	38	3	2	16	3	2
AZ	Grant Road at Stone Avenue	After	26	12	29	9	3	12	9	0
AZ	Valencia Road at Kolb Road	Before	75	0	25	0	0	0	0	0
AZ	Valencia Road at Kolb Road	After	28	30	11	7	0	0	22	2
MN	MN–65 at 157th Avenue Northeast	Before	11	61	6	6	6	6	0	6
MN	MN–65 at 157th Avenue Northeast	After	40	0	0	60	0	0	0	0
MN	MN–65 at 181st Avenue Northeast	Before	8	25	8	0	25	0	0	33
MN	MN–65 at 181st Avenue Northeast	After	33	0	0	33	0	0	0	33
MN	MN–65 at 187th Northeast	Before	17	50	0	17	0	0	0	17
MN	MN–65 at 187th Northeast	After	57	14	0	14	0	0	0	14
MN	MN–65 at 209th Avenue Northeast	Compare-Before	0	0	0	0	0	0	33	67
MN	MN–65 at 209th Avenue Northeast	Compare-After	33	33	0	0	0	0	0	33
MN	MN–65 at Viking Boulevard Northeast	Before	78	10	0	0	0	0	5	7
MN	MN–65 at Viking Boulevard Northeast	After	50	17	0	0	0	0	0	33
TX	SH–16 at West Loop 1604 Access Road	Before	14	26	NA	19	0	1	1	39
TX	SH–16 at West Loop 1604 Access Road	After	17	30	NA	20	0	1	0	32

Table 2. Distribution of crash type by intersection and before and after periods. (Continued)

State	Intersection	Period	RE (%)	Angle (%)	LT (%)	SS (%)	HO (%)	Veh PorB (%)	ROR SV (%)	Other (%)
VA	Indian River Road at Kempsville Road	Before	48	39	NA	7	1	1	1	3
VA	Indian River Road at Kempsville Road	After	32	52	NA	8	2	1	1	4
VA	Military Highway at Northampton Boulevard	Before	62	26	NA	6	2	1	1	2
VA	Military Highway at Northampton Boulevard	After	34	40	NA	16	4	0	4	2

RE = rear-end; LT = left-turn; SS = sideswipe—same direction; HO = head on; Veh PorB = vehicle and pedestrian or vehicle and bicyclist; ROR = ran off road; SV = single vehicle; NA = Texas and Virginia crash data did not include codes that would identify a left-turn crash.

Figure 1. Illustration. Number of crashes by location for the before period (43 mo) for Grant Road at First Avenue in Tucson, AZ.[2]



Source: FHWA.

Crash Types

The research team organized the crash data by crash type. Types of crashes may vary by State, for example, Arizona and Minnesota provide specific codes to identify left-turn crashes. Table 2 includes the crash-type summary per intersection and period. Alternative intersection designs focus on modifying the left-turn traffic pattern; therefore, a reduction in left-turn crashes should be expected. As a proportion, only one of the intersections where a left-turn code was available had an increase in left-turn crashes. For the two Virginia intersections, a reduction in the proportion of rear-end crashes and an increase in the proportion of angle crashes was experienced.

Site Safety Characteristics

Following the general review of crash counts and crash types, the research team expanded the analysis to observations for the various sites per State. Though each site does have unique characteristics, the only recurring trend in the analysis was that the number of crashes in 2020 (consistent with the COVID-19 year) were somewhat elevated.

Pedestrian Walking Path

The number of crashes at the sites are based primarily on motor vehicle crashes. However, at locations where vulnerable roadway users are present, considering impacts for all users is important. Because pedestrian and bicycle crash data tend to be under reported in most States, an alternative strategy that researchers use to estimate the likelihood of pedestrian and bicycle crashes is measuring the exposure of the vulnerable user (primarily the pedestrian) to other road users (primarily motor vehicles). For the developed urban locations in this project, the research team measured driveway widths as they intersect with the adjacent road. The team then determined if exposure to other road users at driveways increased or decreased. For the Minnesota sites, the team did not use this pedestrian assessment because the study corridor had little pedestrian traffic. For the Arizona sites, the team evaluated the Grant Road intersections, and deemed levels of exposure to other road users comparable for the before versus the after condition. The team also evaluated the one Texas site and the two Virginia sites.

The Texas site interchange configuration created a challenge for pedestrians. The configuration change lengthened the relatively short (before reconfiguration) pedestrian paths considerably. Though this issue may appear to be operational, the change also becomes a safety issue. In many cases, the research team observed pedestrians crossing at locations other than locations with a marked crosswalk, most likely because the pedestrians grew impatient at the extra time needed to complete their trip after the pathway was lengthened. For Virginia, direct access to driveways was somewhat minimized using raised narrow islands to channel traffic.

FINDINGS

Based on this safety assessment, traffic professionals can reasonably expect that converting a conventional intersection to one of the alternative intersections included in this study will improve safety performance. Overall, constructing alternative intersections does have significant safety benefits based on a reduction in crash severity. More evaluation is needed for accommodating pedestrians and bicycles at alternative intersection sites. In particular, the intersection configurations that favor the motor vehicle travel times over bicycle and pedestrian travel time would benefit from detailed safety assessments.[5]

The post-construction crash data for the study sites excluded data from the COVID-19 pandemic period due to concerns with altered travel patterns. Ideally a before-and-after safety assessment should include three years of data for before and after implementation. The research team was unable to consider the crash data for an extended duration. Though this issue makes the value of the safety analysis less beneficial, researchers can use the crash data in conjunction with other crash data traits such as maneuver type or commonly observed driver errors at the site.

CONCLUSIONS

Overall, converting traditional intersections to innovative intersections improved safety performance. Unsignalized RCUT configurations perform well in higher speed, rural locations. MUTs are generally used for urban and rural lower speed scenarios. Locations with DLTs and hybrid designs also provide enhanced safety. In some cases, converting conventional intersections to alternative intersections may exhibit only a minor benefit in safety performance, but when traffic professionals balance these findings with improved site operations, traffic professionals can expect the intersection to provide additional improvements.

Researchers selecting sites for this and other deployment studies generally assume that the reconfiguration is used because the conventional intersection is no longer performing optimally. This finding may create a site-selection bias where intersections that need the treatment are addressed first. Because of this selection bias, this team recommends future work to identify selection boundary criteria (e.g., minimum vehicles per day) and optimal geometric configuration (e.g., deceleration length, acceleration length). In addition, researchers need to further assess how bicycles and pedestrians can be safely serviced at alternative design intersections. Concern about adverse walkability at a few of the sites studied is important and emphasizes that pedestrians' and bicyclists' needs must be considered early in the design process.

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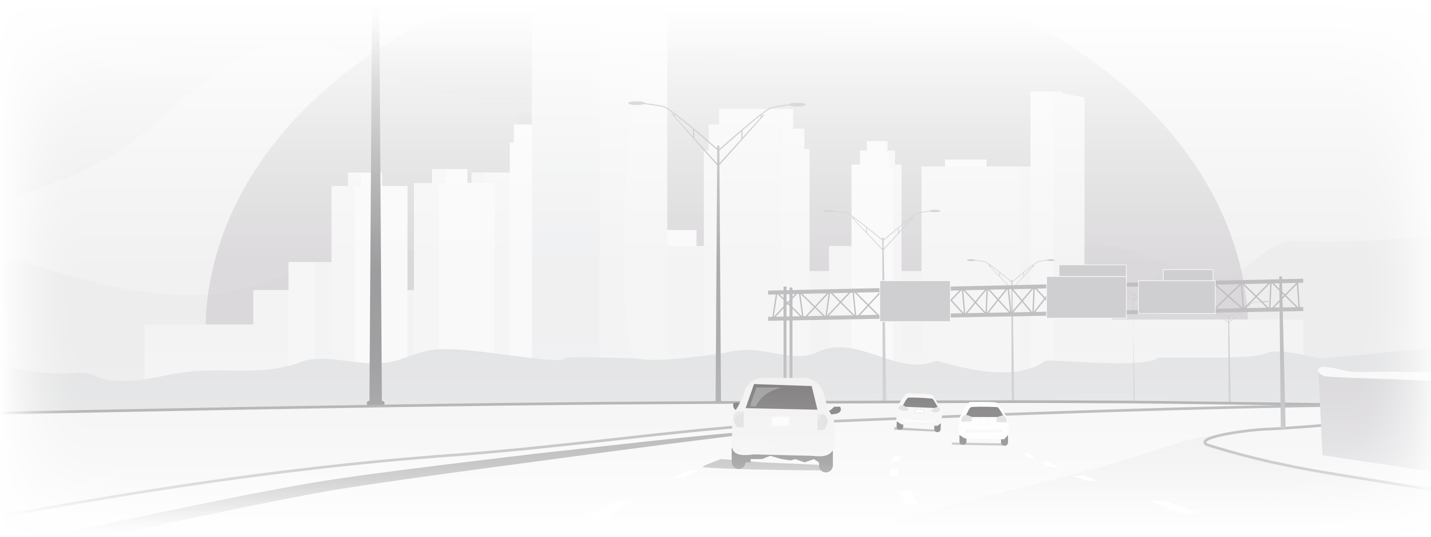

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