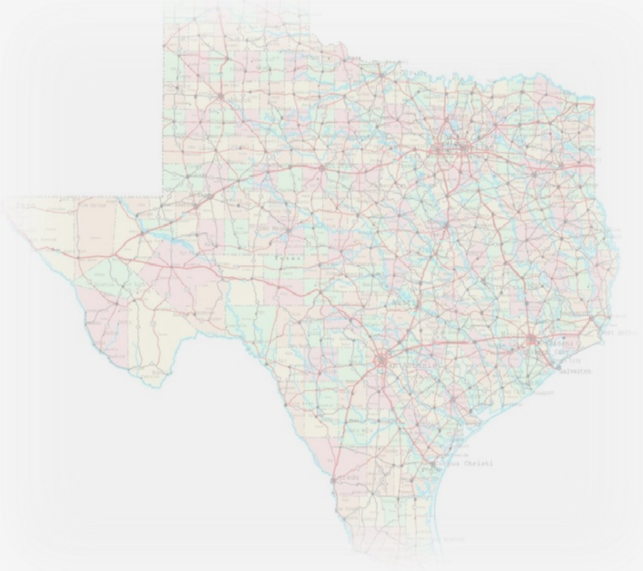
RESEARCH

Is Age a Factor in Crashes at Channelized Right-Turn Lanes? An Exploration of Potential Relationships



www.ATLAS-Center.org

Is Age a Factor in Crashes at Channelized Right-Turn Lanes? An Exploration of Potential Relationships

Report #: ATLAS-2016-14

by

Kay Fitzpatrick, PhD, PE
Senior Research Engineer
Texas A&M Transportation Institute

Subasish Das, PhD
Associate Transportation Researcher
Texas A&M Transportation Institute

and

Adrian Contreras
Graduate Student
Texas A&M University

University of Michigan
2901 Baxter Rd., Room 124
Ann Arbor, MI 48109-2150

Texas A&M Transportation Institute
College Station, TX 77843-3135

October 2016

DISCLAIMER

ACKNOWLEDGMENTS

This research project was supported by the Center for Advancing Transportation Leadership and Safety (ATLAS Center). The ATLAS Center is supported by a grant from the U.S. Department of Transportation, Office of the Assistant Secretary for Research and Transportation, University Transportation Centers Program (DTRT13-G-UTC54). The ATLAS Center is a collaboration between the University of Michigan Transportation Research Institute and the Texas A&M Transportation Institute.

The authors would like to thank Elizabeth Hilton for her comments and encouragement during this study. The authors would also like to thank Elizabeth Hilton and Robert Wunderlich for their patience as the authors worked through several setbacks during the course of this study.

Technical Report Documentation Page

1. Report No. ATLAS-2016-14	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle
Is Age a Factor in Crashes at Channelized Right-Turn Lanes? An Exploration of Potential Relationships

5. Report Date

6. Performing Organization Code

7. Author(s)
Kay Fitzpatrick, Subasish Das, and Adrian Contreras

8. Performing Organization Report No.

9. Performing Organization Name and Address
Texas A&M Transportation Institute
The Texas A&M University System
College Station, TX 77843-3135

10. Work Unit no. (TRAIS)

11. Contract or Grant No.
DTRT13-G-UTC54

12. Sponsoring Agency Name and Address
Advancing Transportation Leadership and Safety (ATLAS) Center
2901 Baxter Rd., Room 124
Ann Arbor, MI 48109-2150

13. Type of Report and Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes
Supported by a grant from the U.S. Department of Transportation, OST-R, University Transportation Centers Program

16. Abstract

The objective of this research was to determine if a relationship exists between crashes and right-turn lane design characteristics with specific consideration of the age of the driver. The research team used crash data of selected intersections in Texas for a six-year period (2009–2014) to perform this study. The types of right-turn lane design considered for analysis included shared lane with island, shared lane with island and dedicated downstream lane, right-turn lane with island, right-turn lane with island and dedicated downstream lane, and shared lane. An examination of the distribution of drivers by miles driven and by involvement in right-turn-related crashes showed that younger drivers were involved in more crashes despite driving less than older age groups. This could be representative of the inexperience or the likelihood of risk-taking behaviors of younger drivers.

The characteristics that were examined included right-turn treatment type, presence of a dedicated departure lane, corner radius, and width of the channelized island. For most of the comparisons, the distribution of drivers by age showed similar patterns regardless of the type of right-turn treatment or other right-turn lane characteristic studied—younger drivers are having a disproportional number of crashes. The distribution of drivers by width of the channelized island (measured along the receiving roadway) did indicate that the widest channelized islands might be associated with more older-driver crashes. A larger sample size or a different study method, perhaps a before-after method, might be needed to verify this observation. A field investigation along with a safety before-after study could also illustrate whether older drivers have greater difficulties or compensate for the difficulties by positioning their vehicle differently on approaches or, perhaps, avoiding these intersections.

17. Key Words Right-Turn Treatments, Driver Age, Crashes		18. Distribution Statement Unlimited	
19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages 46	22. Price

Technical Report Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

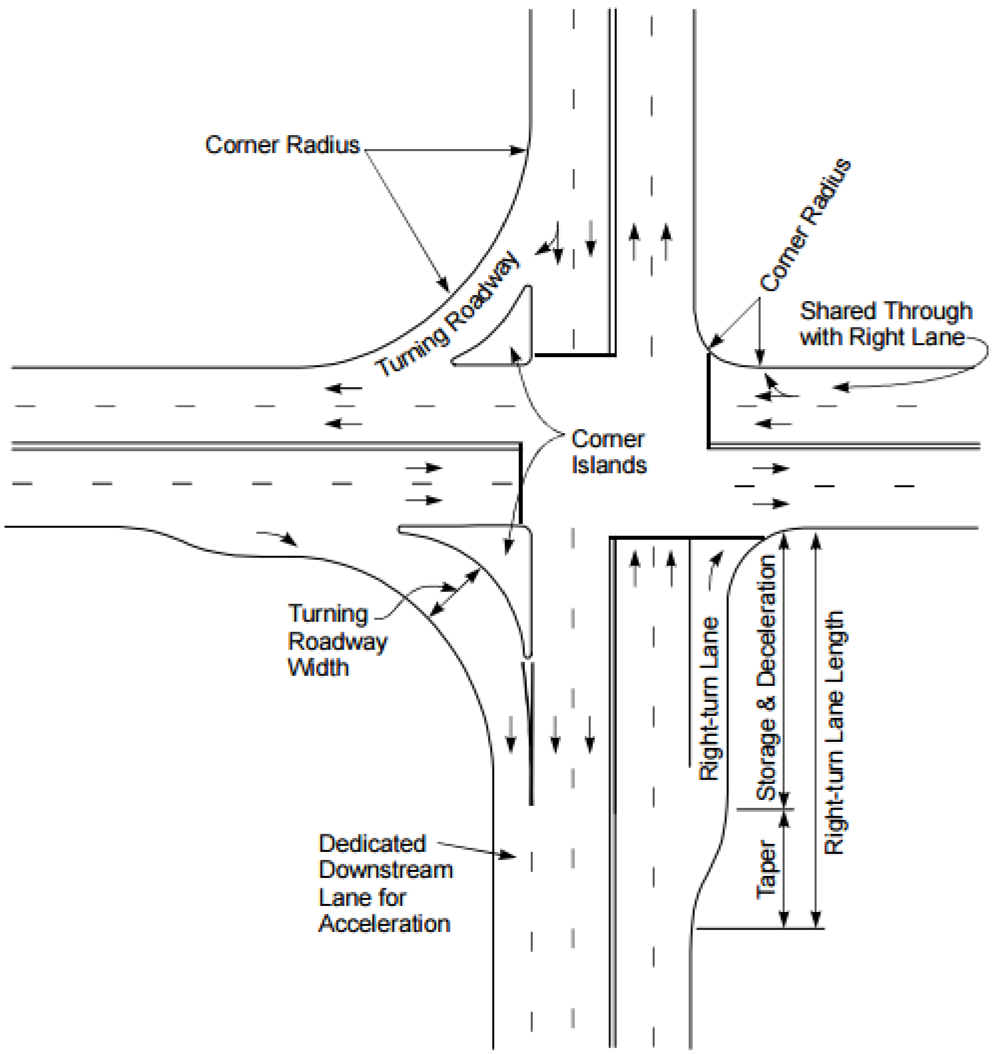
LIST OF TABLES

Page

CHAPTER 1: INTRODUCTION

PROBLEM

Right-turn lanes are used to provide space for the deceleration and storage of turning vehicles and to separate the turning vehicles from the through movement. Right-turn lanes at intersections can be designed with a dedicated right-turn roadway, a corner island, and/or a dedicated approach or departure lane. Figure 1 provides various examples of right-turn lane treatments (*1*). A number of factors can enter into the design decisions for accommodating right turns including operating speeds, pedestrian volumes, traffic volumes, truck percentages, capacity, highway type, and intersection arrangement and frequency.



Source: Figure 4-7 in K. Fitzpatrick, M. D. Wooldridge, and J. D. Blaschke (2005). *Urban Intersection Design Guide*. FHWA/TX-05/0-4365-P2.

Figure 1. Right-turn lane examples (*1*)

As drivers attempt to merge their vehicles with oncoming traffic in the departure lanes, visibility becomes a key factor. Based on the design of the channelized island, drivers may be required to turn their heads at large angles to ensure they can appropriately turn or merge. As drivers age, the action of turning their head becomes more difficult. Several documents, including the 2014 Federal Highway Administration (FHWA) *Handbook for Designing Roadways for the Aging Population* (*2*), state that older drivers have difficulties turning their head to see upstream gaps in a merge situation. The information shown in Figure 2 is used in several design guides (including the FHWA handbook); however, the link between channelized right-turn lane design and crashes is not available. While the turning situation is assumed to be difficult for older drivers, it is desirable to identify the relationship between crashes and channelized right-turn lane island design characteristics with a specific consideration of the age of the driver. The 2014 *Handbook for Designing Roadways for the Aging Population* provides a discussion on the practice along with the benefits to the aging road user. The discussion is reproduced in Figure 2.

With the objective of improving safety at channelized right-turn lanes (CRTLs) in mind, researchers collected characteristics and measurements of CRTLs at intersections within the state of Texas for this project. These intersections were matched to crashes for a six-year period (2009–2014 inclusive) from the Texas Department of Transportation (TxDOT) Crash Records Information System (CRIS) database. This study examined the association between a driver's age and right-turn-related crashes to explore whether older drivers have greater difficulties with specific design characteristics of channelized right-turn lanes.

STUDY OBJECTIVES

The key objective of this research project was to identify if the age of a driver is associated with crashes at channelized right-turn lanes.

OUTLINE OF THE REPORT

This report is organized as follows. Chapter 1 discusses the problem and the key objective of the study. Chapter 2 provides the literature review on the existing body of research. Chapter 3 describes the methodology used in this study, while Chapter 4 documents the performed data analysis. Chapter 5 provides the research conclusions.

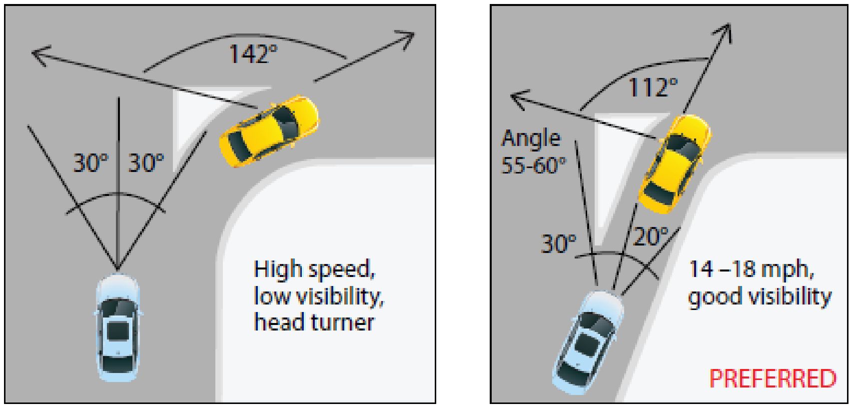


Figure 33. Right-Turn Channelization Design

Description of Practice: This practice reflects improved design of the corner island, turning lane width, and turning radii for channelized right turns to discourage high-speed turns while still accommodating large trucks and buses, and also facilitating pedestrians crossing the intersection. Specifically, the triangular corner island should have the "tail" pointing to approaching traffic. This will make the total pedestrian crossing distance of the intersection shorter, as the channelized right-turn is closer to the through lanes. In addition, the crossing of the channelized right-turn lane itself is shorter as pedestrians can cross at a right angle. This design has the additional advantage of the crosswalk being located in an area where the driver is still looking ahead; older designs place the crosswalk in a location where the driver is already looking left for a break in the traffic. The improved channelized right-turn lane design will place a sharper curve at the downstream end of the lane, which will force drivers to negotiate the lane more slowly; and by having the slip lane intersect the destination street at a larger angle, a driver will have better sight lines of approaching traffic on the destination street. Known implementations of this design include an intersection in Charlotte, NC, and several intersections in Florida and Texas.

Anticipated Benefits to Aging Road Users: Aging drivers, who as a group experience reduced head/neck mobility, should have a longer time in which to search for conflicts with through traffic before entering the destination street as the result of these design changes. They should also benefit from carrying out this search without dividing their attention to potential conflicts with pedestrians crossing to the corner island. Aging pedestrians, who as a group walk more slowly, should benefit from the shorter crossing distances afforded by this design. The safety of aging pedestrians—and all pedestrians—should also be enhanced to the extent that this design compels turning drivers to enter the turn lane at a lower speed, while permitting them to direct attention to the search for conflicts with pedestrians and conflicts with traffic in separate phases of the turning maneuver.

Source: Figure 33 and text on page 215 in M. Brewer, D. Murillo, and A. Pate (2014). A Handbook for Designing Roadways for the Aging Population. FHWA-SA-14-015.

Figure 2. From FHWA's 2014 Handbook for Designing Roadways for the Aging Population discussion on right-turn channelization design (2)

CHAPTER 2: LITERATURE REVIEW

Because the existing body of research does not specifically explore issues involving right-turn-lane crashes and driver's age, this chapter provides information on existing literature on right-turn-lane crashes. Right-turn lanes are used to provide space for the deceleration and storage of turning vehicles. They may be used to improve safety and/or operations at intersections. As discussed in the TxDOT *Urban Intersection Design Guide* (*1*), channelized right-turn lanes should be used only where significant capacity and safety problems may occur without them and adequate pedestrian crossings can be provided.

Harwood et al. (*3*) in 2002 found that the implementation of right-turn lanes on the major-road approach in rural and urban areas reduced the number of crashes. A 4 percent reduction was associated with the installation on one approach at a signalized intersection, and an 8 percent reduction was identified when the right-turn lane was installed on both major-road approaches.

A study conducted by Schattler et al. (*4*) in 2015 examined crash characteristics for right-turn lanes with channelized islands in Illinois. The study included three years of crash data for 68 approaches that were chosen based on their high frequencies of right-turn-related crashes. The authors gathered several intersection angles, as illustrated in **Error! Reference source not ound.**. Their analysis found that crash rates were higher for the following:

- Approaches with head-turn angles greater than 140 degrees.
- Approaches with right-turn angles less than 45 degrees.
- Acute intersection skew angles less than 75 degrees.

The work of Autey et al. (*5*) in 2012 also placed emphasis on the geometric design of CRTLs. Their study was a before-after safety evaluation after the angle between the vehicle and the oncoming traffic was changed. The width of the channelized island (along the cross street) was also decreased. The term given to this design choice was "smart channels." After applying this change to three intersections in British Columbia, average hourly conflict was reduced by about 51 percent and average conflict severity was reduced by 41 percent. The authors commented that these results show that the implementation of the right-turn treatment has resulted in a considerable reduction in severity and frequency of merging, rear-end, and total conflicts.

Al-Kaisy et al. (*6*) investigated driver behavior at three sites with signals and channelized right-turn lanes in southwest Montana. Results showed that a majority of drivers using the channelized turn lane treated the traffic signal as a yield control.

Potts et al. (*7*) in 2013 reported on a study that examined the safety of right-turn treatment type. The study included three types: 217 shared (through and right-turn lane) approaches, 95 conventional right-turn lanes, and 83 channelized right-turn lanes. The approaches were located in Toronto, Ontario, Canada, and seven years (1999 to 2005) of crash and volume data were considered. Their study found that channelized right-turn lane approaches had a lower frequency of crashes than conventional right-turn lanes, but a higher frequency than shared through and right-turn lanes. Note, however, that these differences were not statistically significant. In other words, the right-turn treatment had no statistically significant effect on total or fatal plus injury motor vehicle crashes. In terms of pedestrian safety measures, channelized right-turn lanes performed similarly as the shared lanes. The conventional right-turn lanes had more pedestrian crashes. The work concluded with a recommendation for further use of channelized right-turn lanes at intersections with low pedestrian volume.

CHAPTER 3: METHODOLOGY

The research team used three databases to prepare the final database used for the analysis in this study. These three databases included the intersection geometrics data collected manually by the research team, the Texas CRIS data, and the 2009 National Household Travel Survey (NHTS) data.

INTERSECTION GEOMETRIC DATABASE

Intersections with a channelized right-turn lane present on at least one approach were considered for the study. These intersections were identified from previous research team member experiences or using Google Earth. The research team examined major cities in Texas using Google Earth aerial photographs, scanning them to find intersections with a channelized right-turn lane. Intersections with either signal or stop control were initially considered. Most of the identified intersections had signals; therefore, the non-signalized intersections were removed prior to the analysis. The final database included intersections with either three legs or four legs. Some of the approaches had one-way traffic, while most had two-way traffic.

The research team collected several geometric characteristics for each intersection approach along with traffic control devices present at the intersection or on the approach. Table 1 summarizes the characteristics collected. For the intersection, the number of legs (three or four), the type of intersection traffic control (stop or signal control), and the presence of street lighting were collected. The latitude and longitude of the center of the intersection along with the major and minor road street names were obtained and used for matching the geometric characteristics with the crash data. Because several crashes did not have latitude and longitude data, street names were used for the matching. A review of selected counties for the crash database revealed that alternative names needed to be added, so up to four alternative names were added. Examples of alternative names included the use of different spellings, the use of the freeway name, or the use of the words “feeder” or “frontage” for intersections on a frontage road.

For each approach, several roadway characteristics were collected, as listed in Table 1. Based on previous experience, the angle between the approach and the cross street can affect the likelihood of crashes, so information on whether the angle was near 90 degrees or was skewed (75 degrees or less) was obtained. Because the graphics in Figure 2 emphasize the angle between the turning driver and the oncoming vehicles, that value was also sought. Initial measurements were attempted; however, reviews of the values revealed variability in measurements depending on the assumed stopping position of the turning vehicle. Therefore, the research team focused on other measurements that could be more consistently obtained from aerial photos, such as corner radius or island dimensions. Characteristics of the physical or painted island such as length and width were collected. The physical dimensions were used to calculate the size of the island.

Table 1. Geometric or traffic control characteristics collected for each approach

Characteristic	Name
Approach length: Measured before turn (ft).	A_RT_L
Approach: Does another significant intersection exist within 300 ft of the subject intersection on the approach leg—yes or no.	A_Int_Prox
Approach: Does approach have one-way or two-way traffic—OW (one way) or TW (two way).	A_OW or TW
Approach: Is crosswalk present—yes or no.	A_crosswk
Approach: Number of driveways within 1000 ft of stop bar on right edge of approach leg (also includes intersecting streets).	A_DwRt
Approach: Number of lanes on approach (number of through + left-turn lanes at stop bar; does not include exclusive right-turn lanes, if present).	A_LN
Approach: Right-turn lane width before turn (ft).	A_RTb_W
Approach: Right-turn lane width within turning roadway, midpoint (ft).	A_RTw_W
Approach: Right-turn type—SLwI (shared lane with island), SLwIDL (shared lane with island and dedicated downstream lane), RTLwI (right-turn lane with island), RTLwIDL (right-turn lane with island and dedicated downstream lane), SL (shared lane), ER2TL(exclusive double right-turn lane), ERTL (exclusive right-turn lane).	A_RT_type
Approach: Speed limit on approach (mph).	A_PSL
Approach: Street lighting present—yes or no.	A_light
Approach: Traffic control at right turn—none, yield, signal (SG) control, stop sign (ST) control.	A_trf_rgt
Corner curve: Length (ft).	Curv_leng
Corner curve: Radius (ft).	Radius
Cross street: Speed limit (mph).	C_PSL
Departure: Departure lane length measured following turn (ft).	R_RT_L
Departure: Number of driveways within 1000 ft of stop bar on right edge of receiving leg (also includes intersecting streets).	D_DwRt
Departure: Number of lanes on departure.	D_LN
Departure: Right-turn lane width after turn (ft).	D_RTa_W
Intersection: Intersection angle—right angle (near 90 degrees), close (between 75 and 90 degrees), or skew (estimated as being 75 degrees or less).	I_Angle
Intersection: Number of legs (either 3 or 4) and intersection traffic control (either SG or ST control)—3SG, 3ST, 4SG, 4ST. Stop-controlled approaches were removed prior to analysis.	I_trf_cntl
Island: Height (raised or flush).	Isl_height
Island: Curve (ft)—along curve.	Isle_M
Island: Length (ft)—along approach.	Isle_L
Island: Surface area (ft^2).	Isle_area
Island: Width (ft)—along departure.	Isle_W

The focus of the study was on approaches with right-turn lanes and islands. Some of the identified intersections also had an approach with a shared lane (through and right-turn vehicles in same lane) or had an exclusive right-turn lane without an island to separate the turning vehicle from other vehicles. The characteristics of these approaches were also gathered when present at an intersection with a CRTL. Table 2 lists the number of signalized intersection approaches by right-turn lane type and number of legs. For the right-turn lane type, the following types (and abbreviations) were used:

- SLwI = shared lane with island (see example in Figure **3**).
- SLwIDL = shared lane with island and dedicated downstream lane (see example in Figure 4).
- RTLwI = right-turn lane with island (see Figure 5).
- RTLwIDL = right-turn lane with island and dedicated downstream lane (see Figure 6).
- SL = shared lane (see Figure 7, northbound approach).
- ER2TL = exclusive double right-turn lanes (i.e., no island present).
- ERTL = exclusive right-turn lane (i.e., no island present; see Figure 7, eastbound approach).

Because of the limited number of double right-turn lanes and exclusive right-turn lanes (see Table 2), these approaches were removed from the analyses.

Table 2. Number of approaches by type of right-turn lane, number of legs, and type of intersection traffic control

Right-Turn Lane Type	**3SG**	**4SG**	**Grand Total**
ER2TL[a]	0	2	2
ERTL[a]	0	78	78
RTLwI	1	50	508
RTLwIDL	0	122	122
SL	0	209	209
SLwI	1	524	525
SLwIDL	1	68	69
Grand Total **(Total without ER2TL or ERTL)**	**3 (3)**	**1510 (1430)**	**1513 (1433)**

[a] Right-turn lane type not included in analysis.

Figure 3. Example of shared lane with island

Figure 4. Example of shared lane with island and dedicated downstream lane

Figure 5. Example of right-turn lane with island

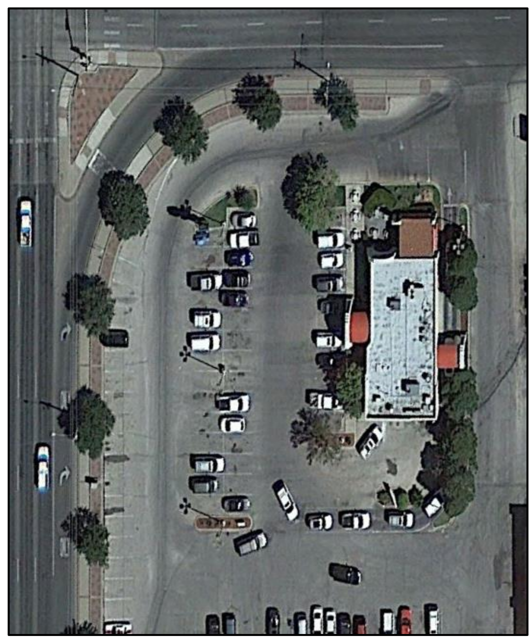


Figure 6. Example of right-turn lane with island and dedicated downstream lane

Figure 7. Example of exclusive right-turn lane (eastbound approach), shared lane (northbound approach), and right-turn lane with island (westbound and southbound approaches—note southbound approach crosses a bike lane after turning to west), assuming north is to the top of the photo.

CRASH DATABASE

Crash data for the intersections were collected for a six-year period (2009–2014 inclusive) using the TxDOT CRIS database. The CRIS database consists of three major files: the crash file with all related crash characteristics, unit file with vehicle characteristics, and person file with collected characteristics for those involved in a crash.

JOINT DATABASE

The next task was to create a merged database using the crash database and the geometric database. A number of CRIS variables were used to filter the data to create a database of crashes that could be related to the right-turn lane characteristics. These variables are summarized in Table 3. Figure 8 illustrates the flowchart of joining the two databases for this study.

Table 3. Filters to identify crashes at intersections of interest

TxDOT CRIS Variable	**Description**	**Filters[a]**
Veh_Trvl_Dir_ID (unit file)	Cardinal direction that the vehicle was traveling prior to the first harmful event or loss of control	Removed: • Not applicable • Not reported • Unknown
FHE_COLLSN_ID (crash file)	Manner of collision (the manner in which the vehicle[s] were moving prior to the first harmful event)	Retained: • 2 OMV—Vehicle Turning Right • 13 Angle—One Straight, One Right Turn • 15 Angle—Both Right Turn • 16 Angle—One Right Turn, One Left Turn • 17 Angle—One Right Turn, One Stopped • 23 SD—One Straight, One Right Turn • 25 SD—Both Right Turn • 26 SD—One Right Turn, One Left Turn • 27 SD—One Right Turn, One Stopped • 33 OD—One Straight, One Right Turn • 36 OD—One Right Turn, One Left Turn • 37 OD—One Right Turn, One Stopped
Prsn_Occpnt_Pos_ID (person file)	Physical location of an occupant in, on, or outside of the motor vehicle prior to the first harmful event or loss of control	Retained: • 1 front left
PRSN_AGE (person file)	Age of person involved in the crash	Removed: • Not applicable • Ages marked as 200 or greater

[a]OMV=one moving vehicle.
SD=same direction.
OD=opposite direction.

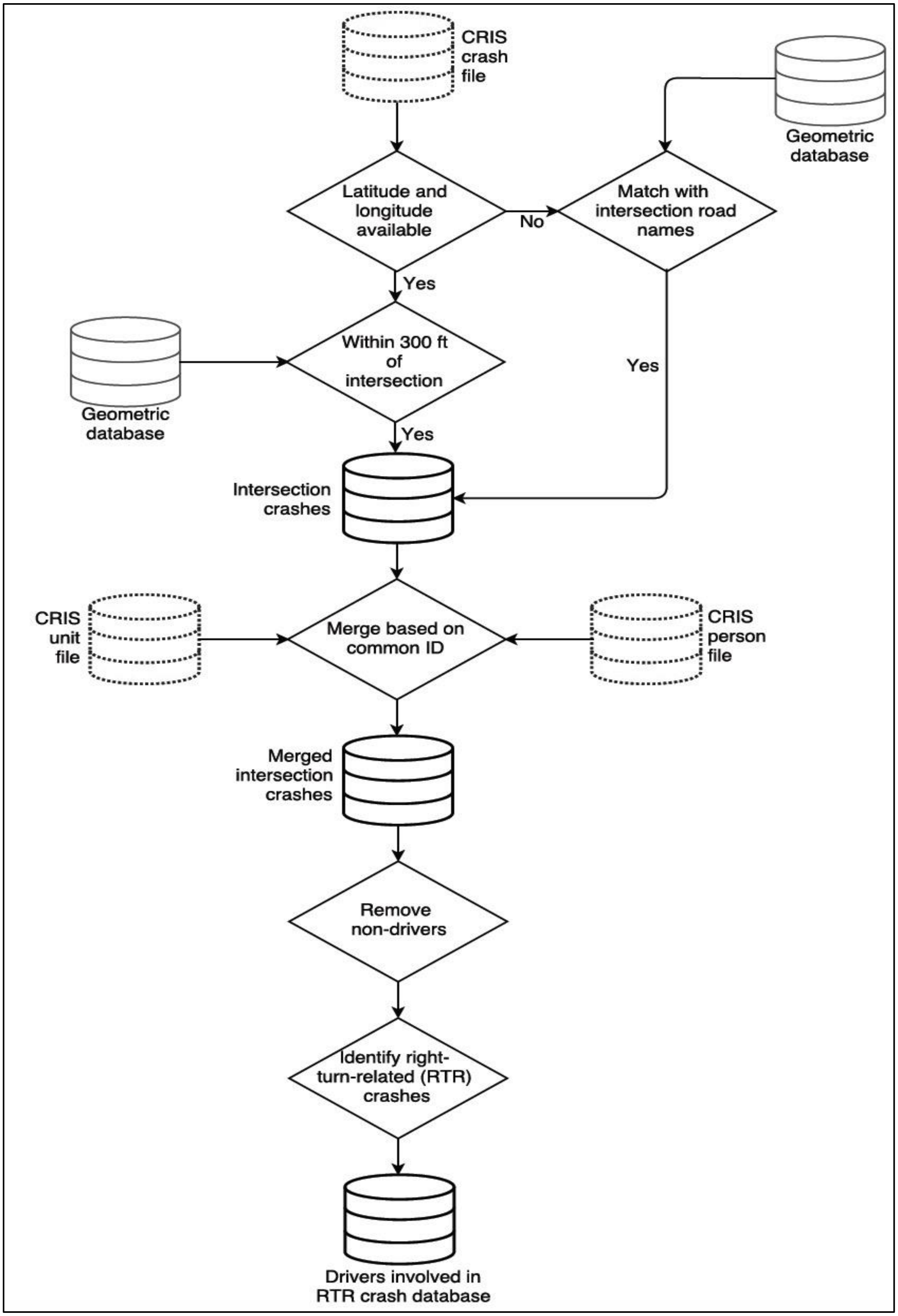


Figure 8. Flowchart of right-turn-related crash database preparation

To create a right-turn-related joint database, the research team performed the following:

- The CRIS database includes spatial locations (latitude and longitude) of many of the crash events, so using the latitude and longitude of each intersection from Google Earth, crash data were identified within a 300-ft radius from the center of each intersection. For crashes that lacked latitude and longitude data, the research team used intersection road names (including alternative names and spelling) to match crashes to the related geometric data.
- The other two CRIS files (unit and person) were merged with the crash data in order to determine the intersection approach for the crash and the age of the driver.
- The physical location of the occupant was used to identify whether the individual was a driver. The filter of "front left" for the person occupant position variable was used to identify drivers. Non-driver data were removed.
- In order to link crash data and geometric data, a common ID tag was created that consisted of a unique intersection number and approach direction. Assigned approach direction for naming the approach was northbound, southbound, eastbound, or westbound. The direction for a vehicle in the CRIS database can be one of eight directions; therefore, the geometric database was adjusted to include up to two directions. The first direction was the nearest cardinal direction (N, S, E, and W), and the second direction was the nearest intermediate direction (NE, NW, SE, and SW). For cases where travel direction was not reported or not enough information was provided in the crash database to make a confident decision, the crashes were assigned to an approach called "NA" and later removed from the analysis.
- The manner of collision variable was used to identify crashes that involved at least one right-turning vehicle. Table 3 lists the filters used.
- In order to focus on the age of the driver in the evaluation, the person age variable was used to identify the age of the driver. Crash entries where the driver age was not known or where the driver age was greater than 200 (assumed to be a miscoding) were removed.

NHTS DATABASE

Since the age of the driver involved in the crash was one of the key factors in this study, it was necessary to examine the age distribution of drivers. To complete this task, the 2009 NHTS (*8*) was consulted. This survey was conducted from March 2008 through May 2009 and targeted households within the United States. Households were contacted if they represented the "civilian, non-institutionalized population of the United States." This means that motels, hotels, prisons, and other related living quarters were not contacted. A total of 150,147 households across the United States were included in the database, and these were determined to be useable as long as at least 50 percent of the adult household members completed an over-the-phone interview.

For the process of collecting data, travel diaries were mailed to eligible households and members of the household were assigned a specific travel day on which they were to record their travel activities. The households were then contacted by trained interviewers to gain information on their travel activities. Surveyed drivers were asked to provide information on travel, including the number of miles they drove on their travel day and the number of miles they had traveled in the past year. For the number of miles traveled in the past year, data showed that many of the surveyed drivers provided an estimate of how much they had driven.

NHTS data were filtered to focus only on Texas drivers and were grouped into five-year increments, as shown in Table 4.

Table 4. 2009 NHTS data for Texas drivers[a]

Age Group	Number of Interviewed Drivers (2009)	Average Annual Miles Driven by the Interviewed Texas Drivers
15–19	917	6,076
20–24	666	12,755
25–29	954	15,248
30–34	1381	15,775
35–39	1810	16,136
40–44	2166	16,014
45–49	2803	16,249
50–54	3465	15,797
55–59	3362	14,619
60–64	3316	13,248
65–69	2774	11,125
70–74	2274	9,288
75–79	1692	7,514
80–84	1034	5,983
>85	320	4,662
Grand Total or Average	**28,934**	**12,033**

[a] Texas drivers, averaged over a five-year increment. Source: (*8*).

In addition to the NHTS data, a secondary data source was used to obtain the total number of drivers in Texas. This information was from the U.S. Department of Transportation and included the number of licensed drivers by age, as shown in Table 5.

Using both sources of Texas driver data, the research team calculated the total annual miles traveled by each age group. Table 6 displays the miles traveled and the percentage of miles of the grand total. Figure 9 illustrates Texas population by age group along with percent of the age group with a driver's license.

Table 5. Distribution of Texas population and licensed drivers by age group, 2010 data

Age Group	Licensed Drivers within Texas[a]	Age Distribution of License Holders (%)	Population within Texas[b]	Eligible Population with License (%)
<15	0	0%	5,738,590	0%
15 to 19	713,345	5%	1,883,124	38%
20 to 24	1,351,199	9%	1,817,079	74%
25 to 29	1,412,464	9%	1,853,039	76%
30 to 34	1,412,465	9%	1,760,434	80%
35 to 39	1,456,426	10%	1,763,587	83%
40 to 44	1,434,245	9%	1,694,795	85%
45 to 49	1,505,030	10%	1,760,467	85%
50 to 54	1,467,250	10%	1,674,869	88%
55 to 59	1,269,222	8%	1,422,924	89%
60 to 64	1,050,538	7%	1,174,767	89%
65 to 69	747,331	5%	853,100	88%
70 to 74	524,071	3%	619,156	85%
75 to 79	384,675	3%	477,245	81%
80 to 84	257,100	2%	347,206	74%
>84	172,289	1%	305,179	56%
Grand Total	**15,157,650**	**100%**	**25,145,561**	**78%**

[a] Source: Total number of licensed drivers in Texas in 2010, by age. In Statista - The Statistics Portal (*9*).
[b] U.S. Census Bureau. Annual Estimates of the Resident Population for Selected Age Groups for Texas in 2010 (*10*).

Table 6. Annual miles driven by age group, Texas data

Age Group	Average Annual Miles Driven[a]	Number of Licensed Drivers[b]	Total Annual Miles	Total Miles Driven (%)
15–19	6076	713,345	4,334,284,220	2%
20–24	12,755	1,351,199	17,234,543,245	8%
25–29	15,248	1,412,464	21,537,251,072	10%
30–34	15,775	1,412,465	22,281,635,375	11%
35–39	16,136	1,456,426	23,500,889,936	11%
40–44	16,014	1,434,245	22,967,999,430	11%
45–49	16,249	1,505,030	24,455,232,470	12%
50–54	15,797	1,467,250	23,178,148,250	11%
55–59	14,619	1,269,222	18,554,756,418	9%
60–64	13,248	1,050,538	13,917,527,424	7%
65–69	11,125	747,331	8,314,057,375	4%
70–74	9288	524,071	4,867,571,448	2%
75–79	7514	384,675	2,890,447,950	1%
80–84	5983	257,100	1,538,229,300	1%
>84	4662	172,289	803,211,318	0%
Grand Total	**12,033**	**15,157,650**	**210,375,785,231**	**100%**

[a] Texas drivers, average over a five-year increment. Source: (*8*).
[b] Source: (*9*).

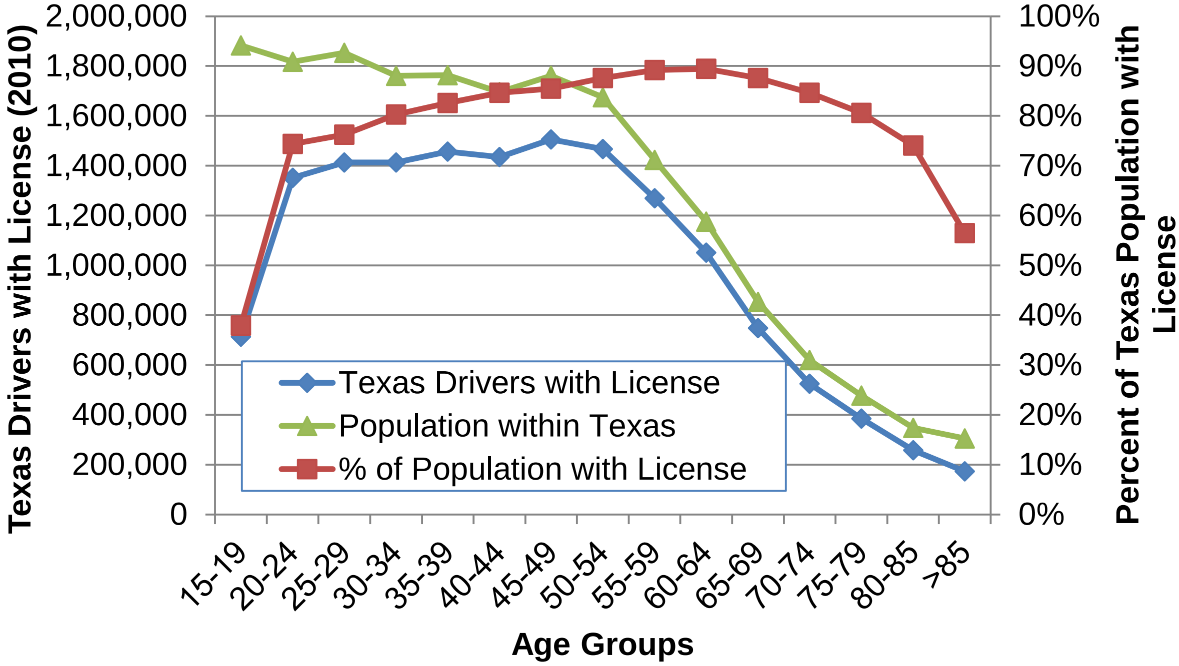


Figure 9. Number and percent of Texas drivers with license (2010 data)

CHAPTER 4: DATA ANALYSIS

There are many factors that could be associated with a right-turn crash. Since the objective of this study was to determine if there is an association between right-turn crashes and a driver's age, select variables were considered in the analysis, including driver age, right-turn treatment type, and right-turn treatment characteristics.

RIGHT-TURN TREATMENT TYPE

The number of drivers involved in right-turn-related crashes by right-turn treatment type is listed in Table 7. To provide an appreciation for the distribution of drivers by age group, Table 8 lists the percent of drivers within each age group and Figure 10 shows a plot of the data. In terms of right-turn treatment type, a noticeable trend shown in Figure 10 is that younger drivers for all right-turn treatment types have disproportionately more crashes than middle-age or older drivers. The plot clearly shows that the right-turn treatment curves are above the miles driven curve (black dashed line) for drivers younger than 30 years old. For example, drivers who are between 20 and 24 years old represent 15 percent of all drivers involved in right-turn-related crashes (see final column in Table 8) while only driving 8 percent of all miles driven (see final column in Table 6).

Another way to illustrate potential trends is to calculate involvement rates by incorporating miles driven and number of approaches. As noted by Hauer (*11*), this normalization equalizes differences in intensity of use, thus making comparisons more meaningful, and can help identify differences between different populations' characteristic crash rates. Figure 11 illustrates the number of drivers involved in crashes per approach per billion miles driven for the different right-turn treatment types by the different age groups.

The trends in percentage of drivers involved in right-turn-related crashes by the different right-turn treatment types (see Figure 10) are similar and appear to be different from the distribution of miles driven. A chi-square test of independence was performed to determine whether the distribution of right-turn-related crashes was the same as the distribution of miles driven. It is important to note that the chi-square test should always be conducted using the actual number of cases, rather than the percentages. The researchers used open source software (*12*) to perform the test, and Table 9 lists the results. The results support the observation that the distribution of miles driven is different from the distribution of age of drivers involved in right-turn-related crashes.

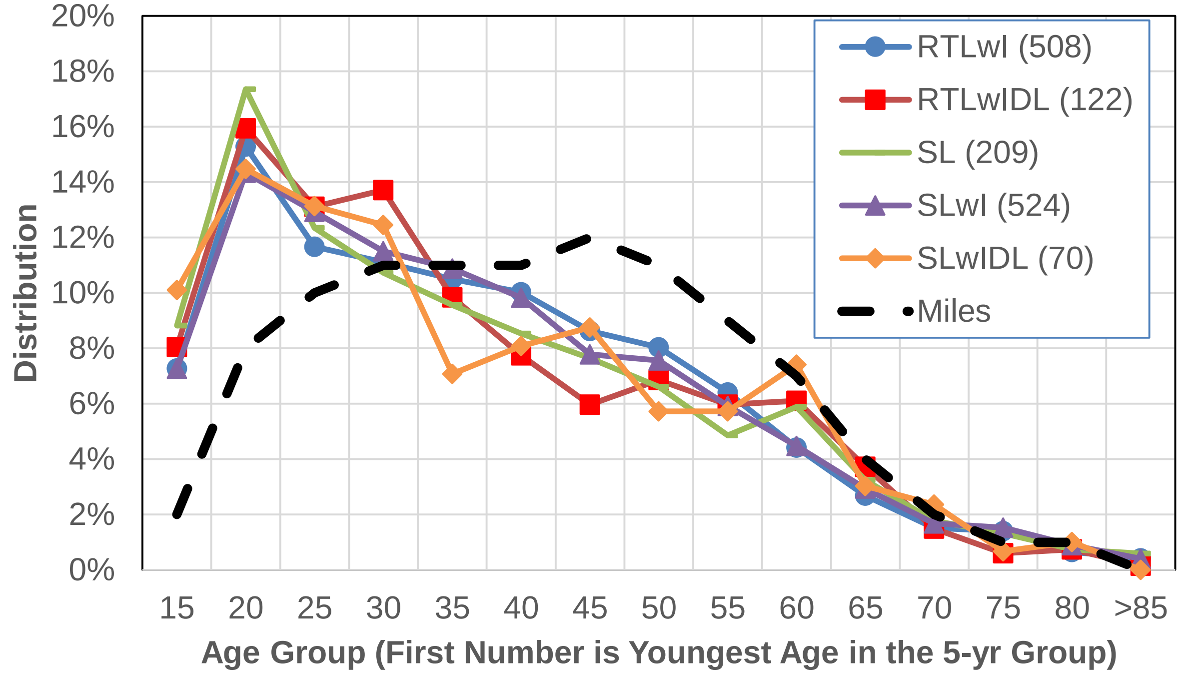
Table 7. Number of drivers involved in right-turn-related crashes by driver age group and right-turn treatment type

Driver's Age	RTLwI	RTLwIDL	SL	SLwI	SLwIDL	Total
15–19	260	54	60	195	30	599
20–24	546	107	118	385	43	1199
25–29	417	88	84	347	39	975
30–34	397	92	73	309	37	908
35–39	375	66	65	292	21	819
40–44	358	52	58	264	24	756
45–49	308	40	52	209	26	635
50–54	287	46	45	203	17	598
55–59	229	40	33	159	17	478
60–64	158	41	40	120	22	381
65–69	96	25	22	79	9	231
70–74	54	10	12	45	7	128
75–79	50	4	9	41	2	106
80–84	23	5	5	24	3	60
>84	15	1	4	11	0	31
Total	**3573**	**671**	**680**	**2687**	**297**	**7904**

Table 8. Percent of drivers involved in right-turn-related crashes by driver age group and right-turn treatment type

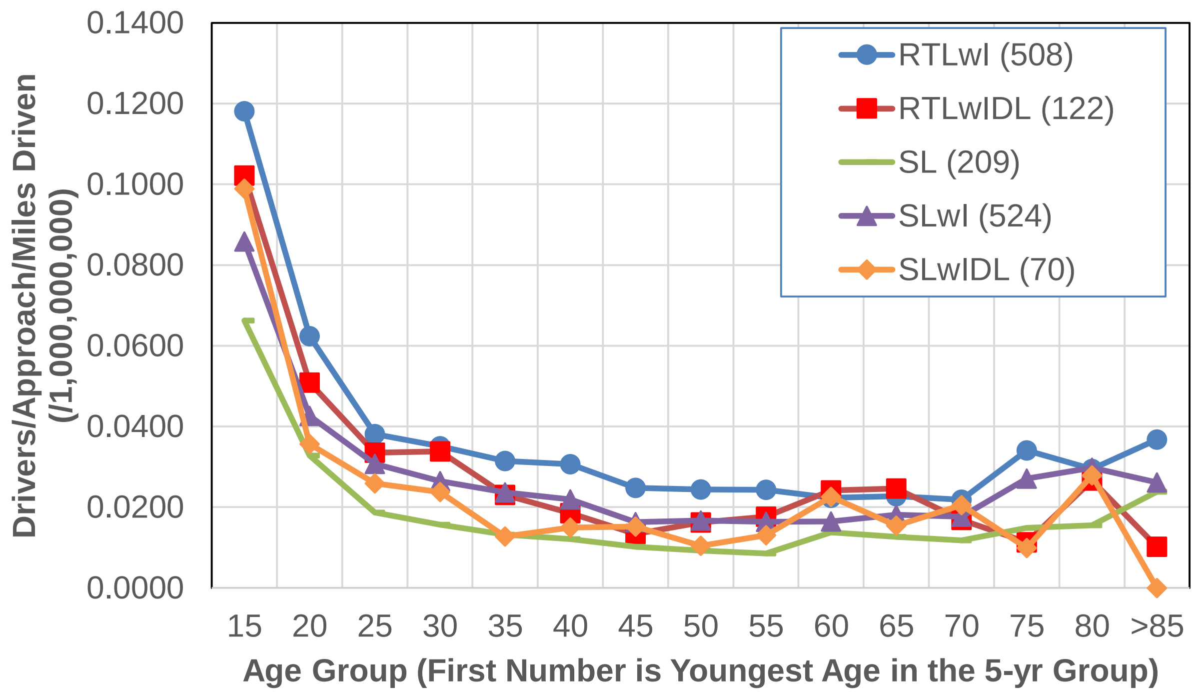
Driver's Age	RTLwI	RTLwIDL	SL	SLwI	SLwIDL	Total
15–19	7%	8%	9%	7%	10%	8%
20–24	15%	16%	17%	14%	14%	15%
25–29	12%	13%	12%	13%	13%	12%
30–34	11%	14%	11%	12%	12%	11%
35–39	10%	10%	10%	11%	7%	10%
40–44	10%	8%	9%	10%	8%	10%
45–49	9%	6%	8%	8%	9%	8%
50–54	8%	7%	7%	8%	6%	8%
55–59	6%	6%	5%	6%	6%	6%
60–64	4%	6%	6%	4%	7%	5%
65–69	3%	4%	3%	3%	3%	3%
70–74	2%	1%	2%	2%	2%	2%
75–79	1%	1%	1%	2%	1%	1%
80–84	1%	1%	1%	1%	1%	1%
>84	0%[a]	0%	1%	0%	0%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

[a] Decimal rounding can cause a nonzero value to be rounded to a zero.



Note: Legend provides the number of approaches for the right-turn treatment type in parentheses.

Figure 10. Distribution of drivers by miles driven and right-turn treatment type for right-turn-related crashes



Note: Legend provides the number of approaches for the right-turn treatment type in parentheses.

Figure 11. Driver involvement rate by right-turn treatment type

Table 9. Chi-square test results for comparison of number of drivers involved in right-turn-related crashes and miles driven

Chi-Square Test Results	Miles Driven versus Drivers in Right-Turn-Related Crashes at Approaches with the Following Right-Turn Treatment					
	All	**RTLwI**	**RTLwIDL**	**SL**	**SLwI**	**SLwIDL**
χ^2	367.81	354.29	359.8	381.17	319.66	297.84
p-value	2.20E-16	2.20E-16	2.20E-16	2.20E-16	2.20E-16	2.20E-16

Chi-square tests were also performed to investigate the difference between distributions of drivers for different right-turn treatment types. The results shown in Table 10 support the observation that distributions of drivers are not significantly different for different right-turn treatment types. In other words, older Texas drivers are similarly involved in crashes for each type of right-turn treatment.

Table 10. Chi-square test results for comparison of number of drivers involved in right-turn-related crashes and different right-turn treatments

Chi-Square Test Results	RTLwI versus SLwI	RTLwIDL versus SLwI	SL versus RTLwI	SL versus RTLwIDL
χ^2	8.09	8.50	14.92	7.25
p-value	0.84	0.81	0.31	0.89

INTERSECTION CRASHES

The review of the distribution of age for drivers involved in right-turn-related crashes by type of right-turn treatment found similar patterns for each type of right-turn treatment—younger drivers are having a disproportionate number of crashes. All crashes at the intersections were also reviewed to determine if a similar trend of younger drivers having a disproportionate number of crashes is also present when considering all intersection crashes. Table 11 provides the number of intersection crashes by driver age group and right-turn treatment type, while Table 12 provides the proportions and Figure 12 graphs the results. Figure 13 shows the age group distribution for drivers involved in all intersection and in right-turn-related crashes per 1 billion miles driven. The curve based on intersection crashes shows the expected shape of higher rates for the youngest and oldest groups. A similar trend for the curve based on right-turn-related crashes is not as obvious because of the scale of the graph; however, the trend is present—younger and older drivers have a higher crash rate compared to middle-age drivers. The percentage of change in drivers involved in crashes increased for drivers aged 65 and above versus drivers aged 35–64 (7 percent for intersection crashes and 11 percent for right-turn-lane related crashes). The number of middle-age drivers in right-turn-related crashes was 0.0202 drivers per approach per 1 billion miles driven compared to 0.0225 older drivers per approach per 1 billion miles driven.

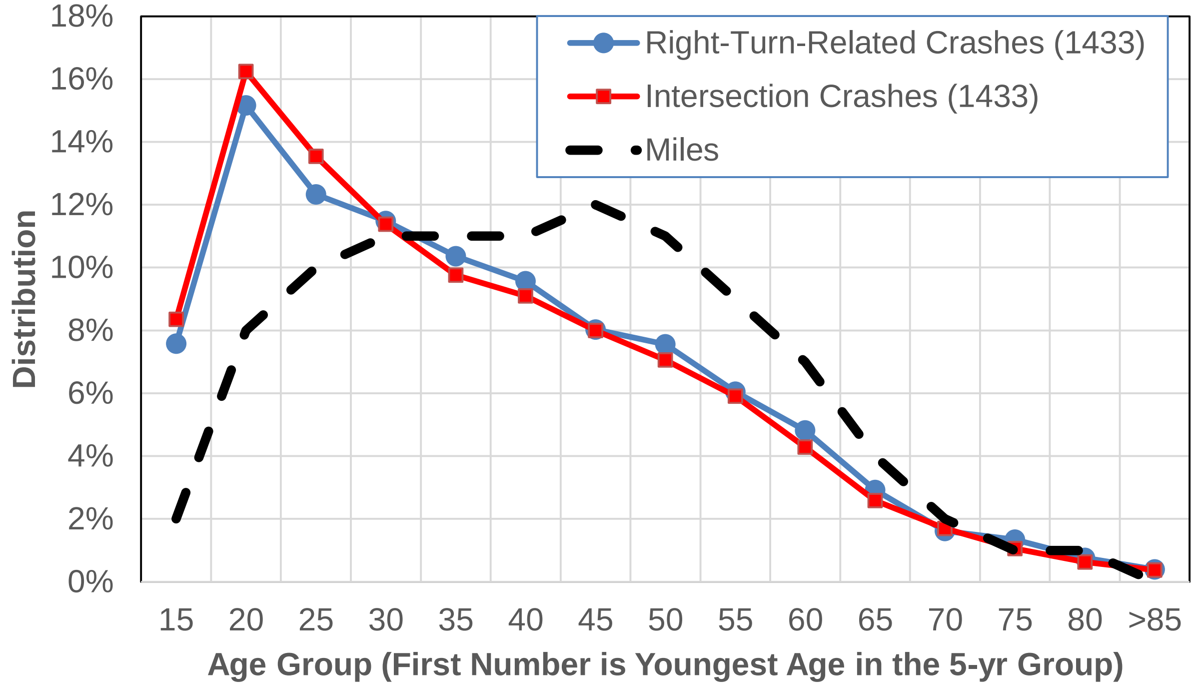
Table 11. Number of drivers involved in intersection crashes by driver age group and right-turn treatment

Driver's Age	RTLwI	RTLwIDL	SL	SLwI	SLwIDL	Total
15–19	2885	691	1008	2362	368	7314
20–24	5707	1345	1975	4599	597	14,223
25–29	4731	1089	1472	4085	478	11,855
30–34	3934	959	1207	3478	386	9964
35–39	3379	814	1036	3025	296	8550
40–44	3254	690	993	2711	318	7966
45–49	2855	602	890	2376	279	7002
50–54	2472	531	744	2174	264	6185
55–59	2093	449	622	1800	212	5176
60–64	1473	327	475	1312	166	3753
65–69	884	204	273	806	100	2267
70–74	576	120	177	540	77	1490
75–79	352	66	117	341	45	921
80–84	198	46	62	208	32	546
>84	113	23	61	112	17	326
Total	**34,906**	**7956**	**11,112**	**29,929**	**3635**	**87,538**

Table 12. Percent of drivers involved in intersection crashes by driver age group and right-turn treatment

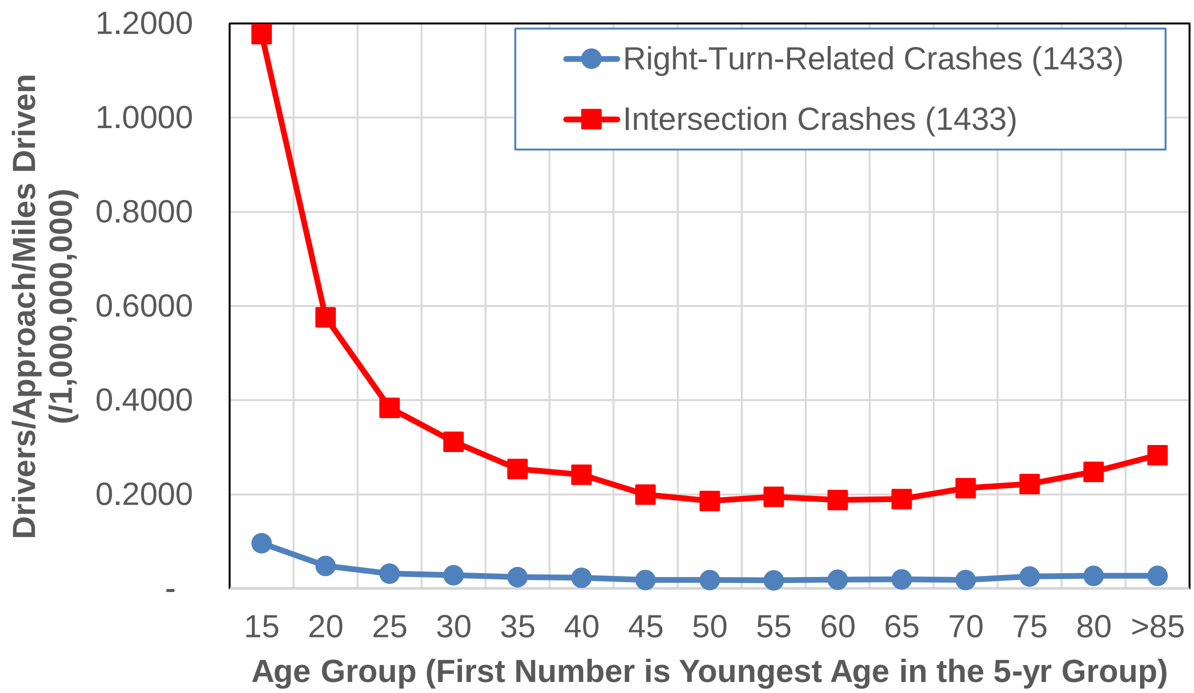
Driver's Age	RTLwI	RTLwIDL	SL	SLwI	SLwIDL	Total
15–19	8%	9%	9%	8%	10%	8%
20–24	16%	17%	18%	15%	16%	16%
25–29	14%	14%	13%	14%	13%	14%
30–34	11%	12%	11%	12%	11%	11%
35–39	10%	10%	9%	10%	8%	10%
40–44	9%	9%	9%	9%	9%	9%
45–49	8%	8%	8%	8%	8%	8%
50–54	7%	7%	7%	7%	7%	7%
55–59	6%	6%	6%	6%	6%	6%
60–64	4%	4%	4%	4%	5%	4%
65–69	3%	3%	2%	3%	3%	3%
70–74	2%	2%	2%	2%	2%	2%
75–79	1%	1%	1%	1%	1%	1%
80–84	1%	1%	1%	1%	1%	1%
>84	0%[a]	0%	1%	0%	0%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

[a] Decimal rounding can cause a nonzero value to be rounded to a zero.



Note: Legend provides the number of approaches in parentheses.

Figure 12. Distribution of drivers by miles driven and by intersection or right-turn-related crashes



Note: Legend provides the number of approaches in parentheses.

Figure 13. Driver involvement rate for intersection and right-turn-related crashes

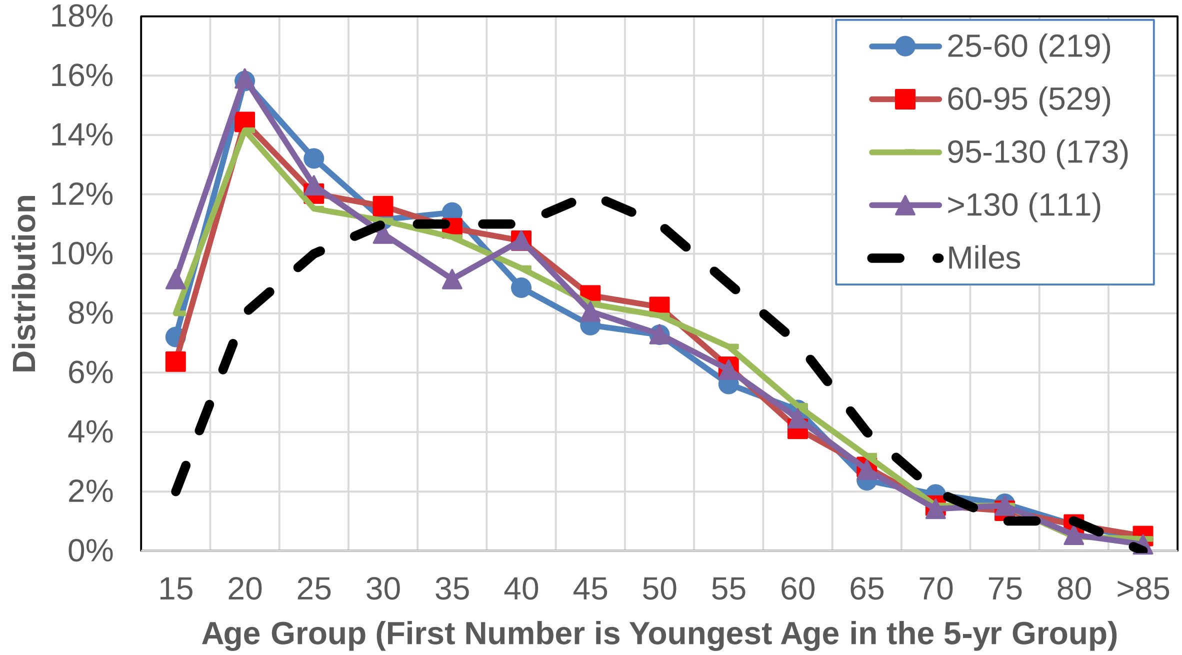
CORNER RADIUS

The radius for the right-turn lane was measured for those approaches with a channelized right-turn island. The results were reviewed by right-turn lane treatments and by grouping the treatments by presence of island or presence of upstream or downstream dedicated lane. Table 13 provides the number and percentage of drivers involved in right-turn-related crashes by the right-turn radius group for those approaches with a channelized island and without a downstream dedicated lane. Figure 14 illustrates the distribution of drivers for different corner radius, and Figure 15 shows the data by driver involvement rate.

Table 13. Number and percentage of drivers involved in right-turn-related crashes by driver age group and right-turn radius for approaches with a channelized island and without a downstream dedicated lane (i.e., RTLwI and SLwI)

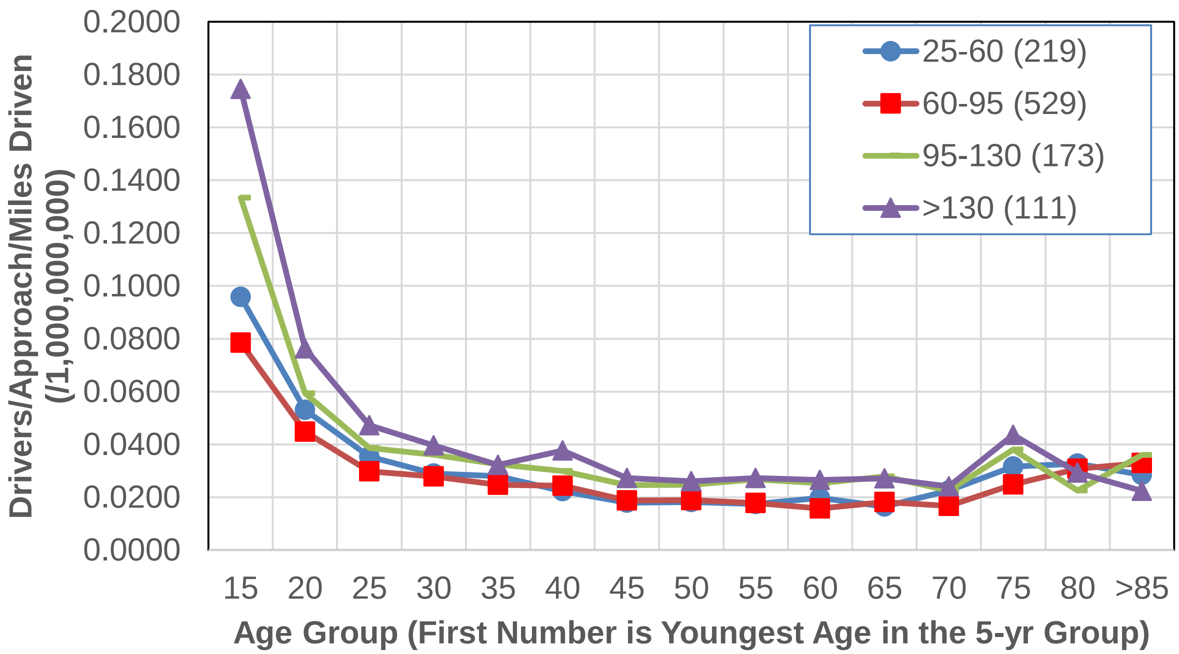
Driver Age	Number of Drivers Involved in Right-Turn-Related Crashes by Right-Turn Radius When Channelized Island Is Present					Percent of Drivers Involved in Right-Turn-Related Crashes by Right-Turn Radius When Channelized Island Is Present				
	25–60 ft	**60–95 ft**	**95–130 ft**	**>130 ft**	**Grand Total**	**25–60 ft**	**60–95 ft**	**95–130 ft**	**>130 ft**	**Grand Total**
15–19	91	180	100	84	**455**	7%	6%	8%	9%	**7%**
20–24	200	408	177	146	**931**	16%	14%	14%	16%	**15%**
25–29	167	340	144	113	**764**	13%	12%	12%	12%	**12%**
30–34	141	328	139	98	**706**	11%	12%	11%	11%	**11%**
35–39	144	307	132	84	**667**	11%	11%	11%	9%	**11%**
40–44	112	295	119	96	**622**	9%	10%	10%	10%	**10%**
45–49	96	243	104	74	**517**	8%	9%	8%	8%	**8%**
50–54	92	232	99	67	**490**	7%	8%	8%	7%	**8%**
55–59	71	175	86	56	**388**	6%	6%	7%	6%	**6%**
60–64	60	116	61	41	**278**	5%	4%	5%	4%	**4%**
65–69	30	80	40	25	**175**	2%	3%	3%	3%	**3%**
70–74	24	43	19	13	**99**	2%	2%	2%	1%	**2%**
75–79	20	38	19	14	**91**	2%	1%	2%	2%	**1%**
80–84	11	25	6	5	**47**	1%	1%	0%	1%	**1%**
>84	5	14	5	2	**26**	0%[a]	0%	0%	0%	**0%**
Total	**1264**	**2824**	**1250**	**918**	**6256**	**100%**	**100%**	**100%**	**100%**	**100%**

[a] Decimal rounding can cause a nonzero value to be rounded to a zero.



Note: Legend provides the number of approaches by right-turn radius in parentheses.

Figure 14. Distribution of drivers by miles driven and by channelized right-turn radius for right-turn-related crashes



Note: Legend provides the number of approaches by right-turn radius in parentheses.

Figure 15. Driver involvement rate for right-turn-related crashes by radius of channelized right turn

A review of the data implies that the age of the driver involved in crashes does not vary based on the corner radius present. The plots of the age distribution shown in Figure 14 and Figure 15 are similar. For larger radii (greater than 130 ft), the driver involvement rate does show a decrease after 75 years (see purple curve with triangles in Figure 15); however, that curve is based on only a few crashes. Chi-square tests were also performed to investigate the difference between distributions of drivers for different corner radii present. The results shown in Table 14 support the observation that distributions of drivers are not significantly different for the different corner radius values.

Table 14. Chi-square test results for comparison of number of drivers involved in right-turn-related crashes and different corner radius present

Chi-Square Test Results	**25–60 ft versus 60–95 ft**	**25–60 ft versus 95–130 ft**	**25–60 ft versus >130 ft**	**60–95 ft versus 95–130 ft**	**60–95 ft versus >130 ft**	**95–130 ft versus >130 ft**
χ^2	10.89	9.72	9.71	9.19	14.79	5.83
p-value	0.71	0.78	0.78	0.82	0.39	0.97

In order to better focus on potential effects on older driver, the driver crash involvement rates for middle-age and older drivers were calculated. As shown in the final columns in Figure 16, older drivers have a higher involvement rate overall for those right-turn lane approaches with an island and no downstream dedicated lane. For each radius group, older drivers have a higher involvement rate compared to middle-age drivers. Figure 16 also illustrates that middle-age drivers may be having more difficulties with a larger corner radius. Middle-age driver involvement rates are higher for the 95- to 130-ft radius group and the greater than 130-ft radius group as compared to approaches with a radii less than 95 ft.

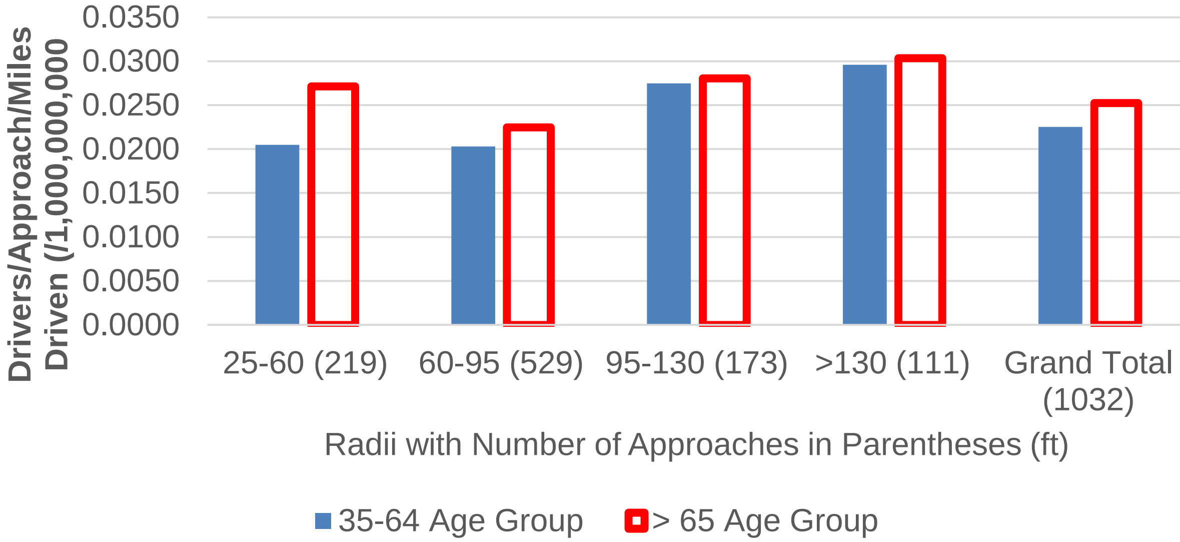


Figure 16. Driver involvement rate for middle-age and older drivers by corner radius for approaches with a channelized island and without a downstream dedicated lane (i.e., RTLwI and SLwI)

PRESENCE OF DOWNSTREAM DEPARTURE LANE

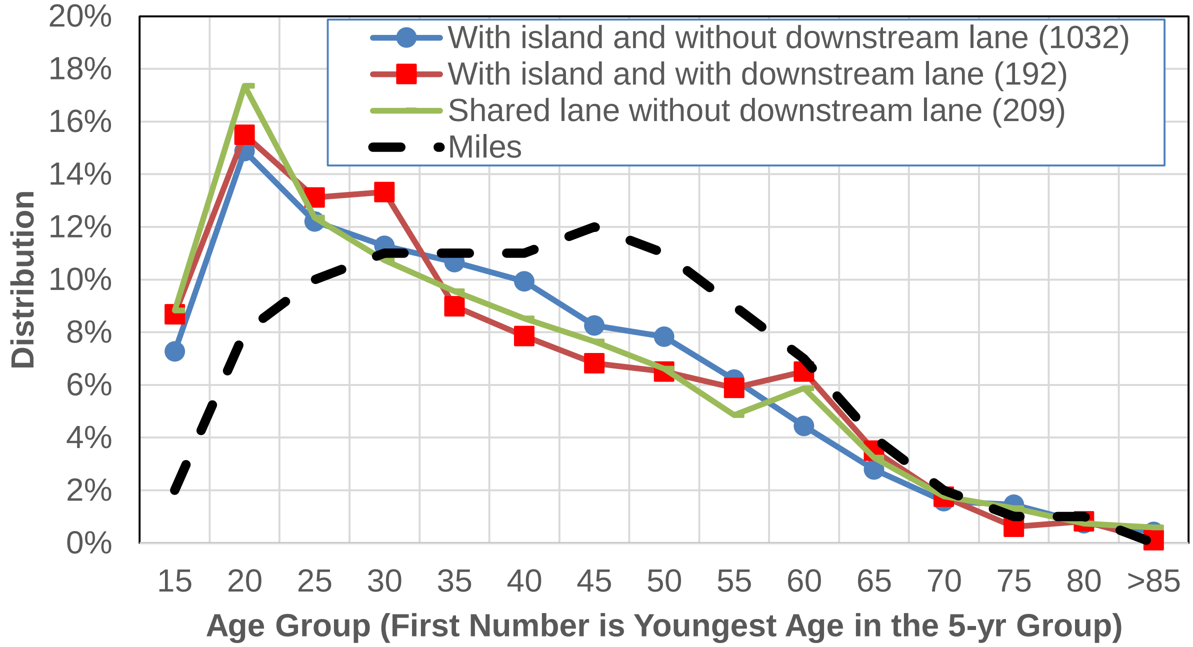
RTLwI crashes and SLwI crashes were grouped together to represent crashes that occurred when dedicated departure lanes were not present, while SLwIDL and RTLwIDL were grouped for crashes that occurred when a dedicated departure lane was present (see Table 15). Figure 17 displays the relationship between drivers involved in right-turn-related crashes and the presence of dedicated downstream lanes. Figure 18 shows the driver involvement rate by age group. The curves shown in the figure have a similar pattern and show that younger drivers are more involved in right-turn-related crashes. The similar patterns indicate that the distribution of drivers is not a function of the presence of a downstream dedicated lane.

The percentage of change in drivers involved in crashes increased (12 percent) for drivers age 65 and above versus drivers aged 35–64 for right-turn lanes with no dedicated downstream lanes. On the other hand, the percentage decreased (4 percent) for drivers aged 65 and above versus drivers aged 35–64 for right-turn lanes with dedicated downstream lanes, which could be an indication that the presence of a downstream dedicated lane is a benefit to older drivers.

Table 15. Number and percentage of drivers involved in right-turn-related crashes by driver age group and presence of island and downstream dedicated lane

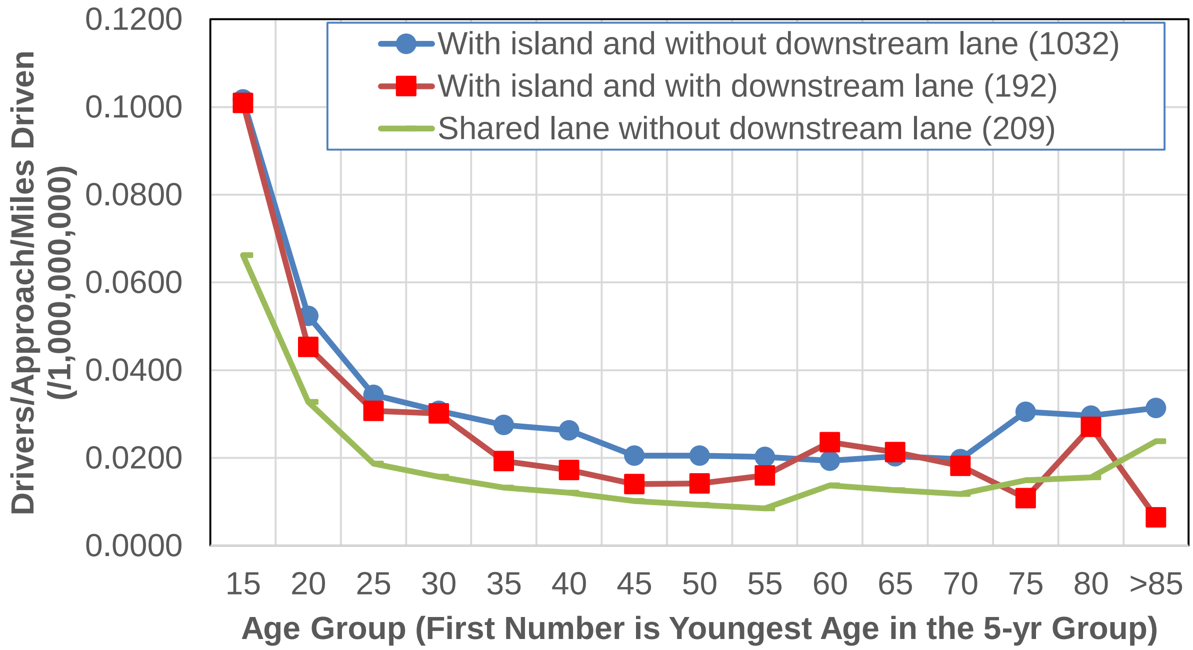
Driver Age	Number of Drivers Involved in Right-Turn-Related Crashes by Presence of Island and Downstream Dedicated Lane				Percent of Drivers Involved in Right-Turn-Related Crashes by Presence of Island and Downstream Dedicated Lane			
	RTLwI and SLwI	RTLwIDL and SLwIDL	SL	Grand Total	RTLwI and SLwI	RTLwIDL and SLwIDL	SL	Grand Total
15–19	455	84	60	599	7%	9%	9%	8%
20–24	931	150	118	1199	15%	15%	17%	15%
25–29	764	127	84	975	12%	13%	12%	12%
30–34	706	129	73	908	11%	13%	11%	11%
35–39	667	87	65	819	11%	9%	10%	10%
40–44	622	76	58	756	10%	8%	9%	10%
45–49	517	66	52	635	8%	7%	8%	8%
50–54	490	63	45	598	8%	7%	7%	8%
55–59	388	57	33	478	6%	6%	5%	6%
60–64	278	63	40	381	4%	7%	6%	5%
65–69	175	34	22	231	3%	4%	3%	3%
70–74	99	17	12	128	2%	2%	2%	2%
75–79	91	6	9	106	1%	1%	1%	1%
80–84	47	8	5	60	1%	1%	1%	1%
>84	26	1	4	31	0%[a]	0%	1%	0%
Total	**6256**	**968**	**680**	**7904**	**100%**	**100%**	**100%**	**100%**

[a] Decimal rounding can cause a nonzero value to be rounded to a zero.



Note: Legend provides the number of approaches in parentheses.

Figure 17. Distribution of drivers by miles driven and by presence of downstream lane for right-turn-related crashes



Note: Legend provides the number of approaches in parentheses.

Figure 18. Distribution of drivers involved in right-turn-related crashes by presence of dedicated downstream lane

WIDTH OF ISLAND

Several other intersection characteristics were investigated to try to obtain additional insights into the relationships between right-turn treatment characteristics and the age of drivers involved in right-turn or intersection crashes. The width of the channelized island when a downstream dedicated lane was not present provided potentially interesting findings. The longer island widths were associated with a larger angle between the turning driver and the approaching vehicles, a characteristic that could generate difficulties for older drivers because of the amount of head turn needed to merge. Figure 19 shows one of the study approaches with a long island width. The estimated angle between the turning vehicle and the oncoming major-road vehicles is about 150 degrees.

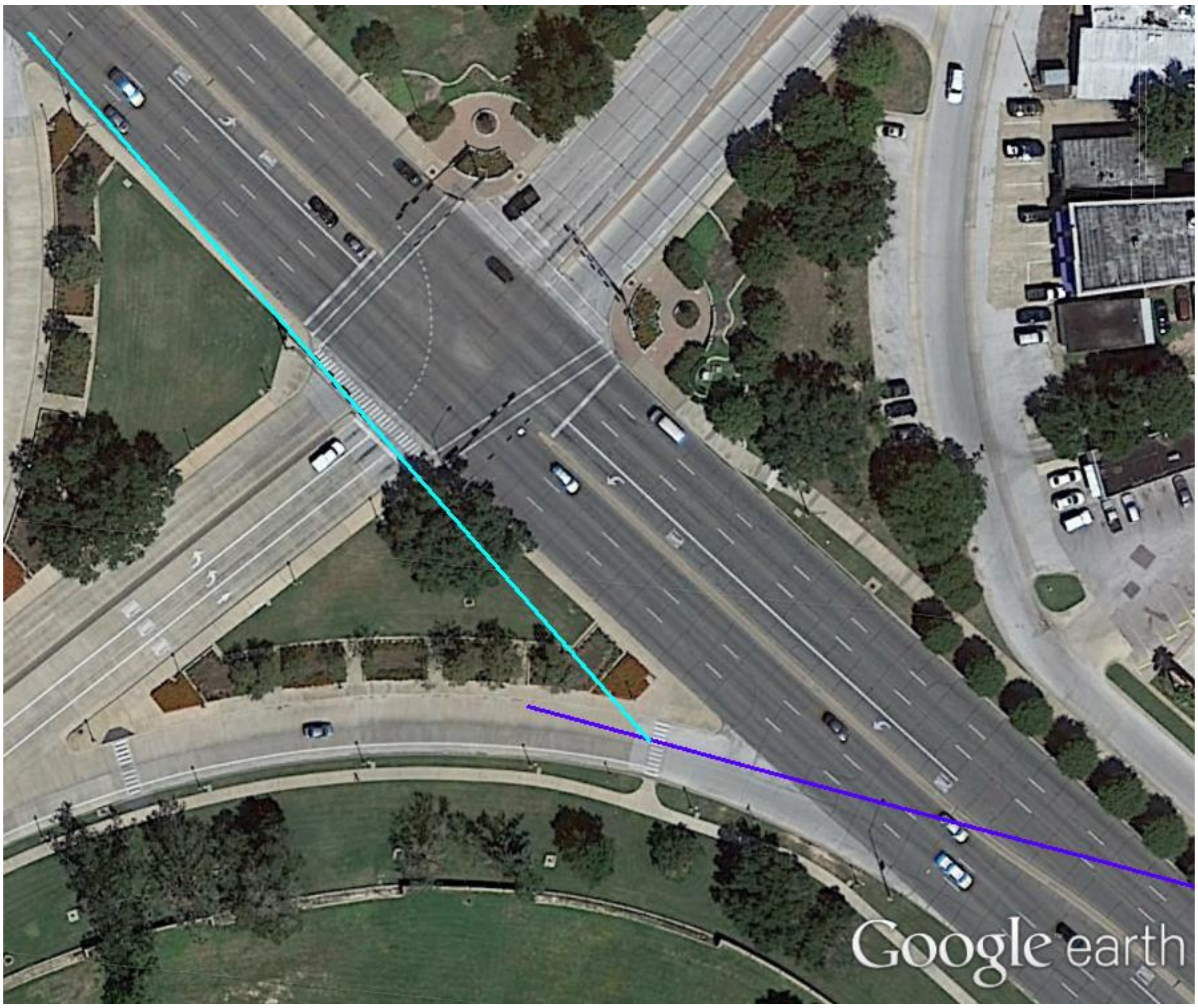
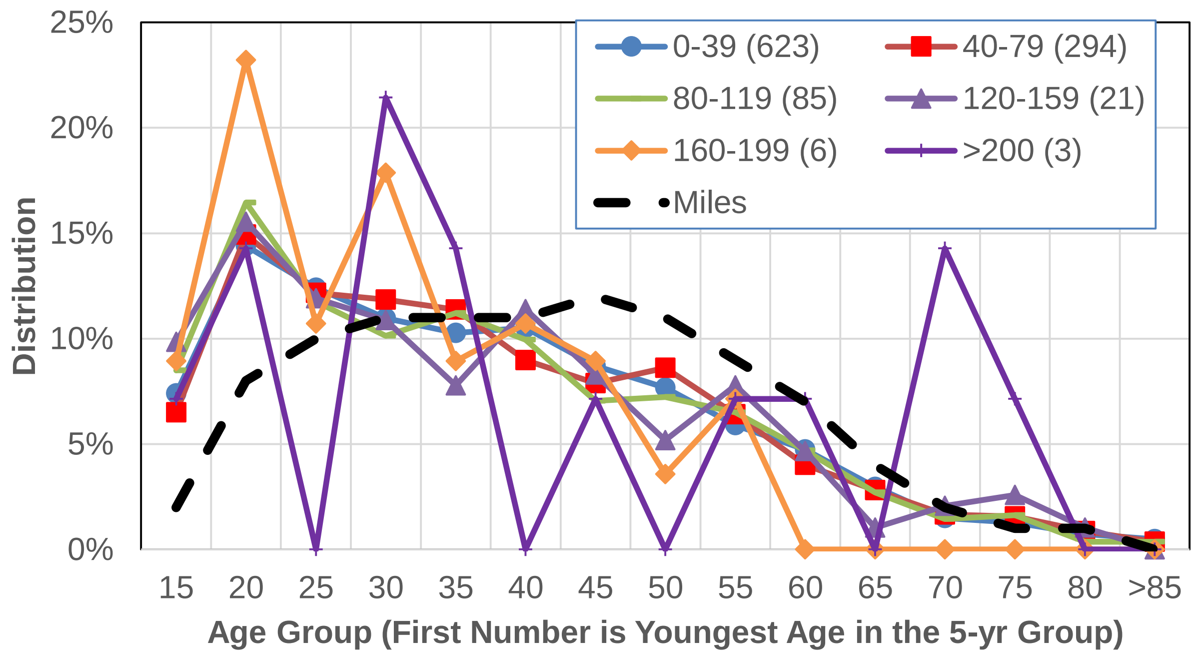


Figure 19. Example of one of the approaches with a long island width

Figure 19 illustrates a challenge with determining where a vehicle may be stopping if it is stopping in the right-turn lane. The vehicle may be stopping at the crosswalk or much nearer to the merge point.

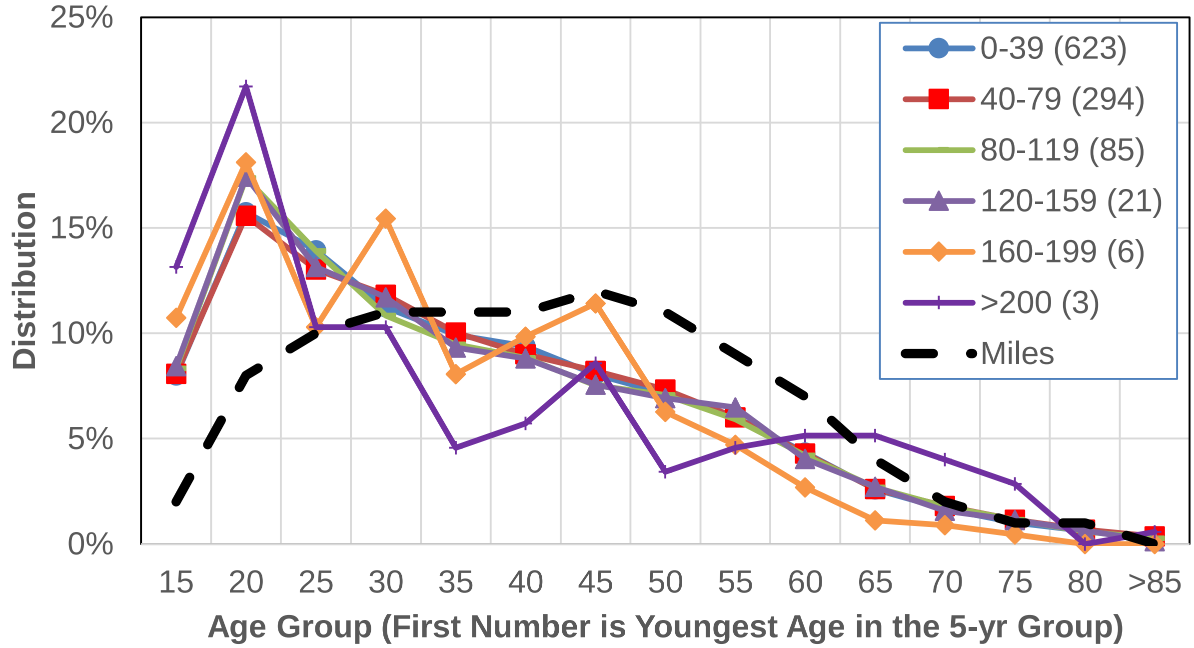
A review of the plots for right-turn-related crashes indicated that longer island widths might be associated with a greater proportion of older-driver crashes. As shown in Figure 20, the plots of the data for island widths greater than 200 ft appear to exceed the miles driven curve for older drivers. The sample size of only three approaches limits this observation, so the results of all intersection crashes were also reviewed. The distribution of all intersection crashes by island width groups is shown in Figure 21 and Table 16, with the number of drivers listed in Table 17. With the greater amount of data, the trend of more older drivers being involved in crashes on approaches with a wide channelized island is more obvious (see purple curve with plus symbols in Figure 21; the curve is above the miles driven curve for the 65- to 80-year-old groups).



Note: Legend provides the number of approaches for the width of the channelized island in parentheses.

Figure 20. Distribution of drivers by miles driven and by width of channelized right-turn island for right-turn-related crashes at approaches without a dedicated downstream lane

Using all crashes rather than only right-turn-related crashes does introduce another caution. This finding may be the result of other intersection characteristics that are typically present when a large channelized island is present, such as high speeds on the approach or the presence of a high turning volume. Additional investigation is needed to be able to conclusively say that the size of the island is the reason for the higher crash involvement of older drivers.



Note: Legend provides the number of approaches for the width of the channelized island in parentheses.

Figure 21. Distribution of drivers by miles driven and by width of channelized right-turn island for intersection crashes at approaches without a dedicated downstream lane

Table 16. Percent of drivers involved in intersection crashes by driver age group and width of channelized island (ft)

Driver's Age	0–39 ft	40–79 ft	80–119 ft	120–159 ft	160–199 ft	>200 ft	Grand Total
15–19	8%	8%	8%	8%	11%	13%	**8%**
20–24	16%	16%	17%	17%	18%	22%	**16%**
25–29	14%	13%	14%	13%	10%	10%	**14%**
30–34	11%	12%	11%	12%	15%	10%	**11%**
35–39	10%	10%	9%	9%	8%	5%	**10%**
40–44	9%	9%	9%	9%	10%	6%	**9%**
45–49	8%	8%	8%	8%	11%	9%	**8%**
50–54	7%	7%	7%	7%	6%	3%	**7%**
55–59	6%	6%	6%	6%	5%	5%	**6%**
60–64	4%	4%	4%	4%	3%	5%	**4%**
65–69	3%	3%	3%	3%	1%	5%	**3%**
70–74	2%	2%	2%	2%	1%	4%	**2%**
75–79	1%	1%	1%	1%	0%	3%	**1%**
80–84	1%	1%	1%	1%	0%	0%	**1%**
>84	0%[a]	0%	0%	0%	0%	1%	**0%**
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

[a] Decimal rounding can cause a nonzero value to be rounded to a zero.

Table 17. Number of drivers involved in intersection crashes by driver age group and width of channelized island (ft)

Driver's Age	**0–39 ft**	**40–79 ft**	**80–119 ft**	**120–159 ft**	**160–199 ft**	**>200 ft**	**Grand Total**
15–19	2985	1627	428	134	48	23	**5245**
20–24	5880	3135	891	277	81	38	**10,302**
25–29	5203	2623	714	209	46	18	**8813**
30–34	4194	2382	556	186	69	18	**7405**
35–39	3705	2019	486	148	36	8	**6402**
40–44	3503	1812	453	140	44	10	**5962**
45–49	3001	1654	386	120	51	15	**5227**
50–54	2661	1476	363	110	28	6	**4644**
55–59	2247	1209	304	103	21	8	**3892**
60–64	1618	864	216	64	12	9	**2783**
65–69	966	526	138	43	5	9	**1687**
70–74	623	364	91	25	4	7	**1114**
75–79	378	230	59	18	2	5	**692**
80–84	228	137	30	10	0	0	**405**
>84	136	71	14	2	0	1	**224**
Total	**37,328**	**20,129**	**5129**	**1589**	**447**	**175**	**64,797**

CHAPTER 5: CONCLUSIONS

SUMMARY AND CONCLUSIONS

The objective of this research was to determine if a relationship exists between crashes and right-turn lane design characteristics with specific consideration of the age of the driver. The research team used crash data for 1433 intersection approaches in Texas for a six-year period (2009–2014) to perform this study. An examination of the age distribution of drivers by miles driven and by involvement in right-turn-related (or intersection) crashes showed that younger drivers were involved in more crashes despite driving less than older age groups. This could be representative of the inexperience or the likelihood of risk-taking behaviors of younger drivers.

The right-turn lane characteristics that were examined included right-turn treatment type, presence of a dedicated departure lane, corner radius, and width of the channelized island. The types of right-turn lane treatments considered for analysis included shared lane (without an island), shared lane with an island, shared lane with an island and dedicated downstream lane, right-turn lane with an island, and right-turn lane with an island and dedicated downstream lane. For most of the comparisons, the distribution of drivers by age showed similar patterns regardless of the type of right-turn treatment or other right-turn lane characteristic studied—younger drivers are having a disproportional number of crashes.

In order to better focus on potential effects on older driver, focus shifted to comparing older drivers (age 65 and over) and middle-age drivers (aged 35–64) rather than older drivers and younger drivers. From those examinations, the research team found that the presence of a downstream dedicated lane is associated with a lower driver crash involvement rate for older drivers compared to middle-age drivers.

Based on a review of the potential relationships between corner radius and driver involvement, older drivers consistently have a higher involvement rate compared to middle-age drivers. The results also illustrate that middle-age drivers may be having more difficulties with larger corner radii. Middle-age driver involvement rates were higher for the 95- to 130-ft radius group and the greater than 130-ft radius group as compared to approaches with a radii less than 95 ft.

This project identified a potential relationship between island width and older-driver crashes (see Figure 21, which shows that drivers 65 and older may be having a disproportional number of intersection crashes). While this observation was based on grouping the data by width of the channelized island, the width of the island may be serving as a surrogate for other characteristics of those approaches. For example, approaches with long island widths may also always have high traffic volumes or high speeds. While the exact relationship cannot be determined with the data available, there is sufficient evidence—in the opinion of the authors—to justify additional investigation into the relationship(s) between island design and crashes.

FUTURE RESEARCH

The research team suggests that the following be considered in future research. The crash data within this project can be better refined to ensure that the identified crashes are representative of crashes that should be attributed to the right-turn lane design. This task would involve a more detailed look into a sample of the crashes identified as being right-turn related. Also, approaches without a channelized right-turn lane could be compared to approaches with channelized right-turn lanes to better understand the role that the intersection design may have on crashes.

Further analysis can also be conducted with average daily traffic to observe other potential trends. The lack of right-turn lane volume would be limiting.

Expanding the study to include more sites and other Texas cities could benefit the research by providing more data. The study could also be expanded outside of Texas to allow comparisons between states.

The distribution of drivers by width of the channelized island (measured along the receiving roadway) when a downstream dedicated lane did not exist did indicate that longer channelized islands may be associated with older drivers having more crashes. A larger sample size or a different study approach, such as a before-after approach, might be needed to verify this observation. A field investigation along with a safety before-after study could also illustrate whether older drivers have greater difficulties or compensate for the difficulties by positioning their vehicles differently on approaches or, perhaps, avoiding these intersections.

REFERENCES

1 K. Fitzpatrick, M. D. Wooldridge, and J. D. Blaschke (2005). *Urban Intersection Design Guide*. FHWA/TX-05/0-4365-P2.

2 M. Brewer, D. Murillo, and A. Pate (2014). *A Handbook for Designing Roadways for the Aging Population*. FHWA-SA-14-015.

3 D. W. Harwood, K. M. Bauer, I. B. Potts, D. J. Torbic, K. R. Richard, E. R. Kohlman Rabbani, E. Hauer, L. Elefteriadou, and M. S. Griffith (2002). *Safety Effectiveness of Intersection Left and Right-Turn Lanes*. FHWA-RD-02-089.

4 K. Schattler, M. Budzynski, T. Wallenfang, and R. Fuessle (2015). "Areawide Analysis of Right-Turn Crashes at Intersections with Channelized Islands." Presented at the 5th International Transportation Research Board Symposium of Highway Geometric Design, Vancouver, Canada.

5 J. Autey, T. Sayed, and M. Zaki (2012). "Safety Evaluation of Right-Turn Smart Channels Using Automated Traffic Conflict Analysis." Accident Analysis and Prevention, Vol. 45, pp. 120–130.

6 A. Al-Kaisy, S. Roefaro, and D. Veneziano (2011). "Effectiveness of Signal Control at Channelized Right-Turning Lanes: An Empirical Study." Presented at the Transportation Research Board 2011 Annual Meeting, Washington, DC.

7 I. Potts, K. Bauer, D. Torbic, and J. Ringert (2013). "Safety of Channelized Right-Turn Lanes for Motor Vehicles and Pedestrians." *Transportation Research Record: Journal of the Transportation Research Board,* No. 2398, pp. 93–100.

8 Center for Transportation Analysis (2011). 2009 National Household Travel Survey. Available at http://nhts.ornl.gov/introduction.shtml.

9 U.S. Department of Transportation, Office of Highway Policy Information (n.d.). Total Number of Licensed Drivers in Texas in 2010, by Age. Statista—The Statistics Portal. Available at http://www.statista.com/statistics/206455/total-number-of-licensed-drivers-in-texas-in-2010-by-age/.

10 U.S. Census Bureau (n.d.). Annual Estimates of the Resident Population for Selected Age Groups for Texas in 2010. Available at http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk. Accessed on December 15, 2015.

11 E. Hauer (1995). "On Exposure and Accident Rate." Traffic Engineering and Control, Vol. 36, No. 3, pp. 134–138.

12 R Core Team (2016). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Available at https://www.R-project.org/.