PUBLIC PERCEPTION OF ALTERNATIVE INTERSECTION DESIGNS

by

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Dedicated to my loving and supportive family

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ABSTRACT

Improving intersection safety and efficiency are the primary goals of alternative intersection designs. These designs seek to improve on traditional traffic control methods, often by reducing intersection conflict points, reducing or eliminating time-wasting signal phases, or both. However, public opposition to these new designs can be a large barrier to implementation of alternative intersections despite their known safety and efficiency benefits.

This study evaluated current public perception and factors influencing that perception for four alternative intersection designs - the roundabout, the restricted crossing U-turn (also known as J-turn and reduced conflict intersection), the displaced left turn (also known as the continuous flow intersection), and the diverging diamond interchange (also known as the double crossover diamond interchange).

To achieve this objective, a survey instrument was designed and distributed to a target sample of 1,000 adults residing in the State of Indiana. The survey solicited participant awareness of these designs, acceptance of a potential implementation of the design in their community, and driver confidence using the design along with participant socio-demographic data. Descriptive and inferential statistical analysis was then conducted.

The survey results indicate that residents of Indiana are not aware of designs not currently widely implemented in the state, that opposition to these rarer designs is prominent, and that drivers were generally less confident in their ability to safely navigate these unfamiliar designs. Younger respondents, male respondents, more highly educated respondents, respondents who travel more often or for farther distances, and respondents who rate their own driving ability highly are more likely to be aware, accepting, and confident using alternative designs.

The results of this study will inform future outreach efforts pertaining to alternative intersections by improving transportation agency understanding of public opinions and primary concerns regarding these designs and provide potential paths for improving public perception.

1. INTRODUCTION

1.1 Overview

Transportation systems are of fundamental importance to everyday life around the world. The quality of the local transportation network has a noticeable impact on the quality of life in a community. Transportation that is unsafe or inefficient costs a community lives, time, and money. More than 35,000 people died on highways in the United States (U.S.) in 2019 (NHTSA, 2020) and in 2017, congestion around the country was estimated to waste 8.8 billion hours of the nation's time, costing $179 billion ($2017) (Schrank et al., 2019). Improving transportation safety and efficiency is in our best interest.

One avenue to achieve this goal is by improving intersections, which present unique safety hazards and create additional delay for vehicles. More than 50% of total fatal and injury crashes in the United States happen at or close to an intersection (Federal Highway Administration, 2020). In response to the fundamental limitations of traditional designs, several 'alternative' intersection and interchange designs have emerged in recent decades. These designs aim to improve safety by reducing both crash frequency and crash severity and improve efficiency by reducing the delay drivers experience at an intersection. They have been shown to be effective in achieving these goals when used appropriately (Chilukuri et al., 2011; Edara et al., 2015; Hu et al., 2014; Hughes et al., 2010; Inman et al., 2013).

These alternative intersection designs have slowly begun to be implemented where they are warranted across the country, but a number of barriers remain, including but not limited to comparatively minimal design guidance, large right of way required by some designs, and public opposition. Of these barriers, public opposition looms largest in the minds of state transportation agencies (referred to as DOTs). On a recent survey, 86% of DOTs indicated that public opposition has hindered their efforts to implement alternative designs (National Academies of Sciences, Engineering, and Medicine, 2020). Understanding and reducing this public opposition is paramount to increasing the prevalence of alternative designs on the nation's highways.

To date, some efforts have been undertaken to try and improve understanding of general public's perception of alternative designs, but they have primarily focused on roundabouts, with a handful of studies choosing to focus on other designs. This work aims to further enhance our understanding of public opposition as it pertains to roundabouts and to expand that understanding to three additional alternative intersection designs; the restricted crossing U-turn, the displaced left turn, and the diverging diamond interchange.

1.2 Focus and Scope

1.2.1 Background

As the U.S. developed its automobile highway network throughout the 20th century, several typical designs came into common use and dominate modern roadways – the stop sign and traffic signal for intersections, and the diamond and clover-leaf shapes for freeway interchanges, with yield signs as appropriate. In response to fundamental limitations related to safety, efficiency, and capacity of these traditional designs, several initially theoretical alternative intersection designs began to emerge beginning in the 1960s. Construction of these alternative intersection designs began in the 1990s and has been steadily gaining momentum since.

However, this increase in popularity has not been uniform across alternative designs, nor across individual states. Some designs are more widely implemented than others. Different state DOTs have approached implementation of alternative intersections differently – some have very few alternative designs on their highways, while others have dozens or even hundreds. Combined, these two realities mean that depending on the location and design in question, a new alternative intersection is potentially the first of its kind in a given community.

1.2.2 Intersections of Interest

There are many alternative intersection designs that have been conceptualized and constructed; the present work focuses on four, described briefly here and in more detail in Chapter 2. The designs of interest are the roundabout (single and multilane), restricted crossing U-turn (RCUT, also known as reduced conflict intersection, J-turn, superstreet, and very similar to the Michigan left), displaced left turn (DLT, also known as the continuous flow intersection), and diverging diamond

interchange (DDI, also known as the double crossover diamond). These four designs were chosen as being among the most popular and because they were of interest to the Indiana Department of Transportation (INDOT), who funded a large portion of this project.

Roundabouts are used in place of all-way stop or signal control. In a roundabout, vehicles travel counterclockwise around a circular roadway to the desired exit. Entering traffic yields to circulating traffic (which does not stop). The geometry of the intersection reduces the potential for crashes and the elimination of a required stop improves intersection efficiency.

Restricted crossing U-turns are used on high-speed multilane highways at intersections with lower volume roads. Traffic on the main highway proceeds through the intersection without stopping and all traffic on the minor road must turn right at the intersection. If wishing to continue on the minor road or turn left onto the highway, drivers proceed downstream of the intersection and make a U-turn, followed potentially by a right turn to continue on the minor road. Mainline traffic makes right and left turns onto the minor street as normal. This design's primary benefit is the elimination of cross-traffic left and crossing movements on a high-speed roadway, which have the potential to create severe and fatal crashes.

Displaced left turns are used on high-volume arterials at intersections with high volumes of left turning vehicles. They 'displace' the left turn by having left-turning movements cross over oncoming traffic upstream of the main intersection at a separate, smaller traffic signal during the cross-street's signal phase. By the time they arrive at the main intersection, vehicles are already on the far left side of the roadway and can make the left turn unencumbered by oncoming traffic, which can proceed simultaneously. This design allows for a continuous flow of major-street traffic at the main intersection, with all movements (right, through, and left) proceeding simultaneously.

Diverging diamond interchanges are used at traditional diamond interchanges with high volume left turns. As vehicles approach a diverging diamond interchange, vehicles wishing to use the right-hand freeway ramp can do so without stopping at a traffic signal. All other traffic proceeds through a simple traffic signal and crosses over the opposing traffic to the left-hand side of the roadway. Vehicles wishing to use the left-hand freeway ramp can do so without stopping at a traffic signal.

All remaining traffic proceeds through another simple signal and crosses back to the right-hand side. The diverging diamond brings safety benefits from elimination of cross-traffic turns, efficiency benefits from the elimination of phases to serve those cross-traffic turns, and cost benefits as they can use existing diamond interchange bridge structures and do not require a costly rebuild. The interchange makes traffic flow more efficiently at ramp terminals and may also resolve issues with queues backing up onto the mainline of the freeway.

General public perception was broken down into four key measures: awareness of the intersection, acceptance of the intersection, confidence using the intersection, and opinions regarding engineering purpose and common myths about the intersection. Awareness of the intersection was considered as three categories – having never heard of the intersection, having seen pictures or videos of the intersection in action, and having utilized the intersection in a vehicle. Acceptance was considered on a five-point Likert scale with options ranging from strongly opposing to strongly accepting the implementation of the intersection design in the respondent's community. Confidence was considered as a five-point numerical scale for drivers to rate their self-perceived confidence in their ability to utilize the design. The opinions section was presented as a list of statements from which participants could choose which they agreed with. Prior to measuring public perception, participants were shown a visual representation of the intersection rather than a text-based description.

1.3 Relevance of Work

Transportation is primarily a public endeavor, undertaken by governments with public money. A key tenet of modern democracy is that government exists to serve the citizens; thus, public input is a frequent part of government activity in general but transportation-related activity in particular. This public input process takes many forms with public meetings seeking community input on major transportation endeavors being common and, in some cases, legally required. Other forms of public outreach are also common, including surveys and online comment boxes.

Alternative intersections tend to generate a reasonably large volume of negative public input. Concerned members of the public will come to public meetings for alternative intersection projects to express their dislike of the design, complain to their elected officials about it, and lodge general

complaints with a transportation agency about the designs. This perceived negative public perception of alternative designs is one of the largest obstacles for transportation agencies to further implementation of what is otherwise often an excellent engineering solution (National Academies of Science, Engineering, and Medicine, 2020).

Better understanding of this public perception for these four intersection designs will provide several key benefits for those implementing them. Agencies will have a better understanding of the socio-demographic factors that make individuals more likely to have a negative perception, allowing them to target public outreach efforts to specific groups and better understand the likely behavior of a particular community that they are working in. They will also have a better understanding of the specific elements contributing to negative perception for each individual intersection, as the public's main concerns vary for each design, allowing them to target outreach efforts to address those issues more specifically. Taken together, this work will help arm agencies with the tools needed to more effectively improve public perception of the alternative designs they wish to implement on their highways.

Additionally, improved understanding of public perception will be useful to design engineers during the design phase and during the public outreach process. Understanding the public's typical primary concerns with a design early in the design process allows for more careful attention to these concerns, leading to development of a design that more effectively addresses those issues prior to the public outreach process. Furthermore, engineers are often involved during the project-specific public outreach process and attend public meetings alongside other agency staff. Knowledge of the public's concerns allows for development of an effective presentation of a design that speaks to those concerns before they are voiced.

Research surrounding roundabouts suggests that the single most important factor affecting perception is real-world experience. People are much more comfortable with a design once it has been constructed and they are able to see its operation and experience its benefits firsthand. The issue is getting the public to accept that initial construction before they have had the opportunity to use the design for themselves at the proposed location. This issue is repeated in thousands of communities across the country as alternative designs slowly gain traction. Although the DOT

may have experience building the design elsewhere in the state and are confident that it will work, a new intersection design will continue to generate public concern until enough members of the public are comfortable. This study endeavors to understand how we can make the public as comfortable as possible with a design before they are able to use it.

1.4 Research Hypotheses and Methods

1.4.1 Research Questions & Hypotheses

This study aims to answer three key questions:

1. How does public perception vary among the four alternative designs considered?
2. Does that public perception vary depending on the type of media used to explain the design?
3. What factors influence public perception?

Each of these questions has associated hypotheses as follows:

Q1:

1. Public perception is expected to be lower for the designs which vary the most from what is typical in the everyday driving environment. These would be the DLT and DDI, as driving on the left-hand side is very rare in the United States.
2. Public perception is expected to be lower for the designs that are less common within the study area. For Indiana, these would be the DLT (0 intersections), the DDI (3 interchanges), and the RCUT (7 intersections).

Q2:

1. Dynamic media will positively impact public perception – operations seem to be the predominant concern among the public, and seeing the intersection move will more effectively convey the design's operational characteristics, resulting in higher rates of acceptance and confidence with the intersection compared with static media.

2. More informational sources will also positively impact public perception– information justifying the engineering purpose of the designs will help make the case for the treatment in the minds of the public.

Q3:

1. Different socio-demographic groups will respond to the alternative designs differently – prior research suggests that age and gender are relevant characteristics (Savolainen et al., 2012) but others may also be important.
2. Such socio-demographic factors may vary between alternative designs and groups may respond to them differently.

1.4.2 Methodology

This research aims to measure public perception of alternative designs through distribution and analysis of a survey instrument, described more extensively in Chapter 3. The survey instrument was distributed to a large sample (n = 1000) across the State of Indiana. This survey was conducted as part of a funded research project with the Indiana Department of Transportation and contained questions pertaining to public perception of topics in addition to alternative intersections. The survey instrument was analyzed using both descriptive and inferential statistical methods.

1.5 Thesis Organization

Chapter 2 (Literature Review) covers more extensively the intersections in question and research regarding public perception to date. Chapter 3 (Survey Design and Administration) describes the survey instrument in more detail as well as the administration process and the socio-demographics of the sample collected. Chapter 4 (Descriptive Statistics) describes the process and results of the descriptive statistical analysis, while Chapter 5 (Inferential Statistics) presents the process and results of inferential statistical modeling. Chapter 6 (Conclusions) discusses the work's conclusions and key takeaways.

2. LITERATURE REVIEW

2.1 Overview

The four alternative intersection types included in this study have all been the subject of theoretical operational and safety research for several years. As more of these alternative designs have been constructed, field-based studies have begun to emerge, generally supporting the theoretical conclusion that these designs, when used appropriately, are safer and more efficient than traditional signal or interchange approaches (Edara et al., 2015; Hu et al., 2014; Hughes et al., 2010; Hunter et al., 2019). These alternative designs remain rare when compared with traffic signals and traditional diamond or clover-leaf interchanges. Due to their relative rarity, driver familiarity with these designs is limited and despite their proven safety and operational benefit, public opposition to their construction remains prominent (Jackson et al., 2014; National Academies of Sciences, Engineering, and Medicine, 2020).

Public works projects of this magnitude frequently include a public outreach component. This outreach can take many different forms, but all will include public educational materials intended to facilitate public acceptance, guide drivers, and improve understanding of the benefits of the treatment. Relatively little research has been conducted to date to understand the effectiveness of different types of materials for explanation of alternative intersections.

The rest of this literature review will be organized as follows; first, an in-depth explanation of each alternative intersection type, followed by a synthesis of current public outreach practices, a synthesis of previous projects pertaining to public opinion of alternative intersections, and a discussion of implementation barriers.

2.2 Alternative Intersections

Although each of the alternative intersections considered are distinct, they do have a common purpose and method. They all improve safety and operational efficiency through the elimination of cross-traffic left turning movements. Cross-traffic turning movements create the potential for especially dangerous crashes through unfavorable geometry and potentially high speed of cross

traffic. At signalized intersections, left turns frequently require an exclusive phase, increasing the number of signal phases required and reducing signal efficiency.

2.2.1 Roundabout

The roundabout is a circular intersection in which traffic circulates about a center island in a counterclockwise direction. Traffic enters the intersection after yielding to vehicles already in the circular roadway before proceeding to the desired leg and exiting. Figure 2.1 shows a roundabout.

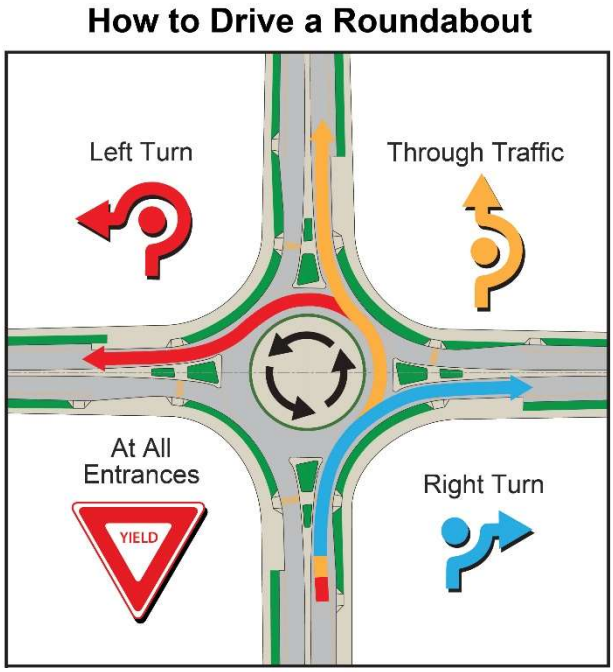

Figure 2.1 Roundabout Diagram (Indiana Department of Transportation, n.d.-b)

The roundabout is known for its safety and operational benefits. The curved approaches and circular roadway force vehicles to reduce their speed and the possibility of head on or side collisions is eliminated as all vehicles travel in the same direction. Multiple studies have confirmed the safety benefits of roundabouts in Indiana (Day et al., 2013; Tarko et al., 2008; Tarko et al., 2015) and other states (Gbologah et al., 2019; Leuer, 2017). As the design requires drivers to yield to traffic in the circle rather than wait at a signal or stop sign, traffic is often able to enter and exit the roundabout with minimal intersection delay so long as volumes are sufficiently low.

By far the most familiar of the four intersections utilized on this list, modern roundabouts were standardized in the United Kingdom in the mid-1960s. The first modern roundabouts were constructed in the United States beginning in the early 1990s. Although they are still more popular in Europe (25,000 intersections in the UK)(Wylie, 2015), the U.S. has over 7,500 roundabouts in operation today (Taylor & Rodegerdts, 2020). According to a survey of state DOTs, 90% of states reported having at least one roundabout in operation, and 20% reported having more than fifty in their roadway networks (National Academies of Sciences, Engineering, and Medicine, 2020).

2.2.2 Restricted Crossing U-Turn

The restricted crossing U-turn (abbreviated RCUT, also referred to as a superstreet or a reduced conflict intersection) is an intersection design that redirects all minor-street movements and major-street left turns into a U-turn downstream of the main intersection. They are more commonly seen at locations where the major street volume is significantly higher than the minor street, frequently at rural intersections along divided highways. Figure 2.2 shows a restricted crossing U-turn intersection.

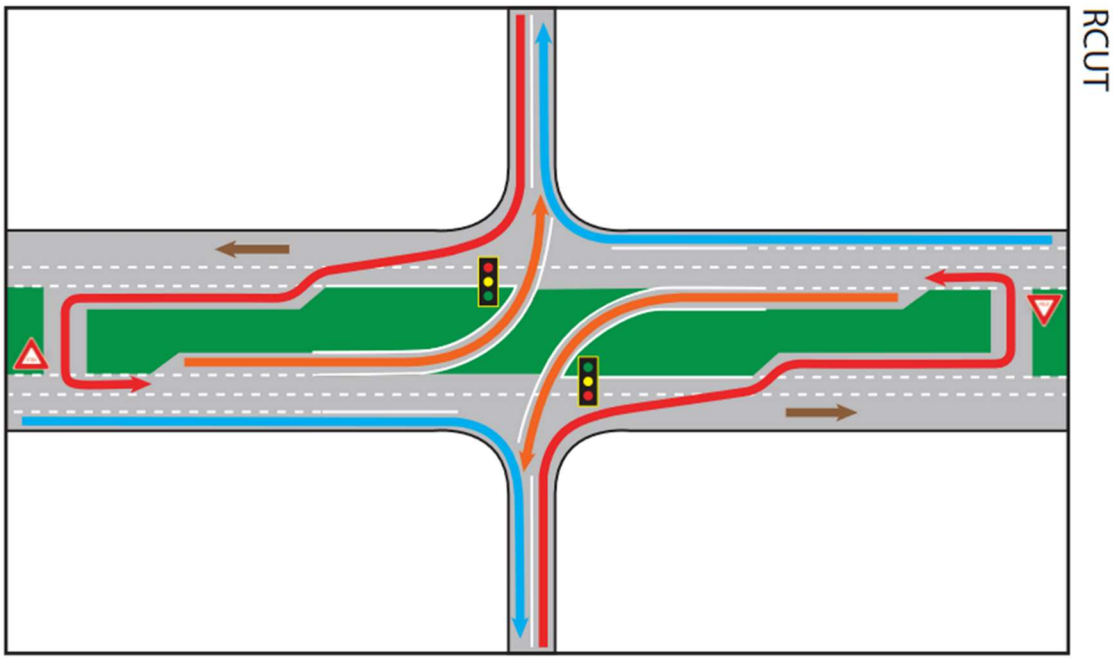

Figure 2.2 Restricted Crossing U-Turn (RCUT) Diagram (Indiana Department of Transportation, n.d.-a)

The restricted crossing U-turn intersection improves safety at rural intersections by eliminating hazardous through and left-turn movements by minor street traffic. The design has been observed to significantly reduce right angle crash frequency of all severities and to reduce crash severity of other types of crashes (Edara et al., 2015; Inman & Haas, 2012; Leuer, 2017; Sun et al., 2019; Tarko et al., 2008). The operational benefits of this intersection design compared with a stop-controlled intersection vary for the major and minor approaches. The major street always has reduced delay as they are never required to stop, but the U-turns required for minor-street through and left turning movements add physical distance and can add time (Edara et al., 2015; Inman & Haas, 2012).

The restricted crossing U-turn was first conceptualized in 1987 (Kramer, 1987) but the design was not constructed and analyzed until the mid-2000's. The design is popular in some state highway networks but rare or nonexistent in most. North Carolina has more than 50 RCUTs, while nine states have between 6 and 50. 11 states have between 1-5 constructed, and 29 states (58%) have no restricted crossing U-turns on their roadway networks (National Academies of Sciences, Engineering, and Medicine, 2020).

2.2.3 Displaced Left Turn

The displaced left turn (abbreviated as DLT, also known as a continuous flow intersection) is an intersection design that crosses left turning traffic over oncoming traffic at a small signal upstream of the main intersection. As a result, all three movements (right turns, through movements, and left turns) can proceed at the same time for both directions since left turns have already crossed over. They are utilized at large signalized intersections on major arterials. Figure 2.3 shows a displaced left turn.

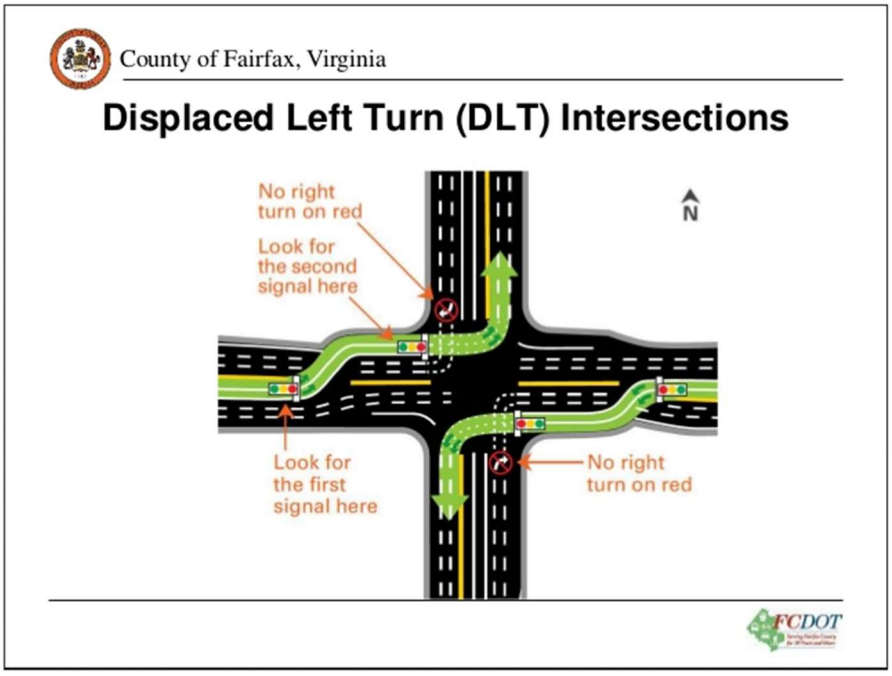

Figure 2.3 Displaced Left Turn Diagram (used with permission from the Fairfax County, Virginia Department of Transportation)

The displaced left turn is intended to improve operational efficiency at the main intersection by reducing the total number of signal phases required by relocating the left turn signal upstream and allowing green for this crossover movement at the same time as minor street movements. The geometry of the intersection allows elimination of right-angle crashes. There is very limited field data available for this intersection type as it remains both new and rare in the United States. Some studies have compared the safety of the displaced left turn with a traditional signalized intersection utilizing conflict points (Qi et al., 2018; Utah Department of Transportation, 2013). Several studies have considered operations and design of key elements using modeling and simulation techniques (Bai & Li, 2017; Carroll & Lahusen, 2013; Tarko et al., 2008; Yang et al., 2013).

The displaced left turn was patented in 1987 (Hummer, 1998), and the first prototype intersection was constructed in 1995. It remains relatively unpopular and is the rarest of the four designs considered in the present work, with two states having between 6 and 10 DLTs (Texas and Utah), nine states having between 1 and 5 DLTs, and the rest (39, 78%) having zero (National Academies of Sciences, Engineering, and Medicine, 2020).

2.2.4 Diverging Diamond Interchange

The diverging diamond interchange (abbreviated as DDI, also referred to as a double crossover diamond, DCD) eliminates the need for separate left-turn lanes and phases at ramp terminals of a traditional diamond interchange by transferring all traffic to the left-hand side of the roadway for the over/underpass portion of the interchange. This transfer allows for a free-flow entry to all ramps, compared to a free-flow right turn and a cross-traffic (often signalized) left turn at a traditional diamond ramp terminal. The DDI is shown in Figure 2.4.

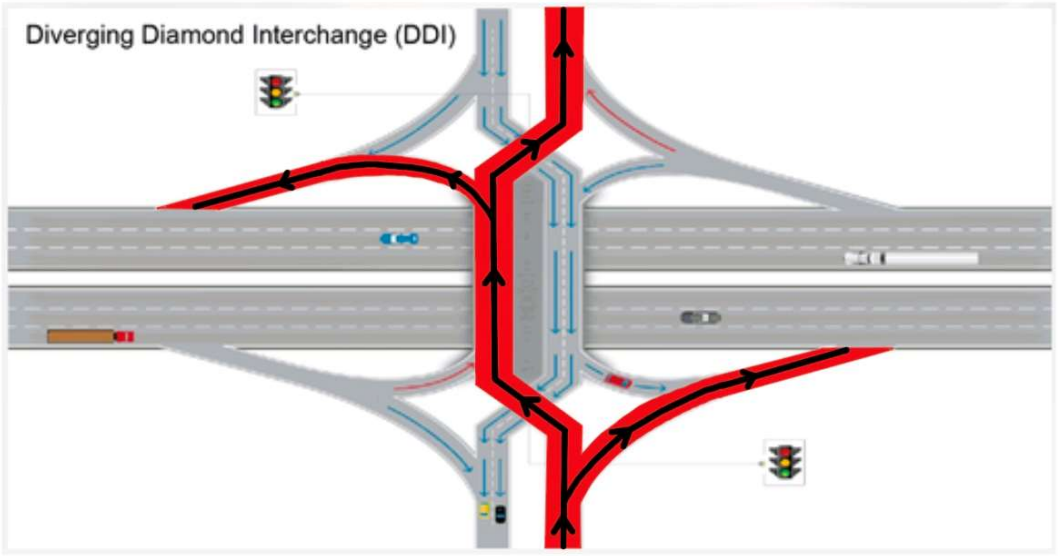

Figure 2.4 Diverging Diamond Interchange Diagram (Wisconsin Department of Transportation, n.d.)

This shape has been shown to improve efficiency compared with a traditional signalized ramp terminal design, especially with high volumes of left-turning vehicles (Chilukuri et al., 2011b; Day et al., 2015; Hunter et al., 2019; Tarko et al., 2017b, 2017a; Yeom et al., 2015). Cross-traffic turning movements are eliminated and protected left-turn signal phases are no longer required. This design has been shown to improve safety at interchange ramp terminals (Hummer et al., 2016; Nye et al., 2019; Walls et al., 2018). Additionally, the diverging diamond shape can be constructed on an existing traditional diamond interchange in approximately the same footprint without requiring a new overpass structure, making it an attractive alternative to costlier solutions.

The first diverging diamond interchange in the U.S. was completed in 2009 in Missouri. More have been constructed in the intervening ten years, but they are still relatively rare; two-thirds of states have at least one, but only six have more than five and none have more than 25.

2.3 Public Outreach

Public outreach efforts are frequently undertaken by transportation agencies to educate the public on a wide variety of issues, including upcoming construction projects, innovative technologies, driver behaviors such as impaired driving or speeding, and work zone safety. The intensity of outreach efforts for a specific project depends on a variety of factors, including the project's physical and economic size, the project's relative novelty, and the project's expected impacts on the surrounding area. A variety of channels may be utilized for outreach efforts, including public meetings, local television/radio stations, newspapers, physical or electronic mailings, social media platforms, and agency or project-specific websites.

2.3.1 Current Public Outreach Regarding Alternative Intersections

A report from the National Cooperative Highway Research Program which evaluated general alternative intersection design and implementation practices included current public outreach practices for alternative intersections nationwide (National Academies of Sciences, Engineering, and Medicine, 2020). The project found that the majority of DOTs have developed or are developing public outreach materials for alternative intersections but that 27% of DOTs have not done so. 61% of DOTs have alternative intersection websites, 39% have at least one video on the subject, 27% have a flyer or pamphlet, and 14% have a social media site dedicated to alternative intersections. 14% of DOTs currently use materials from other agencies including other state DOTs and the Federal Highway Administration (FHWA). Roundabouts are by far the most popular topic, with 56% of DOTs having dedicated roundabout materials, followed by 18% of DOTs having material dedicated to diverging diamond interchanges, 16% having material dedicated to RCUTs, and 6% having displaced left-turn specific material.

As part of their overall efforts regarding roundabouts, The Federal Highway Administration has collected a variety of materials produced by FHWA and other organizations for use in outreach

efforts (formerly known as the Roundabout Outreach and Education Toolbox, now part of their main roundabouts page) (Federal Highway Administration, n.d.). Materials include case studies, implementation guidance for outreach, presentations, videos, and brochures, among other materials.

A 2013 report from the Western Transportation Institute for the Montana Department of Transportation titled Information/Education Synthesis on Roundabouts (Veneziano et al., 2013) provides a summary of outreach efforts undertaken by various state transportation agencies about roundabouts. They found that not all states with roundabouts have roundabout-specific web-based outreach materials, that such websites are typically straightforward presentations of roundabouts including information about benefits, driver tips for navigation, and frequently asked questions. Some websites had videos embedded on the site focusing on the same topics, and no website featured praise for roundabouts from those in areas with them.

Additionally, the project conducted a survey and follow-up interviews with several state agencies discussing roundabout education and outreach. They found that opposition to roundabouts was very common, and that site selection and buy-in from local officials were key to gaining public approvals. No agency tried to sell roundabouts in the abstract but rather to frame them as a justified solution to the problem at hand. The project's separate survey of the general public also supported the idea that clear justification of the roundabout solution was important to them.

2.3.2 Public Opinion Studies

The following section discusses previous work evaluating public opinion and acceptance surrounding alternative intersections. The previously discussed Western Transportation Institute project (Veneziano et al., 2013) conducted a survey of the public to try and understand public opinions regarding roundabouts in Montana. The majority of concerns centered around roundabout safety, efficiency, pedestrian/ bicycle use, and driver confusion. Respondents indicated that they felt more dynamic materials such as videos and simulations or more realistic 3D static models would be useful in presenting roundabouts and improving driver education. They also felt that it was important that the DOT staff listened to their concerns and engaged with them in a conversational manner rather than responding with facts and figures. Lastly, there was a noticeable

sense of ‘exceptionalism’, where respondents believed that although it was clear that roundabouts had been successful elsewhere that they would not be successful in Montana.

Another roundabout focused project focused on Michigan conducted an online statewide survey, collecting the opinions of 11,972 individuals (Savolainen et al., 2012). After estimating multiple ordered probit models, they found that the strongest predictor of support for roundabouts was experience, with those having more experience being more supportive. They also found that younger drivers were more likely to be supportive, with support declining with age. Female drivers, pedestrians, motorcyclists, and commercial drivers were less likely to be supportive, while cyclists were generally more supportive. There have been numerous other studies pertaining to roundabout public perception, all of which support the link between experience and acceptance (Garder, 2002; Redington, 1997; Retting et al., 2002, 2006, 2007).

Following construction of the nation’s first diverging diamond interchange in Missouri, all-around performance of the intersection was evaluated, including public opinion (Chilukuri et al., 2011). An online survey of motorists (n = 53 responses) was conducted along with interviews with two commercial drivers and a company specializing in oversize transportation and an interview with professionals involved with planning, designing, and operating ped/bike facilities. All three groups had positive opinions regarding the new intersection. Specifically, a large majority (80% +) felt that traffic flow had improved, delay had decreased, that crashes were more likely in a standard diamond compared with the DDI, that larger vehicles and ped/bikes had better or similar movements than a standard diamond, and that understanding of the interchange’s operation based on traffic control devices at the site was good.

A later study focusing on to diverging diamond interchanges investigated public perception at five newly opened diverging diamond interchanges around the country using focus groups (three sites), a survey after construction (one site) and a survey before and after construction (one site) with a total of 1,669 participants (Jackson et al., 2014). In general, participants had a positive opinion on operations, safety, and driver understanding, although comments showed that respondents observed some driver confusion. There was also concern regarding off-ramp right turn movements, which had previously allowed right turn on red but no longer do so. Comments regarding

pedestrian and bicycle facilities expressed concerns regarding safety. There was also a suggestion that a broader scope of impact should be considered in order to include nearby intersections, commercial centers, and neighborhoods. Some participants felt that 'local access at all hours may have been sacrificed to improve the experience for commuters, particularly in the peak hours.' There were concerns about the impact the DDI was having on nearby intersections; at some of the sites, the more efficient interchange was thought to increase congestion at nearby less efficient intersections and interchanges.

A project based in North Carolina (Ott et al., 2015) conducted a series of three surveys to evaluate the public perception of residents, commuters, and businesses regarding restricted crossing U-turns (known in the study as superstreets). Those living near the intersection (residents) felt that RCUTs were safer, but those living near signalized RCUTs perceived more travel time and more stopped vehicles at the intersection. Since these individuals reside close to the intersection, they are more likely utilizing minor street approaches, which experience more physical displacement. Commuters felt that the RCUT was safer, reduced delay, and improved travel time, but also that they were more difficult to navigate. Business owners/managers recognized that there were safety and flow improvements but felt that the RCUT had negatively impacted business growth and operations and that customers had access and confusion issues attached to the design. A Louisiana based study evaluated the economic effect of RCUTs and found no evidence of a decline in sales for businesses located near the intersections (Schneider et al., 2019).

2.3.3 Barriers to Implementation of Alternative Intersections

While there are many potential obstacles to implementation of an alternative intersection design, public opinion is one of the major ones. One project surveyed more than 1000 members of the Institute of Transportation Engineers (ITE) and found that the most prominent barrier to implementation of alternative designs was public support, lack of which was motivated primarily by the potential for driver confusion (Shumaker et al., 2013). Other identified barriers included lack of proof of design function, safety concerns, and cost concerns. Eight years later, a report from the National Cooperative Highway Research Program (National Academies of Sciences, Engineering, and Medicine, 2020) found that the most prominent barrier to implementation

remains public opposition as indicated by 86% of state transportation agencies. Other identified barriers include stakeholder concerns, public education access management, and funding concerns.

2.4 Summary

The alternative intersection and interchange designs under consideration have been shown to improve safety and operations compared with traditional intersection and interchange forms. Significant public opposition is seen by members of the transportation profession as a fundamental obstacle to further implementation of these alternative designs. Surveys and focus groups conducted in communities with alternative intersections have shown that such public opposition does exist but generally reduces once local drivers gain more experience with the new design. Primary public concerns relate to issues such as driver confusion, delays caused by intersection geometry, and multi-modal accessibility.

In order to combat this opposition, DOTs conduct public outreach campaigns through a variety of channels using a combination of materials developed in-house and by other DOTs or the FHWA. Few projects have evaluated public perception of alternative designs other than roundabouts or explored in more detail the factors contributing to public perception, including the type of media used to explain the intersection's operational characteristics.

3. SURVEY DESIGN AND ADMINISTRATION

The primary research methodology utilized for this work was analysis of the data from a survey instrument. The survey instrument itself and the data collection process are described in detail in this chapter. Development and administration of the survey was completed in conjunction with the Indiana Department of Transportation (INDOT) for a separate research project. As a result, the survey addresses topics beyond alternative intersection designs. For completeness, those topics are included in this chapter and discussed briefly.

3.1 Survey Design

3.1.1 Survey Sections

The survey instrument consisted of four sections, listed below and subsequently discussed in more detail.

- Awareness of Current and Emerging INDOT Treatments and Strategies
- Attitudes and Preferences Towards INDOT Services
- Respondents' Travel Characteristics and Patterns
- Socio-Demographic Questions

The section 'Attitudes and Preferences Towards INDOT Services' was not included in the analysis conducted to fulfill the objectives of this thesis. The entire survey instrument is provided in Appendix A.

Questions were developed for the survey using several different guiding principles. Multiple choice and three or five-point Likert scales were commonly used, because these question types are easier for respondents to answer and simpler to analyze. Questions were intended to be easy to understand, unambiguous in wording, and were written with the intention of addressing a specific concern. Travel behavior and socio-demographic questions were phrased in such a way as to align with existing data sources, such as the National Household Travel Survey (NHTS) and the U.S. Census.

Awareness of Current and Emerging INDOT Treatments and Strategies

The primary focus of this section was to assess participant awareness and acceptance of emerging traffic-management treatments and strategies that INDOT has or is considering implementing. The treatments are listed below.

- Ramp Meter
- Roundabout
- Restricted Crossing U-Turn (RCUT) /Reduced Conflict Intersection (RCI)/J-Turn
- Displaced Left Turn (DLT)
- Diverging Diamond Interchange (DDI)

Ramp meters are two-lens traffic signals placed on a freeway ramp just upstream of the main merge point to control traffic entering the freeway in order to reduce delays related to oncoming traffic and merging movements. They are considered an emerging technology and were included on the survey as INDOT is interested in implementing them within Indiana. They were not analyzed further for the purposes of this work as they are not an alternative intersection design, which was the focus of this work.

For each treatment, the participant was shown a visual representation of the treatment and asked a series of questions. These visual representations included an arrow diagram, a static .PDF flyer, a brief informational video, and a short simulation, discussed in more detail in Section 3.1.2. The questions evaluated their awareness of the treatment, their understanding and opinions regarding the operations of the treatment and the operational and safety goals of implementation, their acceptance of the treatment in their community using a five-point Likert scale, and their confidence navigating the treatment as a driver on a scale of one to five.

In addition to these questions, a series of questions assessing the effectiveness of different visual representations was asked. This section also included questions discussing the media preferences of participants. Specifically, participants were asked to list their current information sources for INDOT projects and activities, their desired information sources for INDOT projects and activities, and their current information sources for real-time (driver) information.

Attitudes and Preferences Towards INDOT Services

This section included questions regarding a variety of topics, discussed individually below.

Work Zones and Construction

Several different aspects of work zone operations were included. Participants were asked to provide agreement or disagreement on a five-point Likert scale with statements about a variety of topics including INDOT's communications regarding road work, minimization of traffic delay, and understanding of work zone and detour signing. Participants were asked to assess the visibility of work zone traffic control devices, equipment, and workers at night, in the rain, and in the snow on a three-point scale of 'Generally Poor', 'Generally Fair', and 'Generally Good'. Two questions asked for participants to choose between full and partial closure for construction, pertaining to a state highway bridge and major interchange rehabilitation project separately. Additionally, several questions were included requiring respondents to indicate driver behavior regarding speed in response to different combinations of worksite speed limit signing.

Lighting and Visibility

Participants were asked to provide their levels of agreement or disagreement on a five-point Likert scale with statements regarding lighting at interchanges and along roadways in both urban and rural areas. Additionally, participants were asked to rate visibility of signs, raised pavement markers, and pavement markings at night, in the rain, and in the snow on a three-point scale of 'Generally Poor', 'Generally Fair', and 'Generally Good'.

Mobility

Two questions addressed mobility-related topics. Participants were asked to choose between two similar trips – a trip that was longer by distance taken on predominately freeways with smaller arterials required connect to the freeways, and a trip that was shorter by distance taken on predominately major highways with some traffic signals and slightly slower speeds than the freeways.

A different question required participants to first provide their typical (pre-COVID-19) commute time, and then asked how frustrated they were with two commute-related scenarios. The first scenario was a constant commute equivalent to their provided time, and the second scenario was a variable commute taking ± 25% of their provided time, with an even distribution (half the time longer, half the time shorter).

Driver Behavior

A group of questions discussed driver behaviors pertaining to speed. Participants were asked what they perceived to be the average speed to be on interstates, urban roads, and rural roads. They were also asked for opinions and actions regarding a variable speed limit sign and a curve warning sign with speed advisory plaque.

Respondents' Travel Characteristics and Patterns

This short section consisted of four questions evaluating respondents' travel behaviors, including vehicle ownership and mileage, typical trip distances, and typical roadways used. Participants were asked to report behavior prior to any changes in travel behavior caused by the COVID-19 pandemic, which was ongoing during the survey period.

Socio-Demographic Information

This section asked for socio-demographic information, including participant age, gender, educational attainment, income, and employment status. Additionally, information on driver history and the length of Indiana residency was included. Participants were identified geographically by providing their home ZIP code.

3.1.2 Visual Media

The visual representations used in the first section of the survey (Awareness of…) were included to improve participant understanding of the different and potentially new treatments included in that section. With the exception of the ramp meter, each treatment was presented through one of four representations: a diagram with arrows showing traffic movements, a two-page flyer including a diagram and information regarding the treatment, an informational video lasting approximately

three minutes showing operations and providing information regarding the treatment, and a short simulation showing operations of the treatment. All of the flyers and videos were provided by the Virginia Department of Transportation (VDOT) from their Innovative Intersections and Interchanges series (Virginia Department of Transportation, 2020). The diagrams and simulations originated from a variety of other public sources. The ramp meter was represented using a picture of a ramp meter in its environment. The sequence of these visual representations was varied in order to reduce bias in participant response. As an example, the media options for the RCUT are shown here. Media choices for all alternative designs are included in Appendix B and the video-based options are available on YouTube.

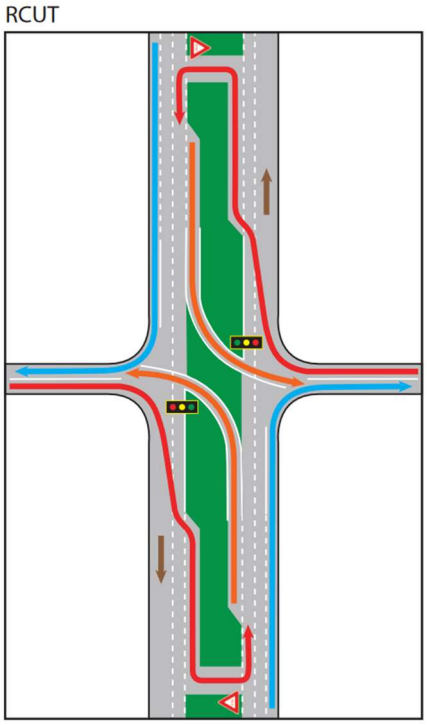

Figure 3.1 RCUT Arrow Diagram (used with permission from INDOT (Indiana Department of Transportation, n.d.-a))

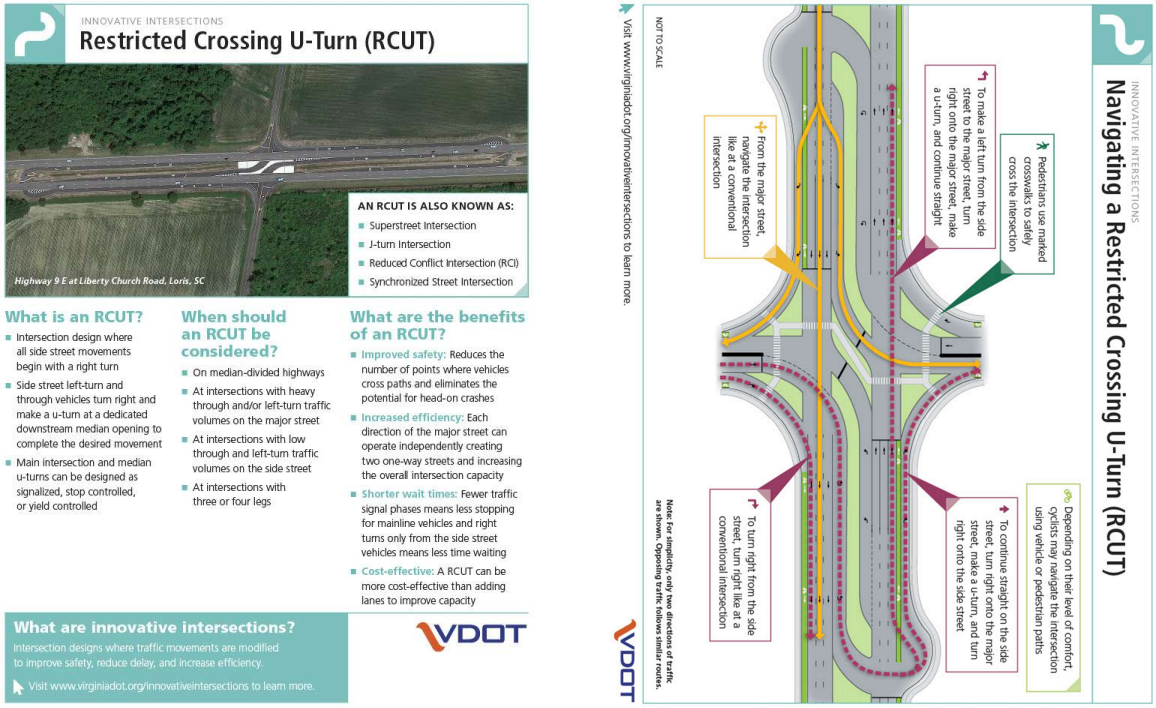

Figure 3.2 RCUT Flyer (used with permission from VDOT)

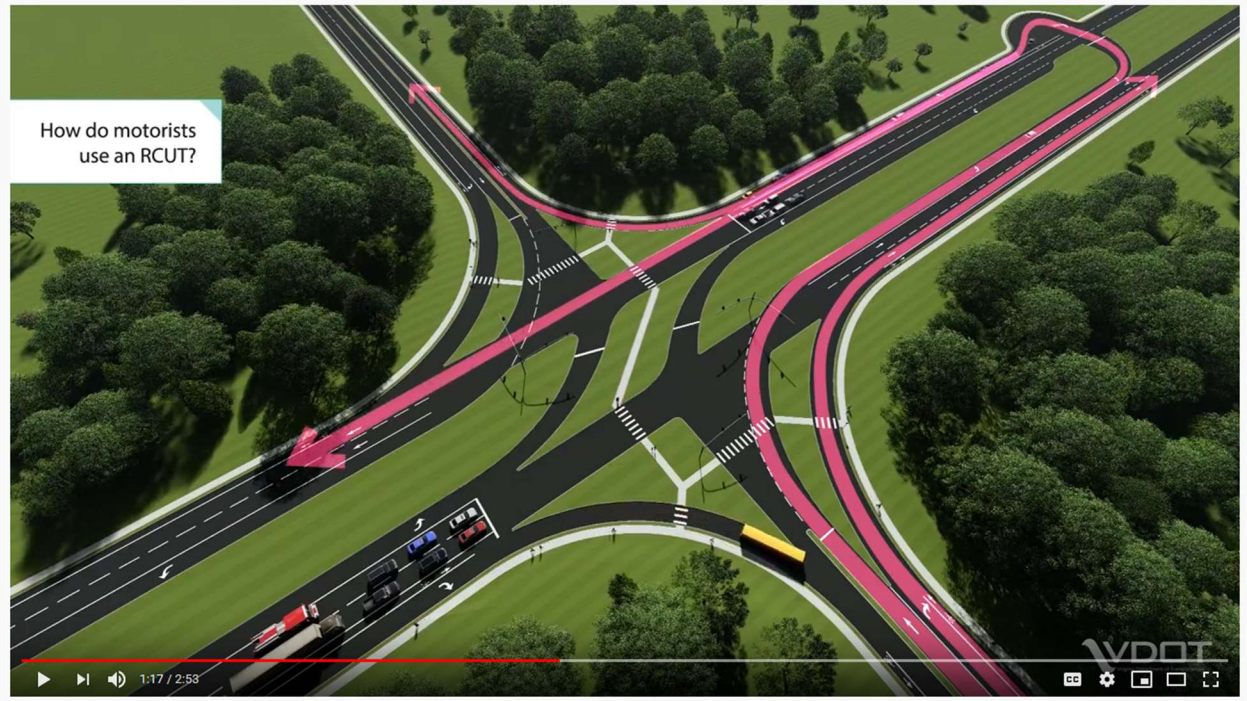

Figure 3.3 RCUT Video Screen Capture (used with permission from VDOT)

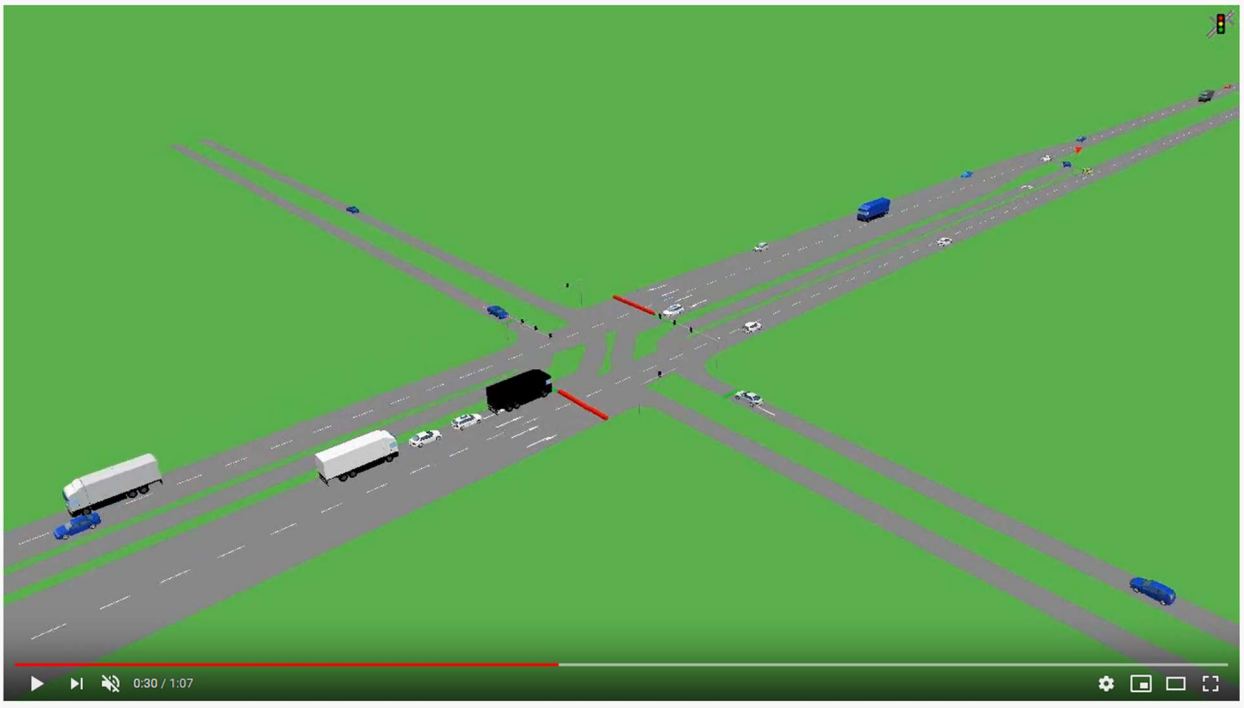

Figure 3.4 RCUT Simulation Screen Capture (used with permission from INDOT (Indiana Department of Transportation, n.d.-a))

3.2 IRB Approval

As this project involved human subject research, approval by the Purdue University Institutional Review Board (IRB) was required. As a survey project being conducted on an adult population, this project was granted an exemption from in-depth review and approved to proceed on April 21, 2020. The IRB# is IRB-2020-337.

3.3 Data Collection

3.3.1 Survey Administration

Administration Company

The survey was administered through a contract with Kantar, a market research company. Participants were sourced from their pool of adult participants in Indiana and compensated by Kantar for their time. The survey was administered using Qualtrics.

Pilot Testing

A pilot test consisting of 10% of the total sample (approximately 100 responses) was conducted during the week of July 12, 2020. Following pilot testing and data cleaning, a quality check was also implemented through the use of an attention check question, asking the respondent to check a particular option (see Question 2.2 Part M in Appendix A). The quality check was located among the questions asking participants to assess visibility and required them to select a specific choice.

Full Launch

Full data collection ran from July 20, 2020 through August 24, 2020.

Data Cleaning

During data collection and afterward, data was cleaned to remove poor quality responses and ensure a complete, high quality sample. Responses were initially screened for three primary criteria. All responses with a duration shorter than 520 seconds (approximately eight and a half minutes) were removed as the research team believed it impossible to complete the survey and read all the questions in that time. All responses that failed the aforementioned quality check were also removed. Additionally, any self-contradictory response was removed with special attention paid to the questions evaluating understanding of the emerging treatments (it is impossible for a treatment to increase and reduce crashes simultaneously). After initial cleaning, data was screened for outliers, which were removed.

3.3.2 Sample Description

The sample consisted of 1,000 adults residing in the State of Indiana, of which 999 were included in the final analysis. This sample size was required to achieve a margin of error or 3% and a confidence level of 95%. Hard quotas concerning the gender and age of respondents were implemented as a remedy to selection bias (under-coverage), based on U.S. Census data for Indiana.

Socio-Demographic Information

The sample was representative of the state in terms of age and gender according to data collected in the 2010 decennial census. Exact composition by age and gender is shown in Table 3.1.

Table 3.1 Age and Gender Composition of Survey Sample

	Males	**Females**
18-24 years old	86 (8.6%)	90 (9.0%)
25-34 years old	81 (8.1%)	85 (8.5%)
35-44 years old	81 (8.1%)	85 (8.5%)
45-54 years old	89 (8.9%)	92 (9.2%)
55-64 years old	73 (7.3%)	76 (7.6%)
65+ years old	79 (7.9%)	83 (8.3%)
Total	**489 (48.9%)**	**511 (51.1%)**

Additionally, current and former employees of INDOT, any other transportation governmental agency (local or federal), or any transportation consultant were screened out on the grounds that these individuals may introduce bias in the sample as they have a higher level of awareness of the current and emerging INDOT treatments and strategies compared to the average Hoosier.

For the purposes of geographic location, respondents provided their home ZIP code. As no further geographic locators were collected, respondents are considered to reside at the geographic centroid of their ZIP code area. The sample ended up being sufficiently geographically representative across Indiana, with responses coming from 83 of Indiana's 92 counties. The counties not included in the sample were Blackford, Daviess, Gibson, LaGrange, Martin, Newton, Rush, Pulaski, and Warren counties. Figure 3.5 shows the distribution of the survey sample across all Indiana counties.

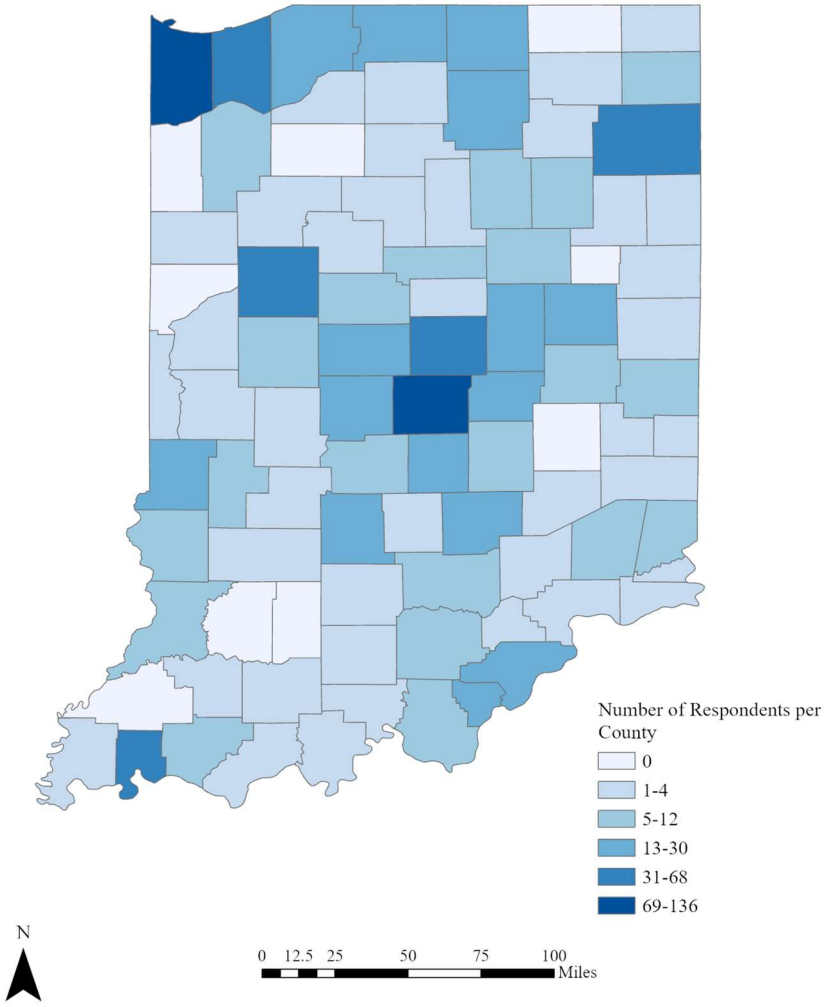

Figure 3.5 Survey Sample Distribution by County of Residence

Additionally, respondents were classified utilizing the U.S. Census Bureau definitions into Urbanized Areas (population greater than 50,000), Urban Clusters (populations between 2,500 and 50,000), and Rural Areas (populations less than 2,500) (United States Census Bureau, n.d.). 708 (70.8%) respondents reported residing in Urbanized Areas, 192 (19.2%) respondents reported residing in Urban Clusters, and 93 (9.3%) respondents reported residing in Rural Areas. Six respondents provided ZIP codes which could not be located.

The survey sample is reasonably representative of the state in terms of income, as shown in Table 3.2. Sample incomes were compared with the 5-year 2018 estimates from the American

Community Survey (ACS). Incomes between $50,000 and $100,000 are slightly overrepresented, and incomes over $100,000 are underrepresented, likely due to the fact that these individuals would be less motivated by financial incentive to be part of the survey pool. Additionally, 76 individuals opted not to disclose their incomes to the research team.

Table 3.2 Income Distribution of Survey Sample

Income	Sample Distribution	2018 5-Year ACS Estimate
Under $25,000	21.2%	21.2%
$25,000 -$49,999	24.9%	24.8%
$50,000 -$74,999	20.6%	19.3%
$75,000 -$99,999	16.7%	13.1%
$100,000 -$149,999	11.7%	13.3%
$150,000 or more	4.9%	8.2%

The survey sample is more educated on average than Indiana as a whole, considering individuals aged 25 and older compared with the 5-year 2018 ACS as shown in Table 3.3. Those with higher educational attainment (some college (no degree), college degree, and graduate or professional degrees) are overrepresented, while those with lower educational attainment (high school graduates and lower) are underrepresented. Both associate's and bachelor's degrees are considered under "college graduate".

Table 3.3 Educational Attainment of Survey Sample

Educational Attainment	Sample Distribution	2018 5-Year ACS Estimate
Less than 9th Grade	0.6%	3.7%
Some High School	1.7%	7.7%
High School Graduate & Technical Training Beyond High School	24.9%	33.5%
Some College (no degree)	21.9%	20.4%
College Graduate	34.1%	25.2%
Graduate or Professional school	16.8%	9.4%

Travel Behavior and Driver History

As the survey was administered while the COVID-19 pandemic was ongoing during the summer of 2020, participants were asked to consider their travel behavior prior to any restrictions or pattern changes caused by the pandemic. As expected, a large portion of the survey sample currently hold

a valid Indiana driver's license (92%), while an additional 3% have previously held a license. Only 5% of the sample indicated they have never possessed a driver's license. Household vehicle ownership and annual mileage across the survey sample is shown in Table 3.4 and Table 3.5.

Table 3.4 Vehicle Ownership Characteristics of Survey Sample

Number of Vehicles	Sample Distribution	2018 5-Year ACS Estimate
0	4.5%	2.8%
1	33.8%	19.2%
2	39.7%	42.2%
>3	22.0%	35.9%

Table 3.5 Annual Vehicle Mileage of Survey Sample

Mileage	Sample Distribution
I do not own a personal vehicle	5.2%
<5,000 miles	20.3%
5,000-9,999 miles	23.3%
10,000-14,999 miles	23.4%
15,000-19,999 miles	11.7%
20,000-24,999 miles	5.0%
>25,000 miles	5.5%
I do not know	5.6%

Figure 3.6 and Figure 3.7 show the trip frequency of the survey sample based on trip length and roadway type utilized.

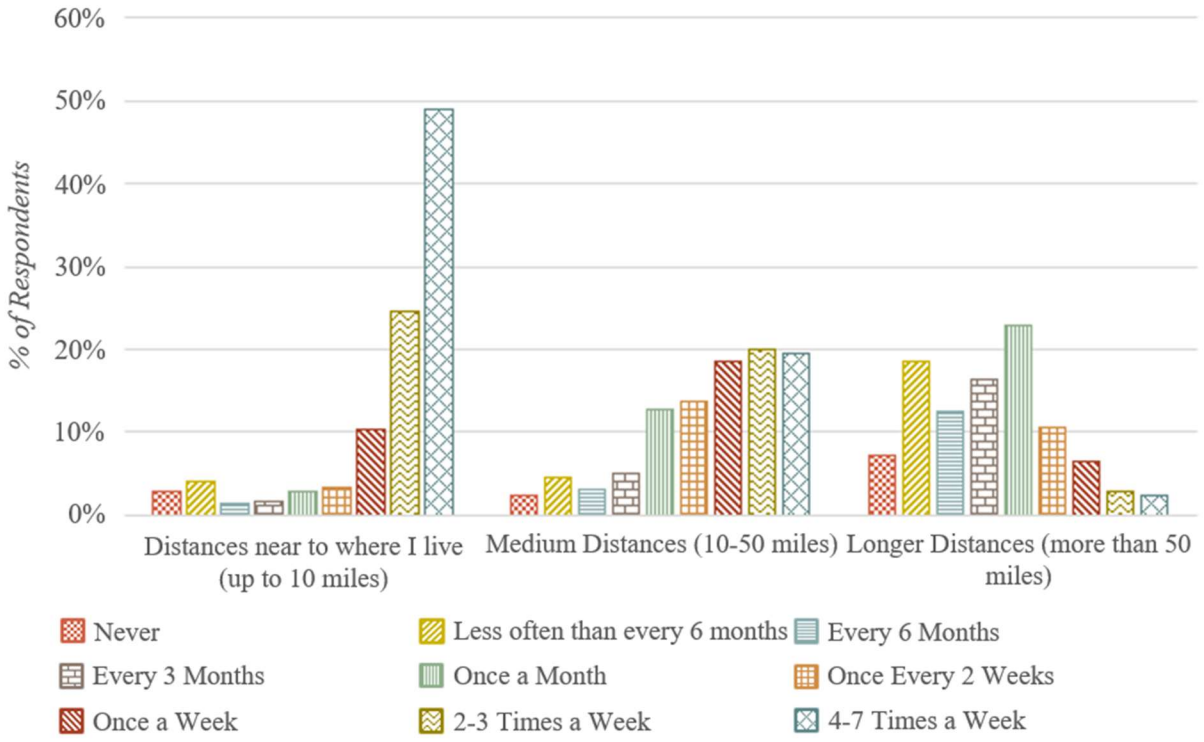

Figure 3.6 Trip Length Frequency Distribution

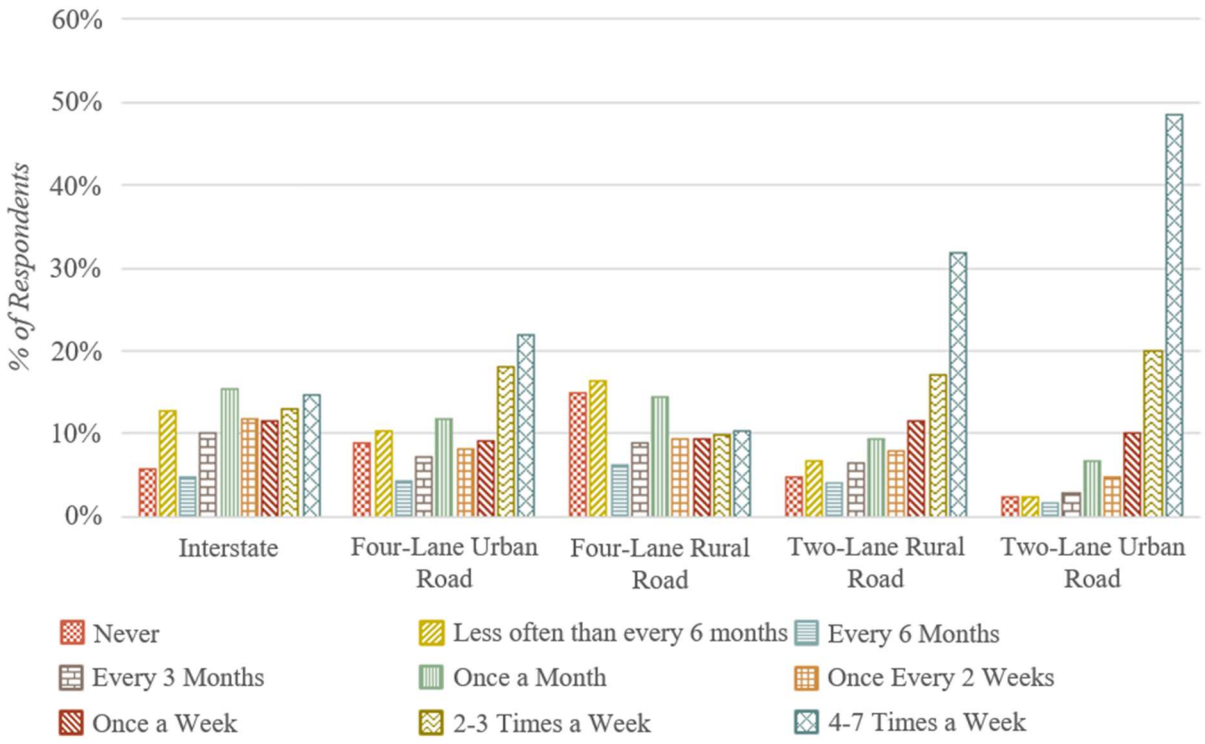

Figure 3.7 Roadway Type Frequency Distribution

In addition to providing their travel behavior, participants were asked to provide information regarding their driver history, including how long they had been driving, crash history, and their self-perceived driving ability. The sample distribution of the length of time driving is shown in Table 3.6. The median length was 27 years. The majority of the respondents stated a good recent crash history, with 83% having experienced no crashes in the last three years, 13% having experienced one crash, and the remaining 4% having experienced two or more crashes in that time.

Table 3.6 Driver History Length of Participants

Number of Years Driving	Sample Distribution
0-10	21.3%
11-20	17.0%
21-30	17.2%
31-40	17.9%
41-50	14.7%
50+	11.9%

The sample has a high proportion of young drivers – of the 21.3% that have less than ten years driving experience, 13.6% have less than five years of experience.

Lastly, participants were asked to rate their own driving ability on a five-point scale ranging from 'Very Poor' to 'Excellent'. This distribution is shown in Figure 3.8. As shown in Figure 3.8, 76% survey respondents believe themselves to be at least above average drivers. This finding is consistent with other studies posing this question (Douma & Alarcon, 2018).

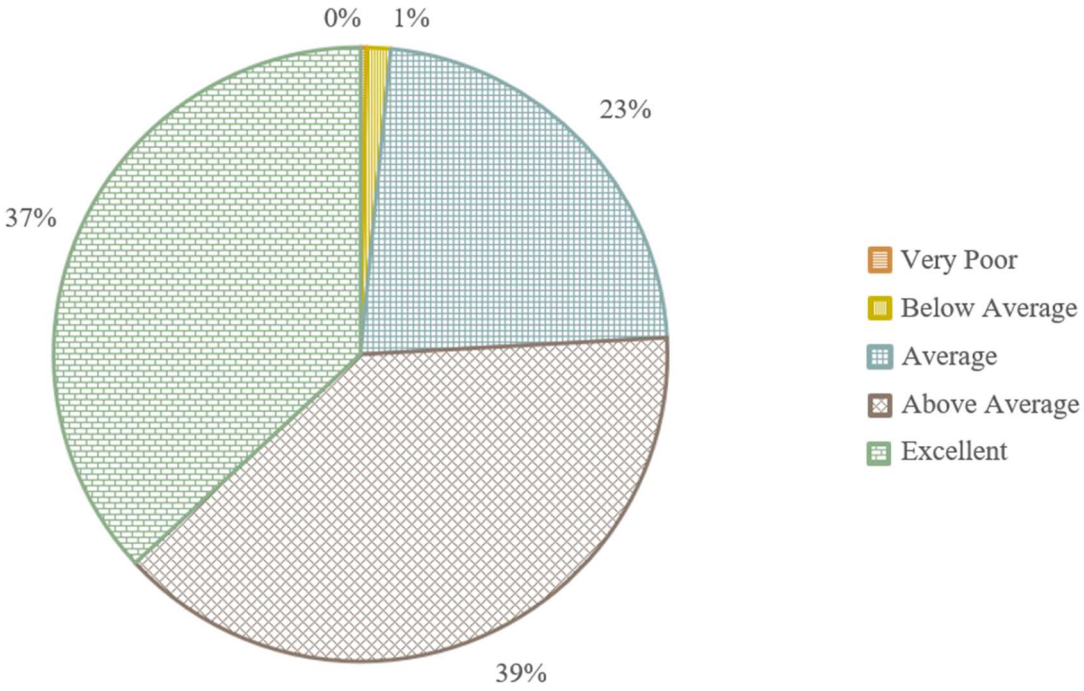

Figure 3.8 Participant Self-Perceived Driving Ability

4. DESCRIPTIVE STATISTICAL ANALYSIS

This chapter will discuss the descriptive statistical analysis of the survey instrument. A full summary of the results of the survey is provided in Appendix C.

4.1 Alternative Intersection Perception Analysis

4.1.1 Alternative Intersection Awareness

For each alternative design, each participant was asked to provide their awareness of the design. Three levels of awareness were used - no awareness, peripheral awareness, and total awareness. These results are shown in Figure 4.1.

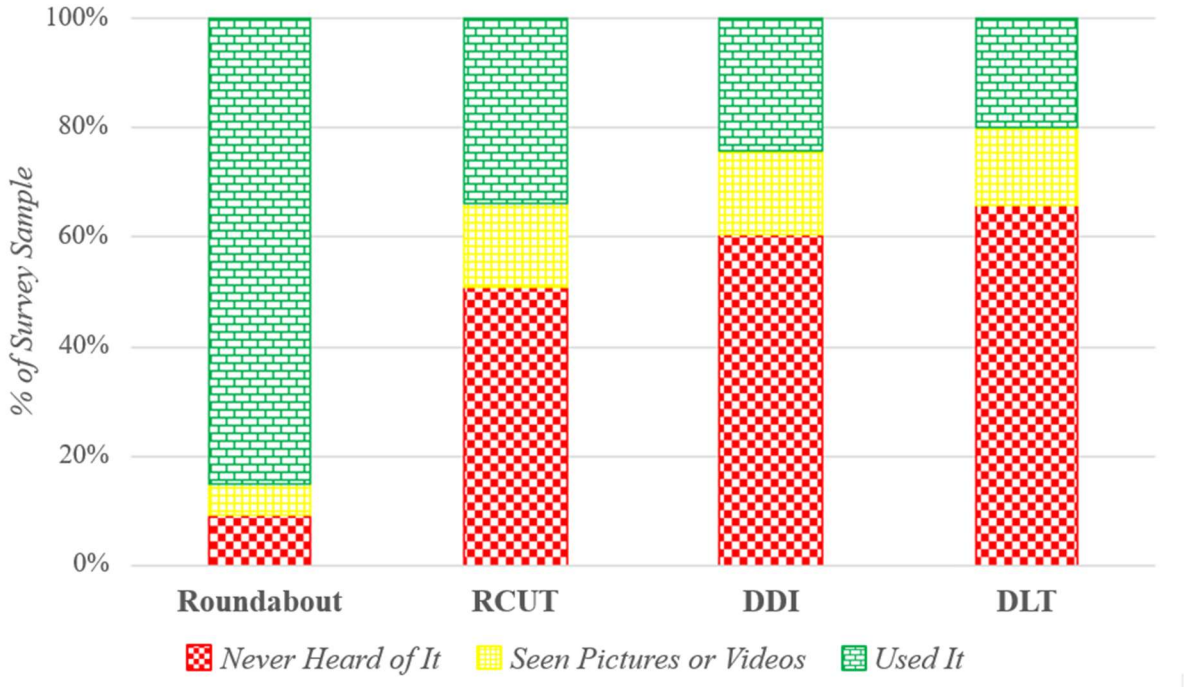

Figure 4.1 Alternative Intersection Awareness

As expected, awareness is highest for the familiar and ubiquitous roundabout, and lowest for the rare displaced left turn (DLT). There are currently no DLTs installed in Indiana, seven restricted crossing U-turns (RCUT), and only three diverging diamond interchanges (DDI), so it follows that more than 40% of the sample is unfamiliar with these designs.

4.1.2 Alternative Intersection Acceptance

For each alternative design, each participant was asked to provide their opinion regarding potential implementation of the design in their area on a five-point Likert scale, which was used to indicate acceptance of the alternative design. As it is known that the public often have different opinions regarding single and multilane roundabouts, they are considered separately. These results are shown in Figure 4.2.

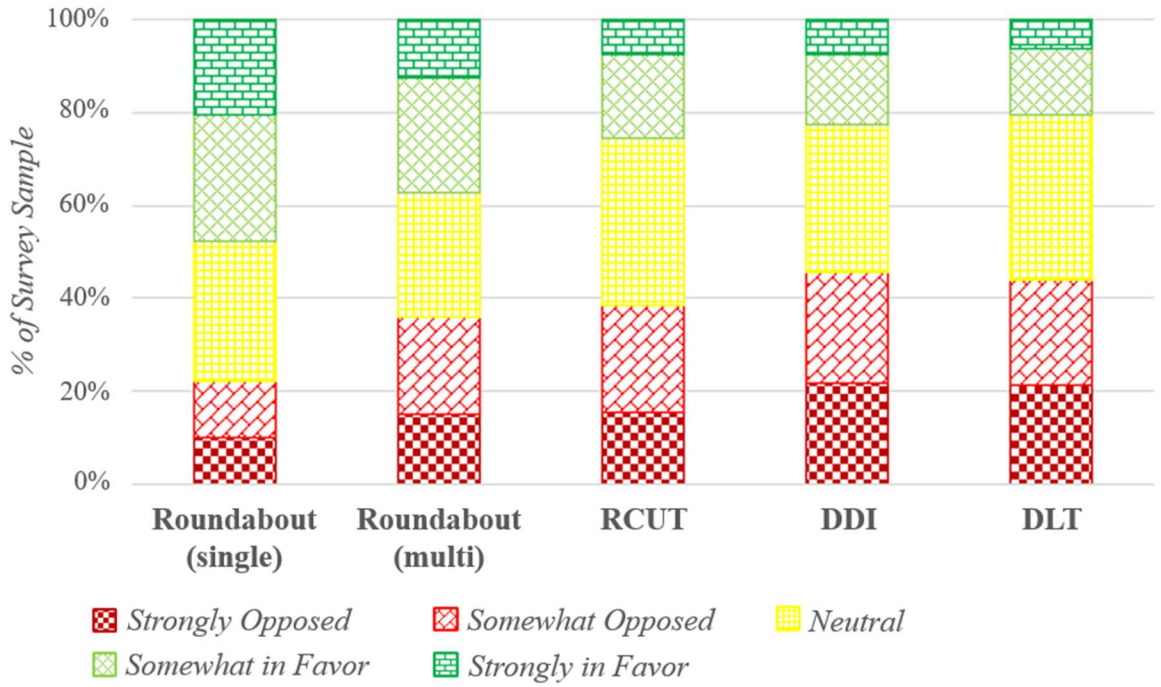

Figure 4.2 Alternative Intersection Acceptance

A large portion of the sample is neutral regarding alternative intersection designs, but they are most ambivalent toward the DLT and least ambivalent toward the multilane roundabout. The most accepted design was the single-lane roundabout, and the least accepted design was the DDI (45% oppose), followed closely by the DLT (43% oppose). Multilane roundabouts garnered significantly more opposition and less acceptance than their single-lane counterparts.

One key trend emerges from this data, especially in comparison to the awareness data shown in Figure 4.1. Designs with higher levels of awareness are related to higher levels of acceptance, and vice versa, though the correlation is not particularly strong (correlation coefficients for this

relationship range from 0.13 to 0.3, p-values < 0.01, excepting multilane roundabout acceptance). This is consistent with other research (Jackson et al., 2014; Savolainen et al., 2012) that has shown that people are frequently more accepting of treatments after they have had experience using them.

The exception to this trend is the multilane roundabout, which has nearly equivalent opposition as the RCUT, even though multilane roundabouts are far more common than RCUTs. However, the multilane roundabout also has more acceptance than any design aside from the single-lane variety. Additionally, the sample was comparatively least ambivalent about this design. Taken together, these facts lead to the conclusion that the public is more opinionated regarding multilane roundabouts than other treatments and that this opinion is split; roughly equal proportions indicated acceptance and opposition. Public opinion regarding multilane roundabouts is much more likely to be a result of positive or negative real-world experience than opinion regarding RCUT, DLT, or DDI.

4.1.3 Alternative Intersection Confidence

Lastly, participants were asked to rank their confidence regarding navigating each treatment. These results are shown in Figure 4.3.

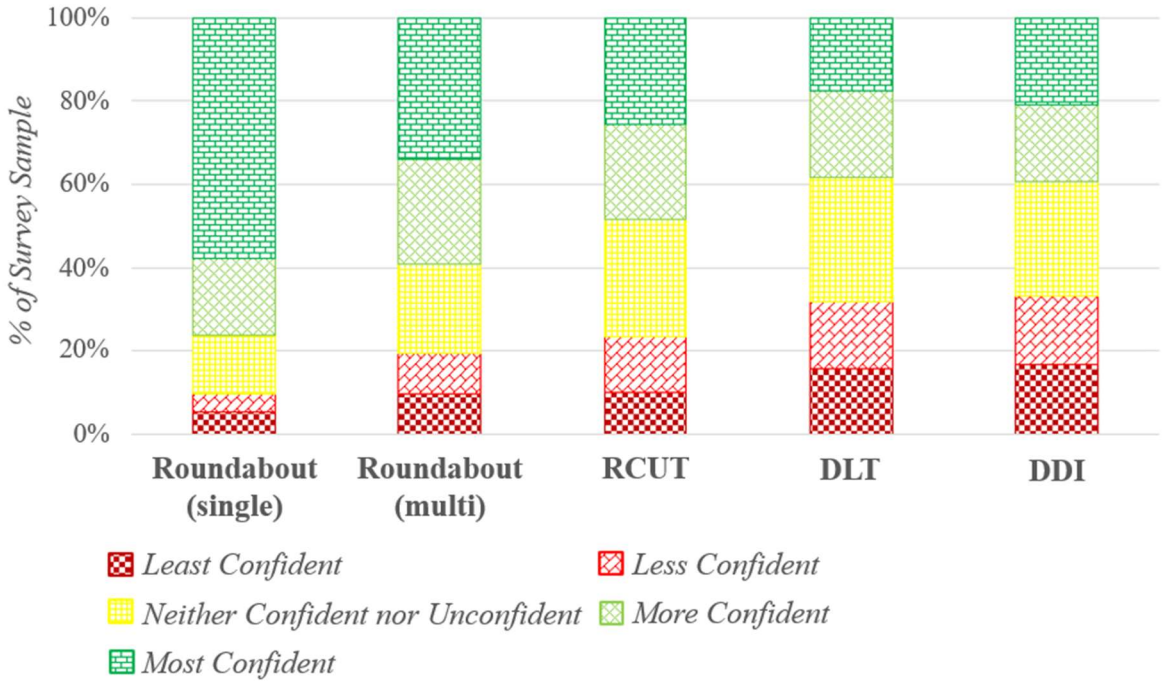

Figure 4.3 Alternative Intersection Driver Confidence

The same shape as seen in Figure 4.1 and Figure 4.2 appears here – the familiar roundabout has high confidence, and the unfamiliar DLT and DDI have lower confidence. Notable is the fact that although 60%-65% of the sample have never heard of either the DLT or the DDI, only 32%-33% of the sample indicated they would not be confident navigating through the treatment, although an additional ~30% indicated neutral confidence.

Additionally, notable and concerning are the confidence levels for both roundabout types. Despite their prevalence on Indiana's highways, only 76% of respondents indicated that they are confident using single-lane roundabouts, a figure that drops to 60% for the multilane version. One in four drivers stated that they are not confident (chose a rating other than more/most confident) in their ability to navigate a single-lane roundabout, and one in three drivers stated that they are not especially confident in their ability to utilize a multilane roundabout.

4.1.4 Understanding of Alternative Intersections

For each alternative design, participants were asked to choose from a series of statements evaluating their understanding of the design's purpose and their opinion of the design. Participants were not required to pass judgement on every statement (but had to choose at least one), and as a result, no single statement had more than 50% of the sample select it. The average statement selection rate across all designs was approximately 25%. Table 4.1 shows the response rates between designs for those statements which were common across most of the designs. Not all options were included for both single-lane roundabouts and multilane roundabouts but rather were offered for roundabouts in general unless otherwise noted.

Table 4.1 Participants' Cross-Treatment Understanding

Statement	Roundabout	RCUT	DLT	DDI
Is Too Confusing	10.3%/40.6%*	36.0%	49.5%	38.6%
Drivers Will Avoid	28.6%	29.0%	31.4%	28.3%
Will Cause More Crashes	14.8%	20.3%	27.5%	21.4%
Will Cause Fewer Crashes	32.7%	26.5%	22.9%	21.9%
Will Increase Travel Time	10.2%	19.8%	16.2%	11.2%
Will Reduce Travel Time	46.8%	22.0%	21.7%	21.2%
Won't Work Here	11.7%	20.6%	25.0%	24.7%
Will Work Here	33.1%	24.3%	20.8%	20.8%

*single-lane / multilane

From the information in Table 4.1, a couple of important conclusions arise. Firstly, all of the treatments, with the exception of the single-lane roundabout, are thought to be too confusing by more than a third of the survey sample. Additionally, it is thought that drivers will actively avoid intersections where these treatments are installed, an idea with some merit. One study (Hu et al., 2014) found that older drivers (70 years or older) in particular, avoided newly built multilane roundabouts.

Statements regarding crashes and travel time were phrased in comparison to the relevant traditional intersection/interchange; roundabouts and DLTs were compared with a signalized intersection, RCUT with a two-way stop, and the DDI with a traditional diamond interchange. More people think that roundabouts and RCUTs will reduce crashes and that DLTs will increase crashes; the DDI is approximately a 50/50 split. Across all treatments, more people think that travel time will be reduced by varying margins.

The pair of *'Won't/Will Work Here'* is attempting to capture a sense of community exceptionalism, and refers to the potential belief that a treatment might work somewhere else, but won't or will work here in the local community. Respondents indicated that roundabouts and RCUTs would work in their local communities, but neither the DLT nor the DDI would.

For select designs, additional statements were included to evaluate the public belief regarding common misconceptions for those individual designs. Table 4.2 and Table 4.3 show the results for those design-specific statements.

Table 4.2 Participants' Understanding Statement for Roundabouts and RCUTs

Statement	**Roundabout**	**RCUT**
Large Vehicles Can't Use	32.9%	25.1%
Large Vehicles Can Use	22.7%	18.1%
Entry to multilane Roundabout – yield to all traffic in roundabout	40.2%	-
Entry to multilane roundabout – yield to traffic only in lane I am entering	37.7%	-

A pervasive myth regarding both roundabouts and RCUTs is that larger vehicles (specified as trucks, buses, farm equipment, and emergency vehicles) cannot use them. These myths remain prominent among the survey population. Additionally, there is obviously confusion regarding proper yielding behavior at a multilane roundabout – entering traffic is required to yield to all traffic within the roundabout, but 37% of the sample believes they are only required to yield to traffic in the lane they are entering. This result points to the need for improved signing on approach to ensure understanding.

Table 4.3 Participants' DDI Understanding Statement Results

Statement	**DDI**
Driving on the Left Side is Unsafe	18.1%
People Will Drive the Wrong Way	36.1%
Peds/Bikes Can't Use	21.3%
Peds/Bikes Can Use	14.6%

The crossover to the left-hand side of the roadway required by the DDI can raise concerns among the public regarding potential safety issues. More than a third of the sample believe that at least some drivers will drive the wrong way through a DDI. Traffic control devices located at DDIs strongly reinforce the desired pathway, but these traffic control devices (particularly signs) are not typically shown on DDI-related media. It is also clear that myths surrounding pedestrians and bicyclists at DDIs remain in the minds of respondents.

4.1.5 Media Preferences

For these questions, participants were required to choose their most utilized source of information and to optionally list a second and third source. This section sought information regarding both current and desired sources for information regarding INDOT projects and services, and current sources for real-time driver information. The response profile for desired information sources regarding projects and services almost exactly matched the current sources profile, meaning that people are getting information where they would like to. For brevity, only the desired profile is shown below in Figure 4.4.

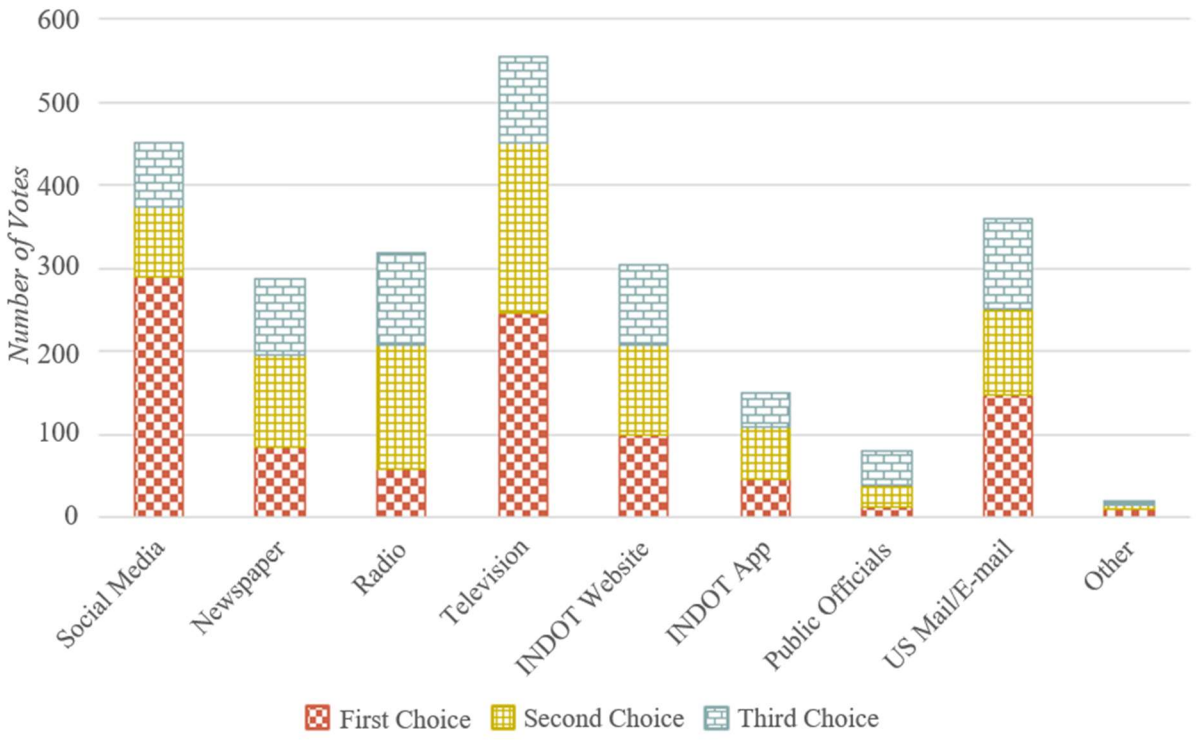

Figure 4.4 Desired Sources of Information for INDOT Projects and Activities

For current and desired sources information regarding INDOT projects and services, social media was the most common response for the first-choice source, while television received the most votes overall. Radio, newspaper, and word of mouth were also heavily utilized sources. Although the profile for current and desired information sources is almost identical, there is one key area where they differ – U.S. Mail/E-mail. A significantly larger portion of respondents (360) indicated they would like to receive information from U.S. Mail/E-mail than those who indicated they are receiving information through that channel presently (59).

Desirable sources of information across all age groups were not uniform and largely conforms to already known trends. Social media is most popular among the youngest age groups, noticeably dropping off for those over 35 years old. Television is most popular among the older three age groups beginning with those over 45 years old. Radio was not a popular first choice but was a common second or third choice across all age groups. Newspapers were by far most popular among those 65 and older, but still pulled a fairly large number of individuals 55-64 years old. Interest in

E-mail or U.S. Mail communications was also highest among those 65 and older, but significant interest was also shown by those aged 35 – 64.

The response profile for real-time driver information is shown in Figure 4.5.

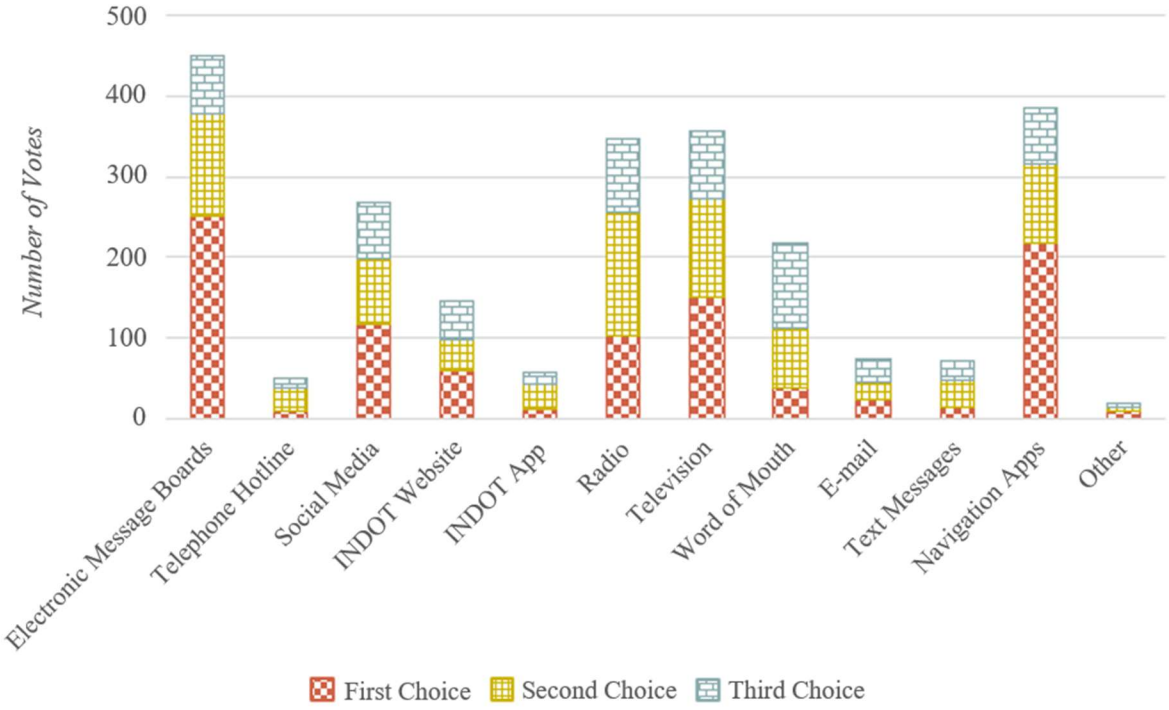

Figure 4.5 Current Sources for Real-Time Information

Electronic message boards (also called dynamic message signs or DMSs) along highways are the most common response for most utilized source, followed by navigation apps such as Google Maps and Waze. Radio, television, social media, and word-of-mouth were all also relatively commonly listed sources for real-time information. Somewhat fewer respondents reported using the INDOT website or app for this purpose.

4.1.6 Alternative Intersection Spatial Analysis

Additionally, an exploratory spatial analysis was conducted to explore any potential relationship between proximity to an alternative intersection and awareness, acceptance, and confidence

utilizing the design. Theoretically, those living closer to an intersection are more likely to be aware of the design and potentially have used it than those living further away.

This analysis was conducted using ArcGIS Pro. As there are no displaced left turns located within Indiana's borders, they were excluded from this analysis. Participants were assumed to reside at the centroid of the ZIP area provided, using the U.S. Census Zip Code Tabulation Areas (ZCTA). Locations of all roundabouts, restricted crossing U-turns, and diverging diamond interchanges within the state were provided by the Indiana Department of Transportation (INDOT). Figure 4.6 - Figure 4.9 show the locations of respondents, roundabouts, restricted crossing U-turns, and diverging diamonds within the state. Please note that respondents who share a ZIP code will exactly overlap, resulting in fewer than 1,000 points on Figure 4.6.

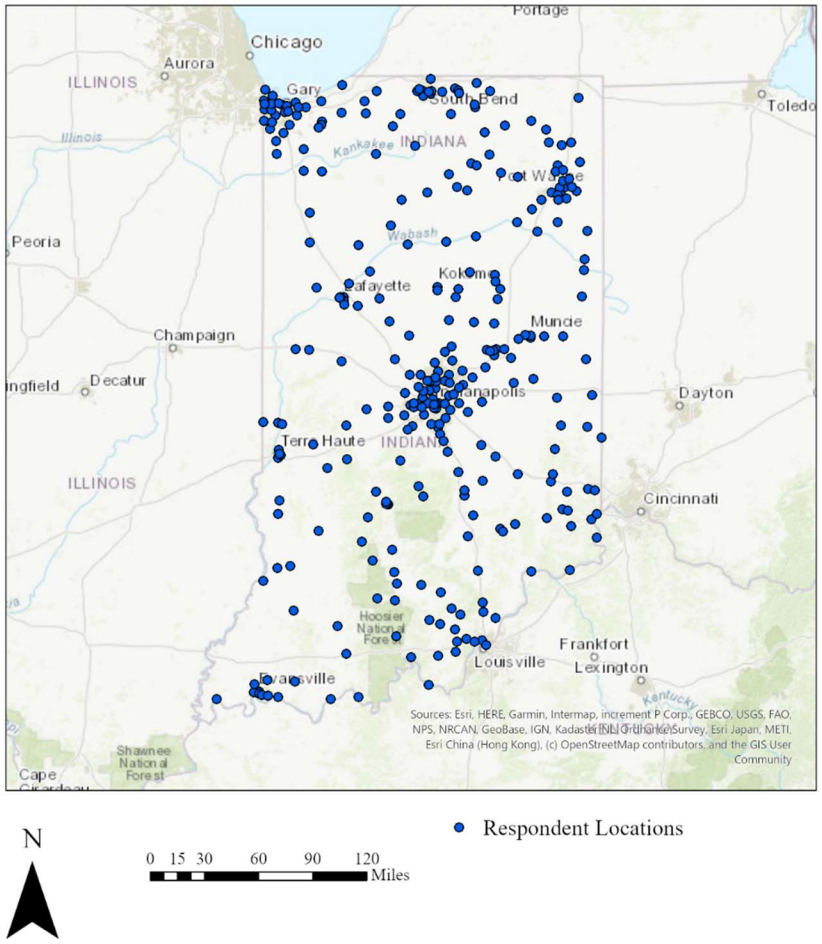

Figure 4.6 Respondent Residential Location Map

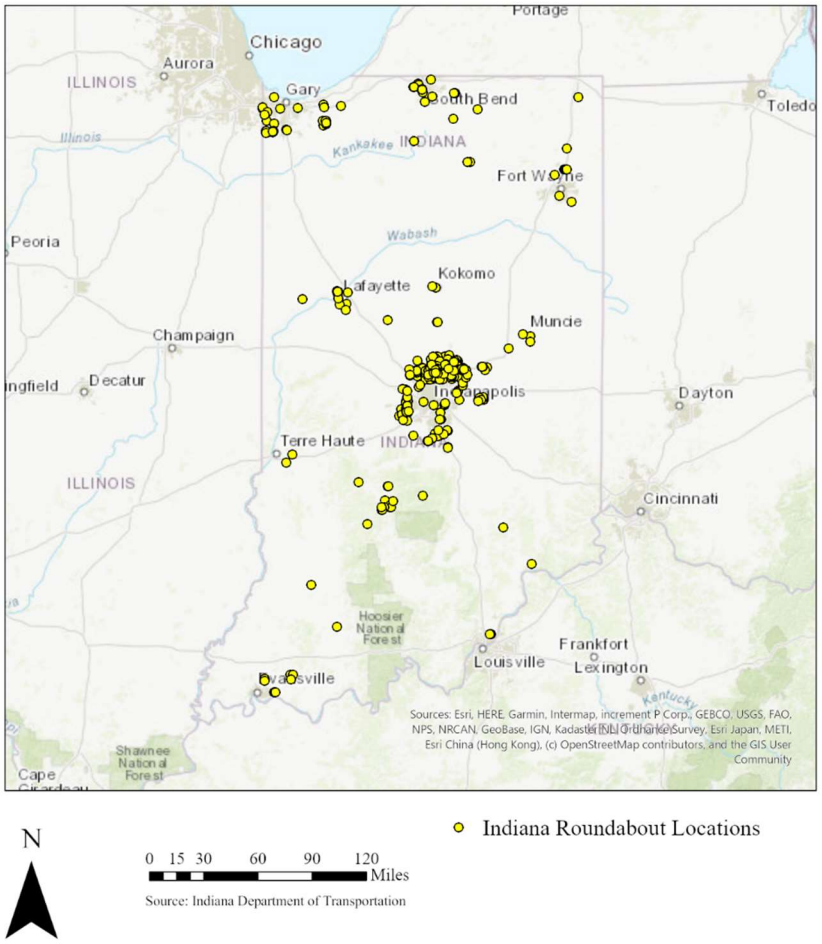

Figure 4.7 Indiana Roundabout Location Map

Indiana RCUT Locations

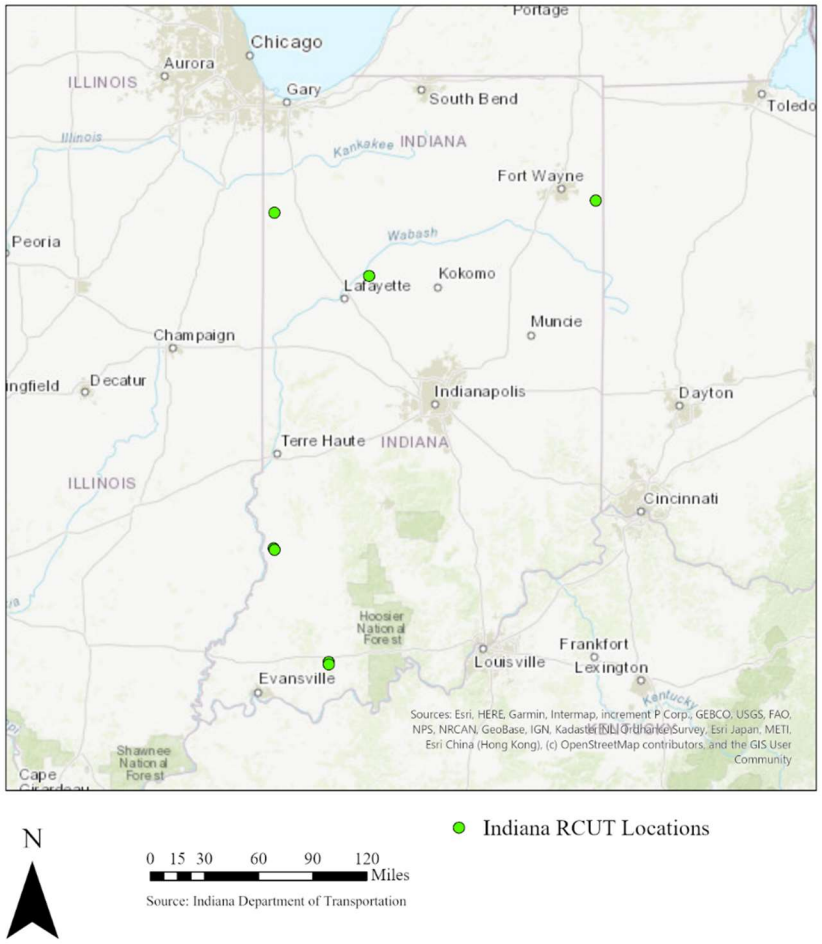

Figure 4.8 Indiana RCUT Location Map

Indiana DDI Locations

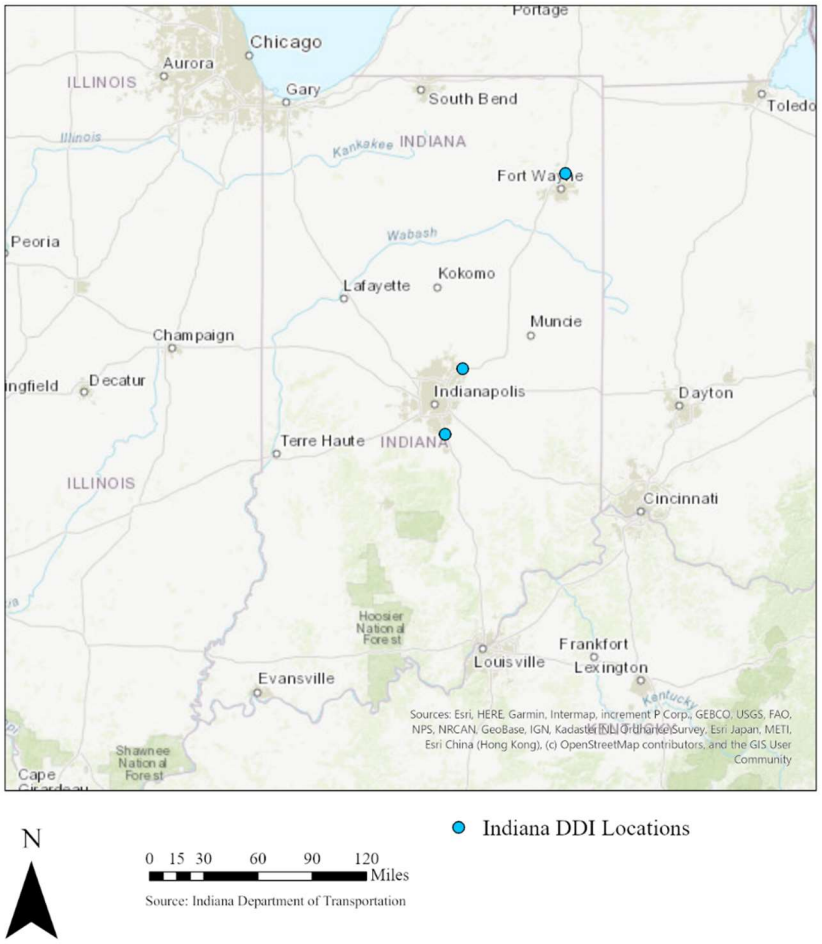

Figure 4.9 Indiana DDI Location Map

Two similar and related analyses were conducted: a proximity analysis and a buffer analysis. The proximity analysis was conducted to determine the distance from each participant to the nearest roundabout, RCUT, and DDI. As there are more than 350 roundabouts within Indiana, nearly all participants live quite close to one. Although there are seven RCUTs within the state, they are located predominately at rural intersections in rural areas, so relatively few respondents live near one, and almost none live within ten miles. Indiana's three DDIs were constructed at high volume interchanges in relatively densely populated areas, so a reasonably large proportion of the sample reside near them. The results of the proximity analysis will be used as independent variables in the inferential analysis in Chapter 5.

The buffer analysis served to simplify and aggregate the results. Around each intersection, a multi-ring buffer was drawn at a distance of five, ten, fifteen, and twenty miles. These buffers were chosen based on a variety of factors, including the results of the trip distribution question shown in Figure 3.6. The RCUT was then excluded from further analysis as there were too few respondents within each ring to make reasonably sound conclusions. The rest of the buffer analysis focused on the roundabout and the DDI. Within each buffer, participants were grouped together and the average awareness, acceptance, and confidence for each buffer was found. The results of this analysis are shown in Figure 4.10 - Figure 4.15.

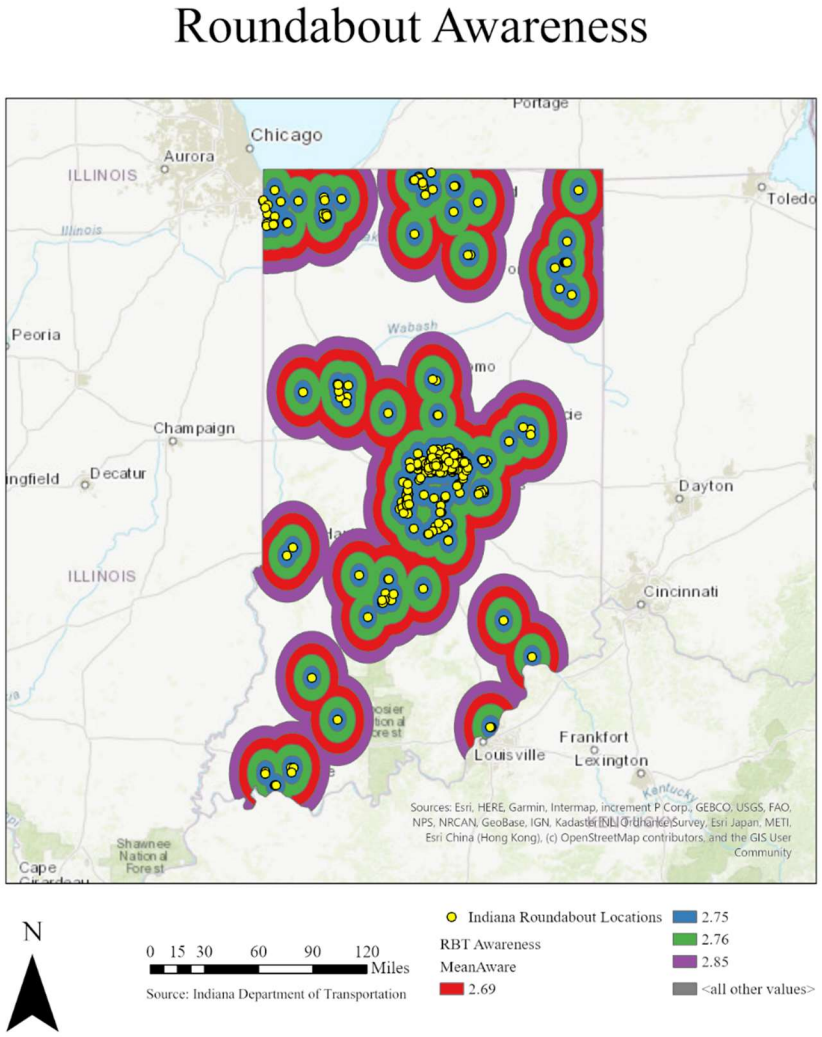

Figure 4.10 Roundabout Awareness Buffer Analysis Map

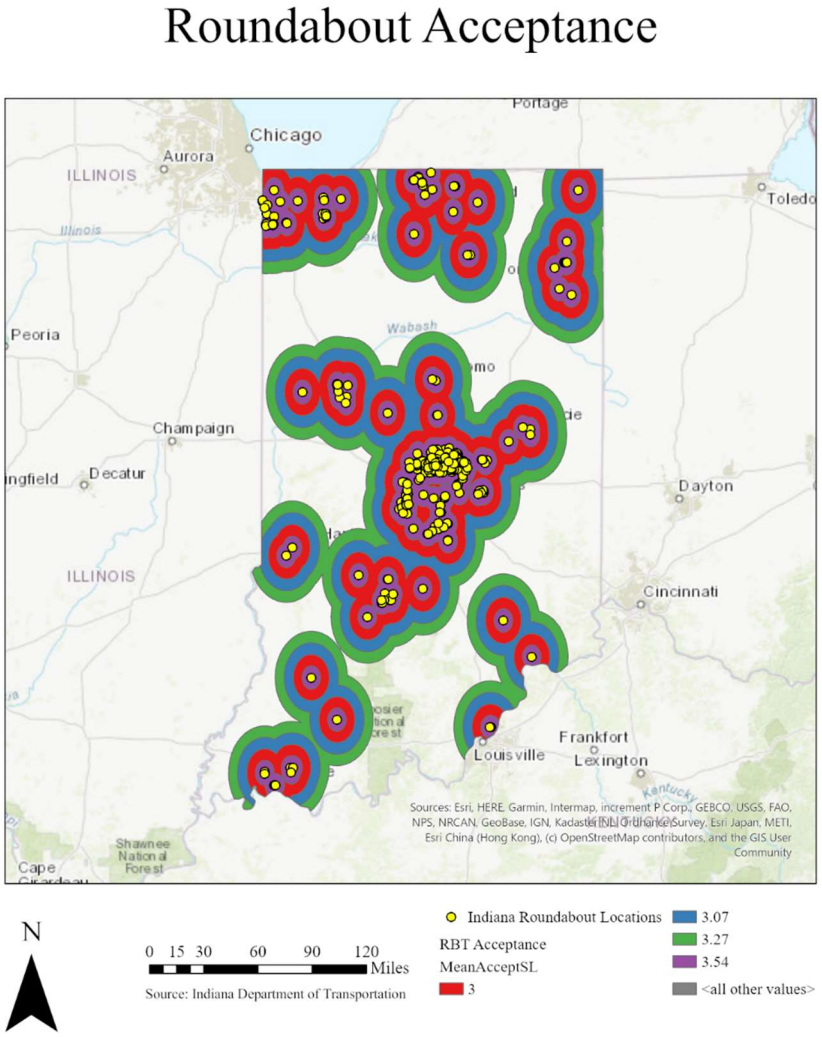

Figure 4.11 Roundabout Acceptance Buffer Analysis Map

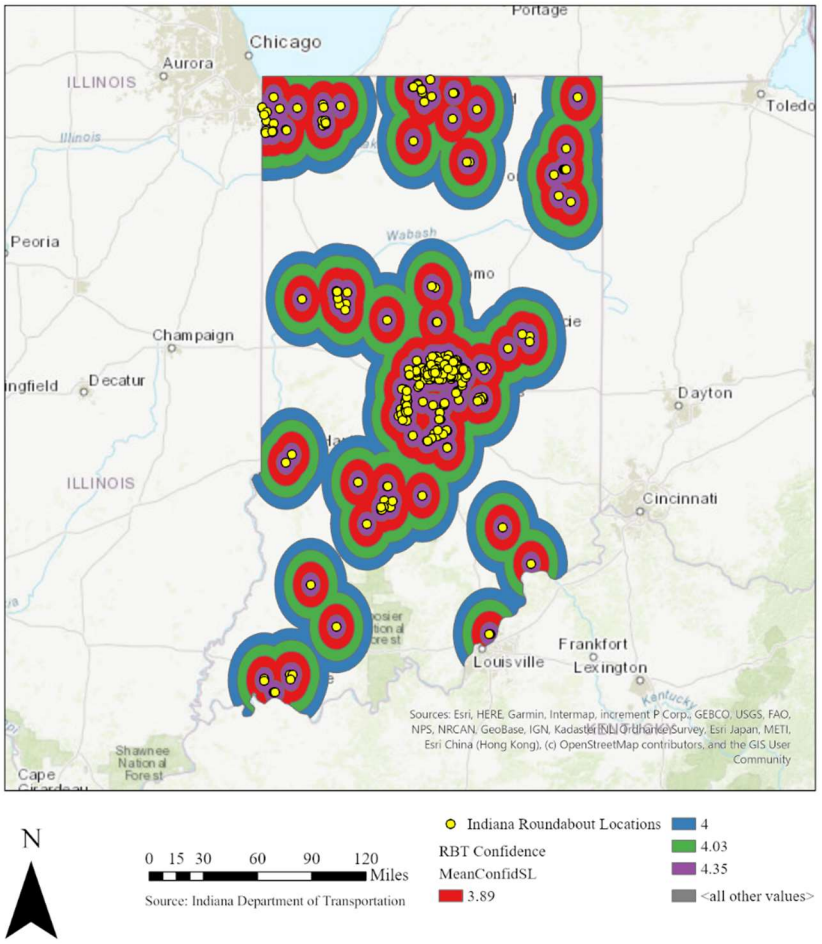

Figure 4.12 Roundabout Confidence Buffer Analysis Map

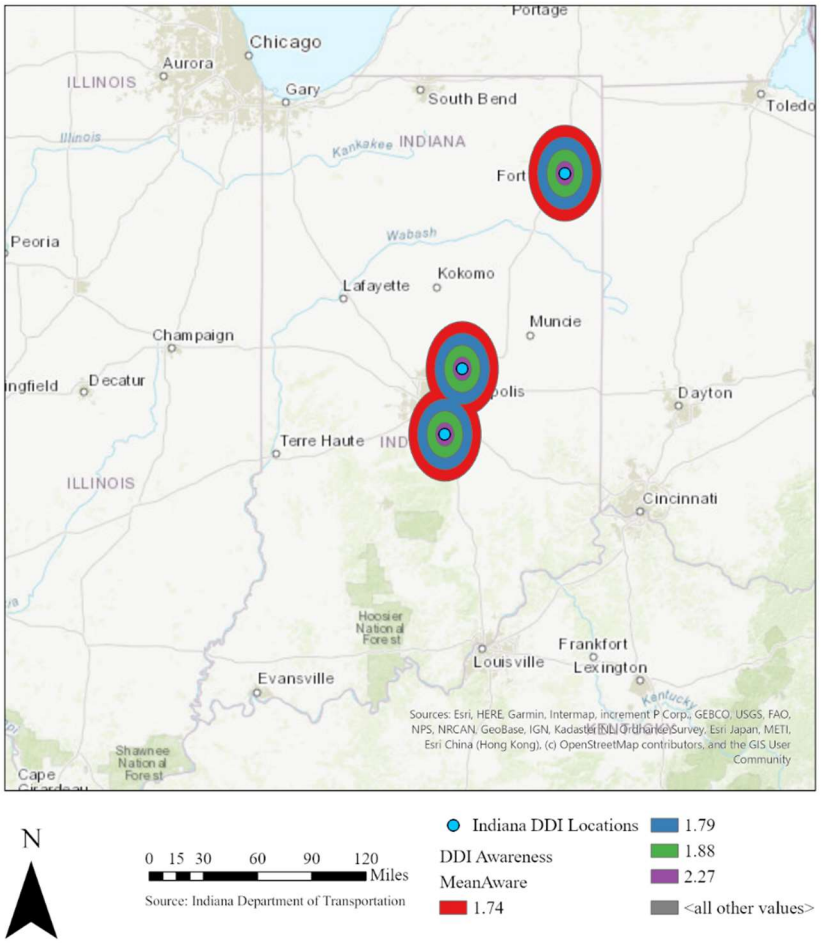

Figure 4.13 Diverging Diamond Awareness Buffer Analysis Map

Diverging Diamond Acceptance

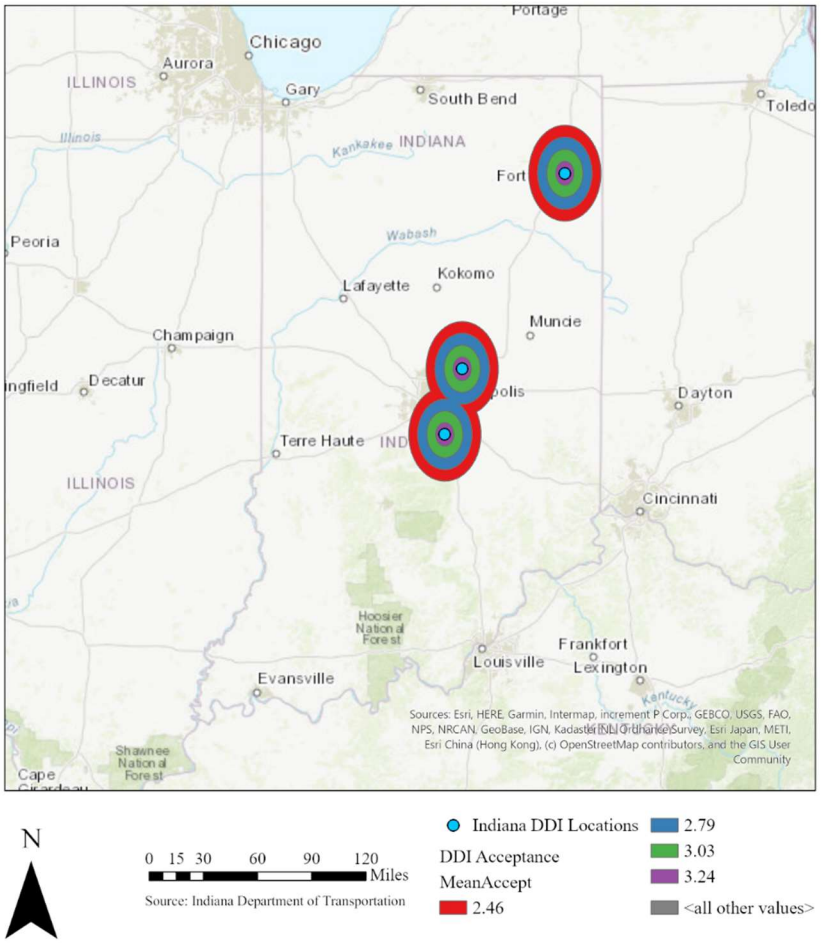

Figure 4.14 Diverging Diamond Acceptance Buffer Analysis Map

Diverging Diamond Confidence

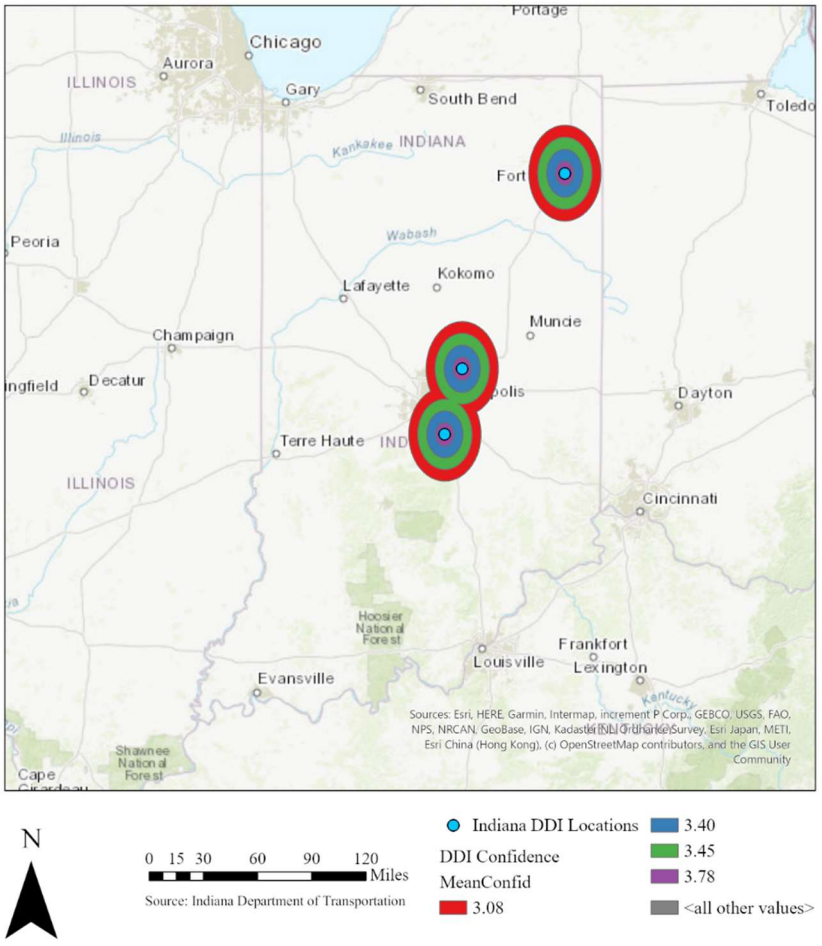

Figure 4.15 Diverging Diamond Confidence Buffer Analysis Map

Figure 4.10, Figure 4.11, and Figure 4.12 show the results of the analysis for roundabouts. Distance seems to have a minimal impact on awareness of roundabouts. All four rings have an average value between 2.75/3 and 2.85/3, and the most aware ring is the 15-20 mile outer ring. Two key factors that may contribute to this lack of variation are the fact that 60% of the sample resides within five miles of a roundabout and that 80% of the sample are highly aware (have used) roundabouts. The relationship between roundabout acceptance and proximity is closer to what was expected – acceptance is highest closest to the intersections and better than sample average, and decreases from there. The same is true for confidence – highest closest to the intersection and better than sample average, and decreases as distance increases.

Figure 4.13, Figure 4.14, and Figure 4.15 show the results of the analysis for the diverging diamond interchange (DDI). The relationship between perception and proximity is much clearer here than for the roundabout. Awareness, acceptance, and confidence are all much higher than sample average for those living within five miles of the intersection of interest (5 miles/sample: 2.26/1.63, 3.24/2.62, 3.78/3.11 for awareness, acceptance, and confidence). As distance from the intersection increases, awareness, acceptance, and confidence decrease.

4.1.7 Alternative Intersection Media Efficacy

One measurement of media type efficacy is number of people who stated that they would be somewhat or strongly in favor of a design for each media type. Across all alternative intersections, the informational video (approximately three minutes) garnered the highest rate of acceptance. The effectiveness of the video compared with other media types varied across the designs. For multilane roundabouts, the diagram performed significantly worse than the video (test of proportions, p-value < 0.05). For the RCUT, the diagram and the flyer performed significantly worse than the video (test of proportions, p-value < 0.1 for the diagram, p-value < 0.05 for the flyer). For the DLT, the diagram and flyer performed significantly worse than the video (test of proportions, p-value < 0.01 for the diagram, p-value < 0.05 for the flyer). For the DDI, the flyer and simulation performed significantly worse than the video (test of proportions, p-value < 0.01).

To measure efficacy more directly, participants were asked to rate the effectiveness of the diagram, flyer, video, and simulation in helping them to understand the intersection designq once all designs

had been shown. The media types were randomized across the designs to remove bias stemming from the varied conceptual difficulty of the alternative intersection designs. Each participant saw each media type only once. Participants were asked to rate effectiveness on a five-point scale, where one represents least effective and five most effective. The results are shown in Table 4.4.

Table 4.4 Participants' Media Effectiveness Ratings

	1	**2**	**3**	**4**	**5**	**AVG**
Arrow Diagram	6%	21%	36%	24%	12%	3.15
Flyer	14%	30%	36%	15%	5%	2.68
Video	2%	5%	13%	31%	49%	4.20
Simulation	3%	9%	18%	38%	32%	3.86

From the results shown in Table 4.4, the video was clearly by far the favorite media type, with an average rating of 4.20. In contrast, the flyer was the least favorite, with an average rating of 2.68. Interestingly enough, of all of the materials used, the video and the flyer were the most uniform across intersections. All videos and flyers used were created by the Virginia Department of Transportation (VDOT) as part of their series on Innovative Intersections and Interchanges (Virginia Department of Transportation, 2020) and contained similar information with a similar production value. Additionally, 25 respondents commented that they felt the video was informative and useful.

In order to try and better understand why participants rated the media types the way they did, they were additionally asked to provide at least one reason for their most highly rated media type. They were allowed to select up to seven reasons, four of which the research team provided, and three of which the participant could type in. The results for the research team provided reasons are shown in Table 4.5.

Table 4.5 Participants' Media Efficacy Rating Reasoning

	Reason No.			
	1	**2**	**3**	**4**
I prefer dynamic (video) media.	65%	11%	9%	5%
I prefer static (print) media.	9%	15%	12%	31%
The media provided enough information to satisfy me.	18%	41%	19%	6%
The media required an appropriate amount of time to view.	7%	25%	25%	15%

Table 4.5 indicates that the reason the video was so effective was simply because it was a video. As navigating an intersection is a moving, dynamic activity, it follows that the best media for explaining this process would be a video. The third reason could help to explain why the video was preferable to the simulation; the video provided more information. The video was approximately three minutes long and included narration regarding how the intersection functions, how different roadway users can use the design, and why the design is effective in achieving its goals. The simulations were generally less than a minute in length and showed only the operations of the intersection with no additional explanation.

4.2 Summary

The descriptive statistical evaluation discussed in this chapter provides a good overview of general perceptions regarding alternative intersection designs. However, to more deeply understand the relationships that may exist between awareness of the design, acceptance of the design, confidence using the design, opinions and beliefs about the design, and the influence of media type, inferential statistical analysis is required. This inferential analysis will be the focus of Chapter 5.

5. INFERENTIAL STATISTICAL ANALYSIS

In addition to a descriptive analysis, an inferential statistical analysis was conducted to explore relationships that may exist between alternative intersection awareness, alternative intersection acceptance, and alternative intersection confidence as well other factors, including socio-demographics, travel behavior, and media type.

5.1 Methodology

The dependent variables of interest are alternative intersection awareness, alternative intersection acceptance, and alternative intersection confidence. Descriptive analysis suggests there may be a relationship between them, so understanding these variables together and separately is important. Awareness was modeled as a univariate model, but moderately high correlation between acceptance and confidence (across all treatments) led to the decision to model these two dependent variables together as a bivariate system. Correlation between all dependent variables across all intersections is shown below in Table 5.1.

Table 5.1 Dependent Variable Correlation Matrix

Multilane Roundabout				**Restricted Crossing U-Turn**			
	Awareness	Acceptance	Confidence		Awareness	Acceptance	Confidence
Awareness	1.000	0.059	0.159	Awareness	1.000	0.189	0.352
Acceptance	0.059	1.000	0.570	Acceptance	0.189	1.000	0.528
Confidence	0.159	0.570	1.000	Confidence	0.352	0.528	1.000
Displaced Left Turn				**Diverging Diamond Interchange**			
	Awareness	Acceptance	Confidence		Awareness	Acceptance	Confidence
Awareness	1.000	0.289	0.311	Awareness	1.000	0.304	0.356
Acceptance	0.289	1.000	0.621	Acceptance	0.304	1.000	0.655
Confidence	0.311	0.621	1.000	Confidence	0.356	0.654	1.000

All intersections were considered separately. For roundabouts, only multilane acceptance and confidence were considered, as multilane roundabouts have significantly lower acceptance and confidence than their single-lane counterpart. Additionally, only acceptance and confidence were modeled for roundabouts, as such a large portion of the population is aware of roundabouts that variation within awareness is minimal. The restricted crossing U-turn (RCUT), displaced left turn (DLT), and diverging diamond interchange (DDI) each generated univariate models for awareness

and bivariate models for a system of acceptance and confidence, for a sum total of seven final models estimations.

Awareness was originally measured on a three-point scale of unaware, somewhat aware, and fully aware. To improve model fit and simplify further analysis, the upper two categories of somewhat aware and fully aware were combined, resulting in two options; unaware and aware, leading to the use of a binary probability model, commonly referred to as binary probit. Binary probit models are a type of regression model and are designed to handle discrete data in two categories. Awareness, once simplified, is a discrete variable with only two categories. (Washington et al., 2011).

The binary probit model estimation equation for two outcomes, denoted as 0 (being unaware) or 1 (being aware), is shown in Equation 5.1, and estimates the probability of outcome 0 occurring for observation *n*.

$$P_n(0) = P(\beta_0 X_{0n} - \beta_1 X_{1n} \geq \varepsilon_{1n} - \varepsilon_{0n}) \tag{5.1}$$

where β_0 and β_1 are vectors of estimable parameters for outcomes 0 and 1 respectively, X_{0n} and X_{1n} are vectors of observable characteristics determining discrete outcomes of 0 and 1 for observation *n* respectively, and ε_{0n} and ε_{1n} are normally distributed random disturbance terms with mean of zero, variances of σ^2_0 and σ^2_1, respectively, and the covariance is σ_{12}.

If $\Phi()$ is the standardized cumulative normal distribution, then:

$$P_n(0) = \phi\left(\frac{\beta_0 X_{0n} - \beta_1 X_{1n}}{\sigma}\right) \tag{5.2}$$

where $\sigma = (\sigma^2_0 + \sigma^2_1 - 2\sigma_{12})^{0.5}$. The parameter vectors β_0 and β_1 are estimated using standard maximum likelihood methods.

The primary model specification utilized for the bivariate analysis was the bivariate ordered probit model. The bivariate ordered probit model is a type of ordinal regression model that is designed to handle two variables, each consisting of discrete, ordered data without loss of information

associated with ordering. Both variables under consideration are discrete and ordered, each having five distinct categories. The categories for alternative intersection acceptance were 'strongly oppose', 'somewhat oppose', 'neutral', 'somewhat in favor', and 'strongly in favor'. Alternative intersection confidence was numbered on a five-point numerical scale, ranging from 1 to 5.

When the ordinal data *y* of each observation is defined, the bivariate ordered probit model is derived (Greene and Hensher 2010; Losada-Rojas et al. 2019). For example, Equation 5.3 is used for the case of two outcomes:

$$\begin{aligned} y_{i,1} &= \beta'_1 X_{\iota,1} + \varepsilon_{\iota,1},\ \ y_{i,1} = j\ if\ \mu_{j-1} < y_{i,1} < \mu_j, j = 0, \dots J_1, \\ y_{i,2} &= \beta'_2 X_{\iota,2} + \varepsilon_{\iota,2},\ \ y_{i,2} = j\ if\ \theta_{j-1} < y_{i,2} < \theta_j, j = 0, \dots J_2 \end{aligned} \tag{5.3}$$

where y corresponds to the ordering of the integer, β is a vector of the estimable parameters, X is a vector of the explanatory variables that affect alternative intersection acceptance and confidence, μ and θ are estimable threshold parameters, j is an integer that represents the ordered severity level, and ε is a random error term that is normally distributed with a mean of zero and a variance equal to one.

The cross-equation correlated error terms are defined in Equation 5.4:

$$\begin{pmatrix} \varepsilon_{\iota,1} \\ \varepsilon_{\iota,2} \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix} \right] \tag{5.4}$$

where ρ is the cross-equation correlation coefficient of the error terms, defined also as the conditional tetrachoric correlation between the two dependent variables of the bivariate ordered probit.

The bivariate ordered probit model with ordered selection joint probability for $y_{i,1} = j$ and $y_{i,2} = k$ is defined as follows in Equation 5.5:

$$\begin{aligned} &P\left(y_{i,1} = j, y_{i,2} = k \left| X_{i,1}, X_{i,2} \right.\right) = \\ &\begin{pmatrix} \Phi_2\left[\left(\mu_j - \beta'_1 X_{\iota,1}\right), \left(\theta_\kappa - \beta'_2 X_{\iota,2}\right), \rho\right] \\ -\Phi_2\left[\left(\mu_{j-1} - \beta'_1 X_{\iota,1}\right), \left(\theta_\kappa - \beta'_2 X_{\iota,2}\right), \rho\right] \end{pmatrix} - \begin{pmatrix} \Phi_2\left[\left(\mu_j - \beta'_1 X_{\iota,1}\right), \left(\theta_{\kappa-1} - \beta'_2 X_{\iota,2}\right), \rho\right] \\ -\Phi_2\left[\left(\mu_{j-1} - \beta'_1 X_{\iota,1}\right), \left(\theta_\kappa - \beta'_2 X_{\iota,2}\right), \rho\right] \end{pmatrix} \end{aligned} \tag{5.5}$$

where *Φ()* is the standard normal cumulative distributive.

The marginal effects of each independent variable can be used to interpret the parameter estimates (Greene and Hensher 2010; Losada-Rojas et al. 2019; Washington et al. 2011):

$$\frac{P(y=j)}{\partial X} = \left[\varphi\left(\omega_{j-1} - \beta X\right) - \varphi\left(\omega_j - \beta X\right)\right]\beta \tag{5.6}$$

where $P(y=j)$ is the probability of outcome *j,* ω is a threshold, and *φ(.)* is the probability mass function of the standard normal distribution.

All modeling was conducted using NLOGIT6, a specialized software package designed to handle econometric and statistical modeling. Full description of the independent variables used in all models, including the correlation matrix is provided in Appendix D.

5.2 Model Variable Summary

In order to facilitate interpretation and understanding of the models, relevant descriptive statistics for all variables used in any model are provided in Table 5.2.

Table 5.2 Model Variable Summary

Variable Name	Variable Description	Response Frequency (%)	Mean	Standard Deviation
OVER55	1 if respondent is over 55 years of age, 0 otherwise.	31	0.311	0.463
UNDER35	1 if respondent is less than 35 years of age, 0 otherwise.	34	0.342	0.475
GENDER	1 if respondent is male, 0 if female.	49	0.489	0.500
MORE_HS	1 if respondent has any college education (completed or not) 0 otherwise.	69	0.686	0.464
UNI_PLUS	1 if respondent has a bachelor's degree or higher, 0 otherwise.	46	0.457	0.498
GRAD_SKO	1 if respondent has a graduate or professional degree, 0 otherwise.	15	0.145	0.352
OVER50K	1 if respondent's annual household income exceeds $50,000, 0 otherwise.	50	0.497	0.500
SM_USER	1 if respondent reported social media as primary current source for INDOT projects and activities, 0 otherwise.	30	0.296	0.456
EXC_DRIV	1 if respondent self-rated themselves an excellent driver, 0 otherwise.	35	0.350	0.477
ABILITY	0/1/2 if respondent self-rated driving ability as average or worse/above average/excellent (not answered by non-drivers)	23/37/35	2.021	0.883
U10K_MI	1 if respondent reported driving fewer than 10,000 miles per year, 0 otherwise.	44	0.435	0.496
SHT_TRIP	Respondent trip frequency for trips less than ten miles (1 if every two weeks or less, 2 if once a week, 3 if 2-3 times per week,4 if 4-7 times per week)	16/10/25/49	3.062	1.113
LNG_TRIP	Respondent trip frequency for trips longer than 50 miles (1 if less often than every six mos. or never, 2 if every six mos., 3 if every three mos., 4 if monthly, 5 if biweekly, 6 if weekly or more.)	26/12/16/23/11/12	3.157	1.690
LNG_MONT	1 if respondent reported taking trips longer than 50 miles at least monthly, 0 otherwise.	45	0.454	0.498
INT_FREQ	Respondent interstate trip frequency (1 if less often than every six mos. or never, 2. if every 3 months or every 6 mos. 3 if monthly, 4 if biweekly, 5 if weekly, 6 if 2-3 time a week, 7 if 4-7 times a week)	18/15/16/12/11/13 /15	3.807	2.083
AA_INTFR	1 if respondent uses interstates at least biweekly, 0 otherwise.	51	0.511	0.500
FRLAN_RU	Respondent four lane rural road trip frequency (1 if never, 2 if less often than every 6 mos., 3 if every 6 mos. or every 3 mos., 4 if monthly, 5 if biweekly, 6 if weekly, 7 if 2-3 times per week, 8 if 4-7 times per week)	15/16/15/14/10/10 /10/10	4.065	2.276
FLRU_MNT	1 if respondent reported using four lane rural roadways at least once a month, 0 otherwise.	53	0.535	0.499

Table 5.2 continued

FRLAN_UR	Respondent four lane urban road trip frequency (1 if less often than every six mos. or never, 2. if every 3 months or every 6 mos. 3 if monthly, 4 if biweekly, 5 if weekly, 6 if 2-3 time a week, 7 if 4-7 times a week)	19/12/12/8/9/18/22	4.193	2.251
TOLAN_RU	Respondent two lane rural road trip frequency (1 if less often than every six mos. or never, 2 if every 3 months or every 6 mos. 3 if monthly, 4 if biweekly, 5 if weekly, 6 if 2-3 time a week, 7 if 4-7 times a week)	11/11/9/8/12/17/32	4.759	2.154
DD_DIST	Distance from respondent's ZIP code to nearest DDI (within Indiana) (ranges from 0 to 2.47)	-	0.911	0.718
RB_VID	1 if respondent was shown the video for roundabout.	22	0.215	0.411
RC_DIA	1 if respondent was shown the diagram for RCUT, 0 otherwise.	25	0.254	0.436
RC_FLY	1 if respondent was shown the flyer for RCUT, 0 otherwise.	24	0.239	0.427
DL_DIA	1 if respondent was shown the diagram for the DLT, 0 otherwise.	27	0.267	0.443
DL_SIM	1 if the respondent was shown the simulation for the DLT, 0 otherwise.	22	0.218	0.413
DD_VID	1 if respondent saw the video for the DDI, 0 otherwise.	27	0.271	0.445
DD_SIM	1 if respondent saw the simulation for the DDI, 0 otherwise.	25	0.252	0.435
PREC_DL4	Predicted probability of binary awareness of DLT, ranging from 0.11 to 0.77, based on the model in Section 5.3.1.	-	0.395	0.128
PREC_DD4	Predicted probability of binary awareness of DDI, ranging from 0.12 to 0.76, based on the model in Section 5.3.1.	-	0.340	0.136

5.3 Model Estimation Results

5.3.1 Alternative Intersection Awareness

Table 5.3 shows the estimation results of the univariate binary probit model. Full model specification is provided in Appendix E (Tables E.1-E.3) As there was not much variability in awareness for roundabouts across the sample (it was found uniformly high), a model for awareness was not estimated for roundabouts.

Table 5.3 Alternative Intersection Awareness Model Estimation Results

Variable Name	Variable Description	RCUT	DLT	DDI
		Coefficient	*Coefficient*	*Coefficient*
CONSTANT	Constant term	-0.429***	-0.666***	-0.565***
OVER55	1 if respondent is over 55 years of age, 0 otherwise.	-0.232**		
UNDER35	1 if respondent is less than 35 years of age, 0 otherwise.	0.238**	0.381***	0.395***
GENDER	1 if respondent is male, 0 if female.	0.280***	0.192**	
MORE_HS	1 if respondent has any education beyond high school (completed or not), 0 otherwise.			0.224**
OVER50K	1 if respondent's annual household income exceeds $50,000, 0 otherwise.	0.189**		
SM_USER	1 if respondent reported social media as primary current source for INDOT projects and activities, 0 otherwise.	0.252***	0.320***	
EXC_DRIV	1 if respondent self-rated themselves an excellent driver, 0 otherwise.			0.281***
U10K_MI	1 if respondent reported driving fewer than 10,000 miles per year, 0 otherwise.		-0.160*	-0.172**
AA_INTFR	1 if respondent uses interstates at least biweekly, 0 otherwise.	0.167**	0.208**	0.284***
SHT_TRIP	Respondent trip frequency for trips less than ten miles (1 if every two weeks or less, 2 if once a week, 3 if 2-3 times per week,4 if 4-7 times per week)		-0.108***	
FRLAN_RU	Respondent four lane rural road trip frequency (1 if never, 2 if less often than every 6 mos., 3 if every 6 mos. or every 3 mos., 4 if monthly, 5 if biweekly, 6 if weekly, 7 if 2-3 times per week, 8 if 4-7 times per week)		0.049**	
DD_DIST	Distance from respondent's ZIP code to nearest DDI (within Indiana).			-0.193***
McFadden pseudo ρ^2		0.0473	0.0645	0.0523
Adjusted McFadden pseudo ρ^2		0.0372	0.0520	0.0418
Log-Likelihood		-659.49	-599.29	-634.97
Log-Likelihood at zero		-692.23	-640.62	-670.00
Likelihood Ratio test statistic		65.48	82.66	70.07

***,**,* refer to significance at 1%, 5%, and 10% level

In order to evaluate the goodness of fit of the models, the McFadden pseudo ρ^2, adjusted McFadden Pseudo ρ^2, and Likelihood Ratio test statistic were calculated and are shown individually for each model in Table 5.3. The McFadden pseudo ρ^2 and adjusted McFadden pseudo ρ^2 indicate that approximately 4.7% of the variance in awareness of the RCUT is explained by the model, that approximately 6.5% of the variance in awareness of the DLT is explained by the model, and that approximately 5.2% of the variance in awareness of the DDI is explained by the model. The Likelihood Ratio test statistic is χ^2 distributed, with 7 degrees of freedom for the RCUT, 8 degrees

of freedom for the DLT, and 7 degrees of freedom for the DDI. The critical values for each intersection at a 10% confidence level are 12.017 (RCUT and DDI), and 13.362, providing evidence that observed decrease in the log-likelihood function across the models is not random.

Although all intersection designs cannot be modeled as one central awareness, common threads do emerge as variables that are significant in multiple models. The first such variables are age-related – particularly being less than 35 years of age. Younger populations are more likely to be aware of alternative designs, and this effect is strong across all three designs. Additionally, currently receiving information about INDOT projects and services via social media platforms ('Current Social Media User') is associated with a higher likelihood of being aware of alternative intersection designs. Although there is a small correlation between being a social media user and being under 35 years old, this effect is more likely related to the fact that it is easier and cheaper for DOTs and other interested parties to share information about alternative intersections on social media than via other traditional media outlets. Additionally, being male is associated with increased awareness of alternative intersections. The reasons behind this are unclear but may be related to the way that genders give directions and view maps differently (MacFadden et al., 2003). When giving directions to others, men are more likely to use cardinal directions (NSEW), while women tend to give directions based on turns or landmarks – an intersection that they do not turn at or is not near a landmark may not be as memorable.

An additional common thread across all intersections is exposure. Driving more is associated with a higher likelihood of being aware compared with driving less. Those who drive fewer than 10,000 miles per year (median for this sample) are less likely to be aware, while those who use interstate highways at least every two weeks (median for this sample) are more likely to be aware.

The intersections additionally show some unique factors contributing to their awareness. Individuals with an annual household income greater than $50,000 are more likely to be aware of restricted crossing U-turns. One possible explanation is that they have financial means to travel further and more often than individuals of lower incomes. This may also be related to the relationship between income and education.

The diverging diamond interchange has three unique factors contributing to a higher likelihood of being aware; being a self-rated excellent driver, having any education beyond high school (including those who attended but did not graduate college), and living closer to a diverging diamond interchange. Although a person may consider themselves an excellent driver for many reasons, one of those reasons could be their attentiveness to the roadway environment and other vehicles around them, making them more likely to notice an alternative intersection design when they encounter one. More highly educated individuals may seek out more information regarding alternative intersection designs and remember those they have seen better than individuals with less education. Living in close proximity to a diverging diamond interchange (considering only those within Indiana) makes an individual far more likely to be aware of or have used the interchange than those who live further away.

5.3.2 Alternative Intersection Acceptance and Confidence

The estimation results of the four bivariate ordered probit models are presented in the following sections. Full model specifications for all models shown are provided in Appendix E. The coefficients provided in the summaries in Table 5.4 - Table 5.7 apply only to the extreme categories. For example, a positive parameter estimate implies that increasing that parameter will increase the likelihood that a given response is in the highest category (such as 'Strongly in Favor') and decreases the likelihood that the response is in the lowest category ('Strongly Opposed'). One common issue with ordered probit models is that model parameter estimates do not allow for interpretation of changes within the interior categories ('Somewhat Opposed', 'Neutral', and 'Somewhat in Favor'). Analysis of marginal effects can help better understand direction of influence on interior categories. These marginal effects are provided in Appendix E alongside the full model specifications.

Multilane Roundabout

Multilane roundabouts were chosen over their single-lane counterparts for this analysis as single-lane roundabouts garnered higher and more uniform levels of acceptance and confidence, while the multilane roundabout had more evenly distributed levels. A summary of the model estimation

results is shown in Table 5.4. Full model estimation and marginal effects can be found in Tables E.4-E.6 in Appendix E.

Table 5.4 Multilane Roundabout Acceptance and Confidence Model Estimation Results

Variable Name	**Variable Description**	**Acceptance**	**Confidence**
		Coefficient	*Coefficient*
CONSTANT	Constant term	0.566***	0.250**
UNDER35	1 if respondent is less than 35 years old, 0 otherwise.	0.219***	
GENDER	1 if respondent is male, 0 if female.	0.220***	0.347***
UNI_PLUS	1 if respondent has a bachelor's degree or higher, 0 otherwise.	0.245***	0.147**
EXC_DRIV	1 if respondent self-rated driving ability as excellent, 0 otherwise.	0.144**	
ABILITY	0/1/2 if respondent self-rated driving ability as average or worse/above average/excellent		0.234***
AA_INTFR	1 if respondent uses interstates at least biweekly, 0 otherwise	0.202***	
INT_FREQ	Respondent interstate trip frequency (1 if less often than every six mos. or never, 2. if every 3 months or every 6 mos. 3 if monthly, 4 if biweekly, 5 if weekly, 6 if 2-3 time a week, 7 if 4-7 times a week)		0.070***
LNG_TRIP	Respondent trip frequency for trips longer than 50 miles (1 if less often than every six mos. or never, 2 if every six mos., 3 if every three mos., 4 if monthly, 5 if biweekly, 6 if weekly or more.)		0.048***
RB_VID	1 if respondent was shown the video for roundabout.	0.163**	0.201**
Threshold 1		0.676***	0.499***
Threshold 2		1.379***	1.181***
Threshold 3		2.232***	1.860***
Disturbance Correlation (ρ (1,2))		0.632***	
McFadden pseudo ρ^2		0.0614	
Adjusted McFadden pseudo ρ^2		0.0544	
Log-Likelihood		-2782.91	
Log-Likelihood at zero		-2965.10	
Likelihood Ratio test statistic		364.38	

***,**,* refer to significance at 1%, 5%, and 10% level

In order to evaluate the goodness of fit of the models, the McFadden pseudo ρ^2, adjusted McFadden pseudo ρ^2, and Likelihood Ratio test statistic were calculated and are shown in Table 5.4. The McFadden pseudo ρ^2 and adjusted McFadden pseudo ρ^2 indicate that approximately 6.1% of the variance in multilane roundabout acceptance and confidence is explained by the model. The Likelihood Ratio test statistic is χ^2 distributed, with 21 degrees of freedom. The critical value at a 10% confidence level is 29.615, providing evidence that observed decrease in the log-likelihood function across the models is not random.

Several variables are positively influential on both acceptance and confidence for the multilane roundabout. Being male increases the likelihood that an individual is highly accepting and confident using multilane roundabouts, although the effect is noticeably stronger for confidence. The influence of gender on roundabout acceptance was previously found in (Savolainen et al., 2012), and it has been shown that men are in general more confident drivers (Gwyther & Holland, 2012; Kostyniuk & Molnar, 2008; Molnar et al., 2019). Marginal effects for the confidence model reinforce the idea that gender is the most important influencing factor for multilane confidence, based on the high magnitude of its marginal effect (see Table E.6 in Appendix E). Marginal effects analysis for the acceptance model indicates that the factors that are associated with a higher likelihood of acceptance are more uniformly influential. Additionally, those who consider themselves excellent drivers in general are more likely to be highly accepting and confident, with the effect being more pronounced with confidence. Although there are numerous reasons one might consider themselves a good driver, the ability to respond well to new situations (such as a new type of intersection) is likely to be one.

For the multilane roundabout, both acceptance and confidence are somewhat influenced by educational attainment, with more educated individuals more likely to be highly accepting and confident. These individuals may be able to understand the operations and purpose of more complex intersections more easily either in abstract or in reality. Although the measures themselves are different, driving more frequently and on different types of roadway is positively associated with higher acceptance and confidence. One possible explanation for this effect is that those who drive more have more experience with a variety of roadway situations and are generally more adaptable and flexible with changing conditions.

Having been shown the VDOT video on roundabouts also positively influenced the likelihood of high acceptance and confidence. The VDOT video used shows a single-lane roundabout, but the effect remains nonetheless. The one variable that appears to influence only acceptance is age – those under the age of 35 are more likely to be strongly in favor of multilane roundabouts. One potential explanation for this phenomenon is that roundabouts have only relatively recently been added to driver's education materials, and those under 35 years old are far more likely to have received education on roundabouts during their driver training. Another possible reason could be

that reaction times and related physical characteristics decline with age, so younger drivers may be better equipped to maneuver a busy multilane roundabout than older ones.

Restricted Crossing U-Turn

A summary of the estimation results of the bivariate ordered probit model for acceptance of and confidence with the restricted crossing U-turn (RCUT) is shown in Table 5.5. Full model specification is provided in Appendix E, Tables E.7-E.9.

Table 5.5 Restricted Crossing U-Turn Acceptance and Confidence Model Estimation Results

Variable Name	**Variable Description**	**Acceptance**	**Confidence**
		Coefficient	*Coefficient*
CONSTANT	Constant term	0.868***	0.765***
UNDER35	1 if respondent is less than 35 years old, 0 otherwise.	0.175***	
GENDER	1 if respondent is male, 0 if female.		0.303***
GRAD_SKO	1 if respondent has a graduate or professional degree, 0 otherwise.	0.145*	
EXC_DRIV	1 if respondent self-rated driving ability as excellent, 0 otherwise.	0.116*	0.359***
LNG_MONT	1 if respondent reported taking trips longer than 50 miles at least monthly, 0 otherwise.	0.164**	0.191***
TOLAN_RU	Respondent two lane rural road trip frequency (1 if less often than every six mos. Or never, 2. If every 3 months or every 6 mos. 3 if monthly, 4 if biweekly, 5 if weekly, 6 if 2-3 time a week, 7 if 4-7 times a week)		0.047***
RC_DIA	1 if respondent was shown the diagram for RCUT, 0 otherwise.		0.269***
RC_FLY	1 if respondent was shown the flyer for RCUT, 0 otherwise.	-0.176**	-0.166*
Threshold 1		0.728***	0.624***
Threshold 2		1.682***	1.446***
Threshold 3		2.470***	2.068***
Disturbance Correlation (ρ (1,2))		0.596***	
McFadden pseudo ρ^2		0.0552	
Adjusted McFadden pseudo ρ^2		0.0485	
Log-Likelihood		-2807.93	
Log-Likelihood at zero		-2972.10	
Likelihood Ratio test statistic		328.34	

***,**,* refer to significance at 1%, 5%, and 10% level

In order to evaluate the goodness of fit of the models, the McFadden pseudo ρ^2, adjusted McFadden pseudo ρ^2, and Likelihood Ratio test statistic were calculated and are shown in Table 5.5. The

McFadden pseudo ρ^2 and adjusted McFadden pseudo ρ^2 indicate that approximately 5.5% of the variance in restricted crossing U-turn acceptance and confidence is explained by the model. The Likelihood Ratio test statistic is χ^2 distributed, with 20 degrees of freedom. The critical value at a 10% confidence level is 28.412, providing evidence that observed decrease in the log-likelihood function across the models is not random.

Similar patterns regarding significant factors are visible for the restricted crossing U-turn that appeared with the multilane roundabout. Gender does not influence acceptance significantly at all, but it was found that male respondents were more likely to state high driver confidence, likely still because men tend to be more confident drivers in general (Gwyther & Holland, 2012; Kostyniuk & Molnar, 2008; Molnar et al., 2019). Considering oneself an excellent driver positively influences likelihood of high acceptance and confidence for the RCUT just as it did for the multilane roundabout, almost certainly for similar reasons. Marginal effects indicate that gender and self-perceived driving ability are by far the most influential factors for improving the likelihood of higher confidence. As with the multilane roundabout, the marginal effects indicate that all the factors that are associated with the likelihood of higher acceptance are more uniformly influential.

Higher general exposure to the roadway environment remains positively influential in both acceptance and confidence, most noticeable for those who drive long distances at least once a month. Respondents under the age of 35 were associated with a higher likelihood of acceptance – potentially because of more information received during driver's education and/or generally shorter reaction times compared with older drivers. Educational attainment is also significant, but only for explaining acceptance. Respondents holding graduate or professional degrees were more likely to be highly accepting of restricted crossing U-turns.

Having seen the RCUT flyer increases the likelihood of high opposition (low acceptance) and low confidence, while having seen the RCUT diagram has a positive impact on the likelihood of high confidence. The flyer was distributed as a .pdf (within a web-based survey) and may have contained too much information for respondents to scan quickly. The diagram was shown as a static image with color coded arrows corresponding to the relevant movements and apparently

provided enough information for respondents to understand the intersection's operational characteristics.

Displaced Left Turn

Table 5.6 shows a summary of the estimation results the bivariate ordered probit model for acceptance of and confidence with the displaced left turn (DLT). Full model specification and marginal effects can be found in Appendix E, Tables E.10-E.12.

Table 5.6 Displaced Left Turn Acceptance and Confidence Model Estimation Results

Variable Name	**Variable Description**	**Acceptance**	**Confidence**
		Coefficient	*Coefficient*
CONSTANT	Constant term	0.522***	0.730***
GENDER	1 if male, 0 if female.		0.280***
GRAD_SKO	1 if respondent has a graduate or professional degree, 0 otherwise.	0.249***	
EXC_DRIV	1 if respondent self-rated driving ability as excellent, 0 otherwise.	0.132*	0.386***
AA_INTFR	1 if respondent uses interstates at least biweekly, 0 otherwise		0.234***
DL_DIA	1 if respondent was shown the diagram for the DLT, 0 otherwise.	-0.364***	-0.283***
DL_SIM	1 if the respondent was shown the simulation for the DLT, 0 otherwise.		0.127*
PREC_DL4	Predicted probability of binary awareness of DLT, ranging from 0 to 1, based on the model in Section 5.3.1.	0.892***	
Threshold 1		0.654***	0.591***
Threshold 2		1.656***	1.396***
Threshold 3		2.411***	2.046***
Disturbance Correlation (ρ (1,2))		0.686***	
McFadden pseudo ρ^2		0.0796	
Adjusted McFadden pseudo ρ^2		0.0735	
Log-Likelihood		-2737.60	
Log-Likelihood at zero		-2974.27	
Likelihood Ratio test statistic		473.34	

***,**,* refer to significance at 1%, 5%, and 10% level

In order to evaluate the goodness of fit of the models, the McFadden pseudo ρ^2, adjusted McFadden pseudo ρ^2, and Likelihood Ratio test statistic were calculated and are shown in Table 5.6. The McFadden pseudo ρ^2 and adjusted McFadden pseudo ρ^2 indicate that approximately 7.9 % of the

variance in displaced left turn acceptance and confidence is explained by the model. The Likelihood Ratio test statistic is χ^2 distributed, with 18 degrees of freedom. The critical value at a 10% confidence level is 25.989, providing evidence that observed decrease in the log-likelihood function across the models is not random.

This model includes a component of awareness, unlike the previous two models, in the variable PREC_DL4. Awareness in general was first tested and ultimately included based on the descriptive analysis from Chapter 4 that suggested a relationship may exist between awareness, acceptance and confidence. Awareness has by far the largest influence of all variables on the likelihood of high acceptance, although it was not significant for confidence; the strength of this influence is reinforced by the marginal effects for acceptance (see Appendix E, Table E.11). The presence of awareness most likely explains the absence of any age-related variable, as the influence of age is likely being considered as an element of awareness (see Section 5.3.1).

Looking beyond awareness, some familiar trends from the multilane roundabout and RCUT models appear here as well. As in the RCUT model, male respondents were more likely to state high driver confidence. Self-rating as an excellent driver is also still positively associated with the likelihood of high acceptance and confidence, with a stronger effect for confidence. As before, the high level of association of gender and self-perceived driving ability on confidence compared with other factors is reinforced in the marginal effects (see Appendix E). General exposure remains positively influential on likelihood of high confidence, but it is not significant for awareness. However, the effect of exposure is also included as an element of awareness, which is a potential reason for its lack of significance here. Educational attainment shows a similar pattern with the RCUT – positively influential for increasing likelihood of high acceptance, but only for those holding graduate or professional degrees, and with no influence on confidence. One potential explanation for this effect is that the displaced left turn is a fairly complex intersection to try and understand, given that it requires consideration of both geometry and signal operations to fully comprehend.

The diagram for the DLT performed inversely to the way the arrow diagram performed for the RCUT, as those who saw the diagram became far more likely to strongly oppose and to have the

least confidence with this design. The diagrams used in the survey all originated from different sources and are thus in different styles with slightly variable levels of information. Few arrow diagrams other than the one created by VDOT and used for the flyer (and therefore unusable as the DLT's arrow diagram) exist as the DLT is quite rare. The diagram used for the DLT does not specify individual movements and more vaguely explains the concept (see Figure 2.3). The diagram evidently provided insufficient information and may ultimately have served to further confuse. The DLT simulation, which carefully showed all movements and made all of the complex signal coordination clear, had a small positive effect on the likelihood of being highly confident using the DLT.

Diverging Diamond Interchange

Table 5.7 below summarizes the bivariate ordered probit model for acceptance of and confidence using the diverging diamond interchange (DDI). Full model specification can be found in Appendix E, Tables E.13-E.15.

Table 5.7 Diverging Diamond Interchange Acceptance and Confidence Model Estimation Results

Variable Name	Variable Description	Acceptance	Confidence
		Coefficient	*Coefficient*
CONSTANT	Constant term	0.047	
GENDER	1 if male, 0 if female.		0.252***
EXC_DRIV	1 if respondent self-rated driving ability as excellent, 0 otherwise.		0.189***
FLRU_MNT	1 if respondent reported using four lane rural roadways at least once a month, 0 otherwise.	0.122**	
TOLAN_RU	Respondent two lane rural road trip frequency (1 if less often than every six mos. or never, 2. if every 3 months or every 6 mos. 3 if monthly, 4 if biweekly, 5 if weekly, 6 if 2-3 time a week, 7 if 4-7 times a week)		0.055***
FRLAN_UR	Respondent four lane urban road trip frequency (1 if less than monthly, 2 if monthly but less than weekly, 3 if weekly, 4 if 2-3 time per week, 5 if 4-7 times per week)		0.041***
DD_VID	1 if respondent saw the video for the DDI, 0 otherwise.	0.249***	0.276***
DD_SIM	1 if respondent saw the simulation for the DDI, 0 otherwise.	-0.163***	
PREC_DD4	Predicted probability of binary awareness of DDI, ranging from 0 to 1, based on the model in Section 5.3.1.	1.644***	1.404***
Threshold 1		0.674***	0.587***
Threshold 2		1.558***	1.342***
Threshold 3		2.308***	1.894***
Disturbance Correlation (ρ (1,2))		0.722***	
McFadden pseudo ρ^2		0.0901	
Adjusted McFadden pseudo ρ^2		0.0838	
Log-Likelihood		-2733.87	
Log-Likelihood at zero		-3004.59	
Likelihood Ratio test statistic		541.43	

***,**,* refer to significance at 1%, 5%, and 10% level

In order to evaluate the goodness of fit of the models, the McFadden pseudo ρ^2, adjusted McFadden pseudo ρ^2, and Likelihood Ratio test statistic were calculated and are shown in Table 5.7. The McFadden pseudo ρ^2 and adjusted McFadden pseudo ρ^2 indicate that approximately 9.0% of the variance in displaced left turn acceptance and confidence is explained by the model. The Likelihood Ratio test statistic is χ^2 distributed, with 19 degrees of freedom. The critical value at a 10% confidence level is 27.204, providing evidence that observed decrease in the log-likelihood function across the models is not random.

Awareness is by far the most important and positively influential factor contributing to increased likelihood of high acceptance and high confidence for the DDI, with magnitudes of the estimates being greater than one. The marginal effects also show that awareness has the strongest impact on the likelihood of high acceptance and confidence across all categories (see Appendix E, Tables E.14-E.15). As before, this awareness is a predicted probability based on the models from Section 5.3.1. The presence of awareness in both models is likely responsible for the absence of factors seen in other models related to age and education as they are key components of the awareness model.

Beyond awareness, trends that have been observed across all previous designs are present here as well. Male respondents and those who rate themselves as excellent drivers are more likely to state high levels of driver confidence. Additionally, exposure to various differing highway scenarios continues to positively influence likelihood of high acceptance and high confidence, as those who drive more frequently are more likely to be highly accepting and confident with DDI.

Having seen the video for the DDI also helps increase the likelihood of high acceptance and high confidence. The video's in-depth information regarding engineering purpose and operations as well as the use of multiple camera perspectives likely contributed to its success. In contrast, the simulation for the DDI increased the likelihood of high opposition. The lack of information beyond an overhead view of operations may have served to confuse some respondents and in turn, reduce their willingness to accept the DDI.

5.4 Inferential Statistical Summary

Although all treatments were modeled and considered separately, there are clear patterns and trends that are visible across most or all designs. Being younger than 35 years of age was associated with an individual being more likely to be aware of an alternative design and more likely to accept it. Men are more likely to be aware of certain designs and more confident with all designs than women. Higher educational attainment serves to help improve likelihood of awareness and sometimes acceptance. There is also a clear trend that those who believe themselves to be excellent drivers are more likely to have high confidence across all designs and often are more likely to be highly accepting as well. Those who drive more frequently or for longer distances are also more

likely to be aware of alternative designs, highly accepting of them, and more confident using them. Lastly, although the effect was not uniform across treatments, the type of media that participants saw was important and influential for alternative intersection acceptance and confidence.

6. CONCLUSIONS

Alternative intersection designs can help improve intersection safety and efficiency compared with traditional intersection designs. However, public opposition to alternative designs has been a common obstacle for agencies wishing to implement them. Improved understanding of the perception of the general public toward alternative intersection designs can facilitate improving public acceptance and ensure these designs are widely implemented as they are warranted. Research focusing on understanding public perception regarding alternative designs remains primarily limited to roundabouts. This project sought to explore public perception for three additional intersection designs and to explore the factors influencing that perception more deeply.

6.1 Public Perception Across Alternative Intersection Designs

As anticipated, public perception is not uniform across the four different alternative intersection designs. The single-lane roundabout was associated with the highest levels of awareness, acceptance, and confidence, followed by the multilane roundabout and the restricted crossing U-turn. While respondents were not aware of the displaced left turn, they stated higher acceptance and confidence compared to the diverging diamond interchange, of which were more aware.

The results support both initial hypotheses. The displaced left turn and the diverging diamond interchange, with their unusual crossover geometry, garnered the most opposition and the least driver confidence of all treatments considered. Meanwhile, the restricted crossing U-turn, which is less common than roundabouts but uses an already existing maneuver (the U-turn), landed squarely in the middle of all three perception categories – worse than either roundabout geometry, but better than the displaced left or diverging diamond.

Those designs with higher levels of awareness also had higher levels of acceptance and confidence, suggesting that a relationship may exist between awareness, acceptance, and confidence. This trend points toward the fact that one major factor in public opposition and lack of driver confidence is likely lack of awareness and a general fear of the unknown. Once drivers are able to get more

information and exposure to the design, they are more likely to accept the design and be confident using it.

The gap between public perception of single-lane and multilane roundabouts is quite wide. As both types of roundabouts are prevalent on Indiana's highways, it is unlikely that a lack of familiarity with multilane roundabouts is the issue. It is more likely that public opposition and lack of confidence using multilane roundabouts stems from negative experiences with them. The fact that nearly 40% of the sample indicated that they believe multilane roundabouts are too confusing provides further evidence of negative driver experience. There is also clear confusion related to the proper yield behavior in a multilane roundabout, as approximately equal proportions of the sample indicated two different behaviors, one of which is incorrect.

More generally, all of the alternative designs were viewed as being too confusing by 35-50% of the sample, depending on the design and with the exception of the single-lane roundabout. Additional concern over general driver confusion is also represented by the approximately 25% of people who indicated that drivers would avoid alternative designs, and the 36% of people who thought drivers would drive the wrong way through a diverging diamond. Other myths about the intersections remain prominent, including the notion that large vehicles cannot use roundabouts and restricted crossing U-turns, and that pedestrians and cyclists cannot use diverging diamonds.

6.2 Factors Influencing Public Perception

In order to more deeply explore the factors that influence public perception, three binary probit and four ordered probit models were estimated. Three of these models investigated the factors that affect awareness of the restricted crossing U-turn, the displaced left turn, and the diverging diamond interchange using a univariate binary probit specification. The other four models explored factors that impact acceptance and confidence of the multilane roundabout, restricted crossing U-turn, displaced left turn, and diverging diamond interchange using a bivariate ordered probit specification.

Although the intersections were modeled separately, model results indicate that many factors are common or similar across designs. A respondent's age is a relevant factor in both awareness of

and acceptance of alternative designs, with those under the age of 35 being more likely to be aware and to be highly accepting. A respondent's gender is one of the most important factors influencing confidence with an alternative intersection, as male respondents were more likely to state high confidence with all designs. Gender is also relevant in some cases for awareness and acceptance, but this effect is not uniform.

A respondent's self-perceived driving ability is another factor that highly influences confidence, as those who indicate a high level of ability are more likely to indicate a high level of confidence across all treatments. Self-perceived driving ability is also positively influential for awareness and acceptance of some intersection designs. Educational attainment is influential across designs in improving likelihood of acceptance, as those with higher levels of educational attainment have an increased likelihood of high levels of acceptance.

Respondent travel behavior (as reported prior to changes related to the COVID-19 pandemic) is also influential on awareness, acceptance, and confidence. Multiple measures were utilized to describe different elements of travel behavior, but between them a reasonably uniform conclusion can be formed; those who have more exposure to roadway environments are more likely to have positive perceptions. Those who report driving more frequently, for longer trip distances, or just for more miles in a given year are all more likely to be aware, to be highly accepting, and to be highly confident. The effect is not noticeably stronger for one dependent variable over the others.

In addition to exploring factors influencing the dependent variables separately, the relationships between them were also investigated. High correlation between the raw variables and the high significance the bivariate model disturbance correlations both suggest a strong relationship between acceptance and confidence for any given design. Additionally, the results of the univariate binary probit awareness model were used as a potential factor in the models of awareness and confidence for the restricted crossing U-turn, displaced left turn, and diverging diamond interchange. Although it was not significant for the restricted crossing U-turn, the high magnitudes of the model estimates and marginal effects indicate that awareness is highly relevant for acceptance for the displaced left and for acceptance and confidence for the diverging diamond.

6.3 Media Type and Public Perception

Public outreach materials are the most important tools to modify public perception of any transportation technology, including alternative intersections. One of the goals of this project was to explore the efficacy of different types of outreach material for the alternative intersection designs in question, using outreach material already in use by various state departments of transportation. Four types of media were used, all of which are reasonably common – the arrow diagram, the flyer, the informational video, and the short simulation.

The informational video was by far the most effective media type shown, as indicated by participants directly but also as indicated by the influence of that media type on their response patterns. All of the informational videos were created by the Virginia Department of Transportation (VDOT) for their Innovative Intersections and Interchanges series and are publicly available on YouTube. The success of the video confirms both hypotheses – people need material that shows them how the intersection moves but additionally explains why it will work and address some common concerns. An additional factor likely contributing to the success of the VDOT video is its focus on the driver and use of a quasi-first person perspective, showing individual vehicles utilizing the intersection.

Each intersection design had at least one media type that was positively or negatively associated with a likelihood of higher acceptance and confidence, although they were more significant for confidence. For the roundabout and the diverging diamond, participants who viewed the VDOT video had a higher likelihood of high levels of acceptance and confidence. For the restricted crossing U-turn, it was the diagram that was most successful in increasing likelihood of high acceptance and confidence. While none of the media types were especially successful at increasing acceptance and confidence for the displaced left turn, the diagram was negatively associated, increasing likelihood of low acceptance (high opposition) and low confidence. All of the diagrams were produced by different organizations, and the diagram used for the displaced left turn had less information available than some of the other diagrams did. Also slightly negatively associated were the restricted crossing U-turn flyer and the diverging diamond simulation.

6.4 Recommendations

As states continue to implement RCUTs/J-turns/RCIs and Diverging Diamond Interchanges (DDIs), public outreach will remain fundamentally important to reducing opposition to these technologies. Alternative intersection designs with higher levels of awareness have higher levels of acceptance. In general, real-world experience with alternative intersections and interchanges is the best way to reduce opposition, but as these designs remain relatively rare, it will remain unlikely that the public has such experience. The next best thing will continue to be information regarding the design and showing how it operates. The information regarding understanding and misconceptions related to the treatments previously discussed within this report can inform outreach efforts.

Outreach efforts in this area to increase awareness should also take into consideration the reality that in general, women and older populations are less likely to be aware of alternative intersection designs than male or younger populations are. As older populations are also more likely to be getting their information from more traditional sources such as television and newspaper, a focus could be placed on disseminating information regarding alternative treatments through those channels. All participants desire to receive more information than they are presently through the U.S. Mail/E-mail and these channels could be utilized for information regarding emerging treatments alongside other project and service-related information.

A roundabout outreach project interviewing several state DOTs (Veneziano et al., 2013) noted that for many DOTs, ensuring that a roundabout project was successful (in the right location, works well and as intended) helped the DOT with public outreach for future projects, since the success story could be highlighted in outreach efforts. Although intended for roundabouts, this recommendation easily extends to other alternative intersections. Highlighting homegrown successful implementations of these technologies would be a useful part of any outreach campaign. Again, expanding sheer awareness and real-world exposure to otherwise novel intersection or interchange designs is an effective way to improve public acceptance. Lack of familiarity is associated with poor public acceptance, irrespective of the engineering countermeasure.

Public outreach efforts should also be shaped by the conclusions that the informational video was generally most effective in gaining acceptance and that the dynamic mediums of video and simulation performed in general better than the static diagram and flyers. The videos all featured a realistic animation of vehicles utilizing the treatment. A narrator describes briefly how the treatment works, what some of its benefits are in terms of safety and operations, and openly states that the treatment is accommodating for all users. The most unique element of the video compared with the other treatments is the use of multiple perspectives – the camera shows both overhead intersection-wide operations and a practically first person view of an individual vehicle utilizing the treatment. As INDOT and other DOTs continue to develop their own alternative intersection outreach tools, these aspects of the VDOT video can provide guidance.

As Indiana and other states continue to add multilane roundabouts to their roadway networks, more driver education would be beneficial. A large portion of the survey respondents indicated opposition to multilane roundabouts, confusion related to their operation, and a lack of confidence using them. As they are far more common than the other technologies on the list, the opposition and confusion cannot be as easily attributed to lack of awareness. It is highly likely that the opposition is related to poor experiences with multilane roundabouts, likely stemming from driver confusion on the part of both the respondent and other drivers on the roadway related to yield and lane change behavior. In addition to more driver education, engineers designing multilane roundabouts could consider ways to reduce confusion at the intersection through modification of intersection geometry or implementation of additional or different signing and pavement marking schemes.

6.5 Limitations and Future Work

The survey that served as the foundation of this work covered a wide range of topics beyond alternative intersection designs and was limited in maximum length. Not all data that could have been used to further understanding of the public perception of alternative intersections or other areas of interest for this survey could be collected, and nearly all of the topics could be studied more thoroughly with additional survey instruments or alternative research methods. Additionally, like all stated preference surveys, this survey is subject to the limitation that stated behavior often does not match the behaviors observed in reality.

Two additional limitations arise in the demographics of the survey population. Although the sample was forced to be representative in terms of age and gender, it was not so forced in terms of geography, income, and education. Although the sample is fairly representative in terms of geography, the sample is slightly overeducated and of slightly lower-income than the Indiana average. Additionally, collecting only ZIP code rather than complete address limits spatial analysis somewhat, particularly pertaining to issues of urban versus rural as respondents appear to reside at the centroid of their ZIP code area – which may be in a town even if the actual respondent lives several miles outside of town. Complete addresses were not collected due to privacy concerns.

Future work in this area could include continued study regarding alternative intersection awareness and acceptance as alternative designs become more common to understand the way the public acceptance improves (or not), and what aspects of the designs are of particular concern to the public. Such work could also continue focus on differences in perception across alternative designs.

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APPENDIX A: COMPLETE SURVEY INSTRUMENT

Following is the entire survey instrument utilized in this project. All of the media types shown in the survey are the arrow diagram option. All media choices are shown in Appendix B.

Public Acceptance and Awareness of INDOT's Transportation Services
(SPR 4441)

Final Survey

Section 0: Screening Questions

Are you a legal resident of Indiana (meaning you pay taxes and vote)?

- ☐ Yes
- ☐ No

Are you a current or former employee of the Indiana Department of Transportation or of any other transportation industry (e.g. consultants, local or federal transportation employees etc.)?

- ☐ Yes
- ☐ No

What gender do you identify with?

- o Male
- o Female

What is your age?

- o Under 18 (respondents will be directed out of the survey)
- o 18-24
- o 25-34
- o 35-44
- o 45-54
- o 55-64
- o Over 65

INFORMED CONSENT INFORMATION

PUBLIC ACCEPTANCE AND AWARENESS OF INDOT'S TRANSPROTATION SERVICES

IRB Research Project Number: 2020-337
Konstantina Gkritza, Ph.D.
Jon Fricker, Ph.D.
Theodora Konstantinou, M.S.C.E.
Sarah Adsit
Lyles School of Civil Engineering, Purdue University

What is the purpose of this study?

The purpose of this study is to assess public acceptance and awareness of the services of the Indiana Department of Transportation (INDOT). Specifically, more information about public awareness and attitudes regarding traffic engineering practices, including use of highway signs, pavement markings (striping), construction zones, and select intersection and interchange forms.

What will I do if I choose to be in this study?
If you choose to participate in this study, you will be asked to answer questions related to your understanding and approval of various traffic engineering practices at the Indiana Department of Transportation (INDOT), your travel behaviors and patterns, and some basic demographic information.

How long will the survey take?
The survey will take approximately 25 minutes.

What are the possible risks or discomforts?
The risks of participating are minimal and no greater than those encountered in everyday activities. However, if you have distressing feelings after completing this questionnaire and feel that you may need to talk with someone, you can contact the national crisis hotline at 1-800-273-8255.

Will information about me and my participation be kept confidential?
The project's research records may be reviewed by departments at Purdue University responsible for regulatory and research oversight. Your responses and participation are completely anonymous and any information you provide will be confidential. Only Professor Konstantina Gkritza, Ph.D., Professor Jon Fricker, Ph.D., Graduate Research Assistant Theodora Konstantinou, M.S.C.E, and Graduate Research Assistant Sarah Adsit will have access to the data, which will be non-identifiable. All data from the surveys will be coded and entered into a computerized data file that will be stored in password-protected computers accessible only to the research study personnel.

What are my rights if I take part in this study?
Your participation in this study is completely voluntary. You may choose not to participate or, if you agree to participate, you can withdraw your participation at any time without penalty or loss of benefits to which you are otherwise entitled.

Will I receive payment or other incentive?
You will receive compensation from Kantar, a global market research company who administers the survey. That compensation will be in the form of LifePoints, the quantity of which corresponds directly to your time investment. You will receive no more than a $6.00 value for your participation; actual compensation may be less. Any discrepancies or questions related to expected compensation should be directed to Kantar.

Who can I contact if I have questions about the study?
If you have questions, comments or concerns about this project, you can talk to one of the researchers. Please contact Sarah Adsit at sadsit@purdue.edu, or Theodora Konstantinou at tkonstan@purdue.edu

If you have questions about your rights while taking part in the study or have concerns about the treatment of research participants, please call the Human Research Protection Program at (765) 494-5942, email (irb@purdue.edu) or write to:
Human Research Protection Program - Purdue University
Ernest C. Young Hall, 10th floor - Room 1032
155 S. Grant Street, West Lafayette, IN 47907-2114

Please Print this Information Sheet for Your Records

Section 1: Awareness of Current and Emerging INDOT Treatments and Strategies

Ramp Metering

1.1 Do you recognize the roadway environment pictured above, seen on freeway ramps?

- o I have never seen something like this before
- o I have seen pictures or videos of this environment but never in real life
- o I have used freeway ramps with these signals in other states (they do not currently exist in Indiana)

This treatment is known as a **ramp meter**. It consists of a traffic light that shows red to stop cars from entering the freeway, and green to allow a single car to enter the freeway. They are used in areas with high traffic volumes and typically only stop cars during peak periods.

1.2 Which of the following statements regarding ramp meters do you agree with? Check all that apply.

- ☐ Ramp meters waste drivers' time
- ☐ People will avoid interchanges with ramp meters
- ☐ Ramp meters **reduce efficiency of the highway**
- ☐ Ramp meters **improve efficiency of the highway**
- ☐ These meters might work somewhere else, but they **won't work** in my local community
- ☐ These meters might work somewhere else, and **I think they would work** in my local community.

1.3 What is your general opinion on potential implementation of a ramp meter in your area?

- o I would be strongly opposed to it
- o I would be somewhat opposed to it
- o I would be neutral
- o I would be somewhat in favor of it
- o I would be strongly in favor of it

Roundabouts

1.4 Do you recognize the roadway environment you just saw?

- o I have never seen something like this before
- o I have seen pictures or videos of this environment but never in real life
- o I have used intersections like this before in Indiana or elsewhere

1.5 Which of the following statements regarding this intersection do you agree with? Check all that apply.

- ☐ Roundabouts with a single lane are too confusing for drivers
- ☐ Roundabouts with multiple lanes are too confusing for drivers
- ☐ People avoid roundabouts
- ☐ On approach to a multilane roundabout, I yield to **traffic in the roundabout lane I wish to enter**
- ☐ On approach to a multilane roundabout, I yield to **all traffic in the roundabout**
- ☐ Larger vehicles (trucks, buses, farm equipment, emergency vehicles) **can't utilize** roundabouts
- ☐ Larger vehicles (trucks, buses, farm equipment, emergency vehicles) **can utilize** roundabouts
- ☐ Roundabouts cause **more crashes** than a traditional signalized intersection
- ☐ Roundabouts cause **fewer crashes** than a traditional signalized intersection
- ☐ Roundabouts **increase travel time** compared with a traditional signalized intersection
- ☐ Roundabouts **reduce travel time** compared with a traditional signalized intersection
- ☐ Roundabouts might work somewhere else, but they **won't work** in my local community
- ☐ Roundabouts might work somewhere else, and **I think they would work** in my local community.

1.6 What is your general opinion on single-lane roundabouts that have been implemented in your area?

- o I am strongly opposed to them
- o I am somewhat opposed to them
- o I am neutral
- o I am somewhat in favor of them
- o I am strongly in favor of them

1.7 What is your general opinion on multilane roundabouts that have been implemented in your area?

- I am strongly opposed to them
- I am somewhat opposed to them
- I am neutral
- I am somewhat in favor of them
- I am strongly in favor of them

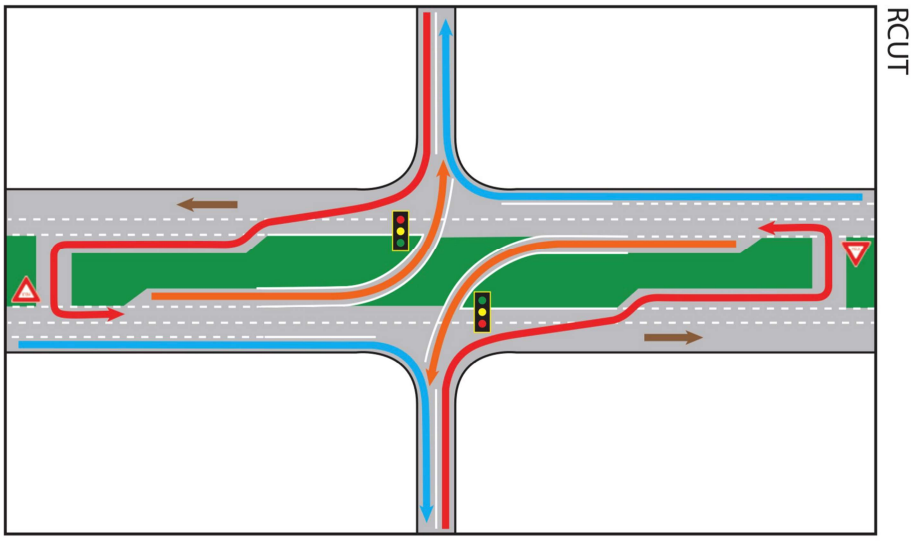
1.8 On a scale of 1-5, where 5 is most confident and 1 is least confident, how confident are you that you can safely navigate *single-lane* roundabouts when you encounter them?

- 1
- 2
- 3
- 4
- 5

1.9 On a scale of 1-5, where 5 is most confident and 1 is least confident, how confident are you that you can safely navigate *multilane* roundabouts when you encounter them?

- 1
- 2
- 3
- 4
- 5

Reduced Conflict Intersection



1.10 Do you recognize the intersection you just saw?

- I have never ever seen something like this before
- I have seen pictures or videos of this environment but never in real life
- I have used intersections like this before in Indiana or elsewhere

1.11 Which of the following statements regarding this intersection do you agree with? Check all that apply.

- ☐ Restricted crossing U-turns are too confusing for drivers
- ☐ People will avoid restricted crossing U-turns
- ☐ Larger vehicles (trucks, buses, farm equipment, emergency vehicles) **can't utilize** restricted crossing U-turns
- ☐ Larger vehicles (trucks, buses, farm equipment, emergency vehicles) **can utilize** restricted crossing U-turns
- ☐ Restricted crossing U-turns will cause **more crashes** than a two-way stop-controlled intersection
- ☐ Restricted crossing U-turns will cause **fewer crashes** than a two-way stop-controlled intersection
- ☐ Restricted crossing U-turns **increase travel time** compared with a two-way stop-controlled intersection
- ☐ Restricted crossing U-turns **reduce travel time** compared with a two-way stop-controlled intersection
- ☐ Restricted crossing U-turns might work somewhere else, but they **won't work** in my local community
- ☐ Restricted crossing U-turns might work somewhere else, and **I think it would work** in my local community.

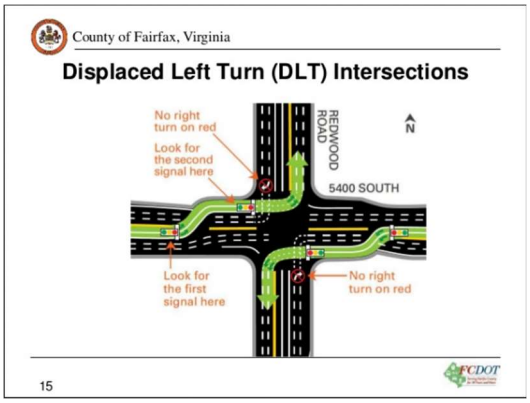
1.12 What is your general opinion on potential implementation of a Restricted Crossing U-Turn in your area?

- o I would be strongly opposed to it
- o I would be somewhat opposed to it
- o I would be neutral
- o I would be somewhat in favor of it
- o I would be strongly in favor of it

1.13 On a scale of 1-5, where 5 would be most confident and 1 would be least confident, how confident are you that if you were to encounter this intersection while driving that you could safely navigate it?

- o 1
- o 2
- o 3
- o 4
- o 5

Displaced Left Turn



1.14 Do you recognize the intersection you just saw?

- o I have never seen something like this before
- o I have seen pictures or videos of this environment but never in real life
- o I have used intersections like this before in Indiana or elsewhere

1.15 Which of the following statements regarding this intersection do you agree with? Check all that apply.

- ☐ Displaced left turns are too confusing for drivers
- ☐ People will avoid displaced left turns.
- ☐ Displaced left turns will cause **more crashes** than a traditional signalized intersection
- ☐ Displaced left turns will cause **fewer crashes** than a traditional signalized intersection
- ☐ Displaced left turns **increase travel time** compared with a traditional signalized intersection
- ☐ Displaced left turns **reduce travel time** compared with a traditional signalized intersection
- ☐ Displaced left turns might work somewhere else, but they **won't work** in my local community
- ☐ Displaced left turns might work somewhere else, and **I think they would work** in my local community.

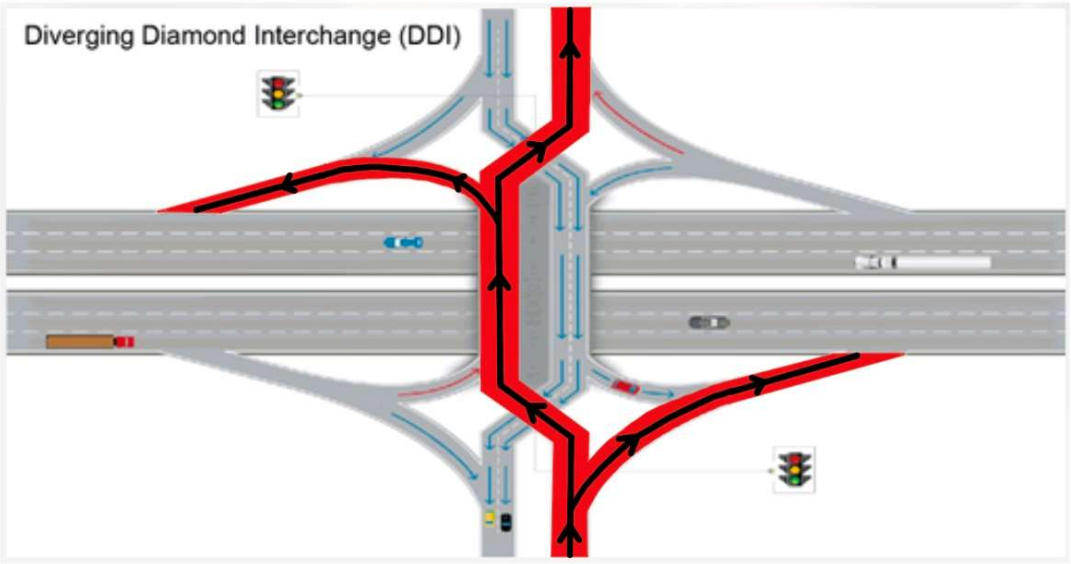
1.16 What is your general opinion on potential implementation of a Displaced Left Turn in your area?

- o I would be strongly opposed to it
- o I would be somewhat opposed to it
- o I would be neutral
- o I would be somewhat in favor of it
- o I would be strongly in favor of it

1.17 On a scale of 1-5, where 5 would be most confident and 1 would be least confident, how confident are you that if you were to encounter this intersection while driving that you could safely navigate it?

- o 1
- o 2
- o 3
- o 4
- o 5

Diverging Diamond Interchange



1.18 Do you recognize the roadway environment you just saw?

- o I have never seen something like this before
- o I have seen pictures or videos of this environment but never in real life
- o I have used intersections like this before in Indiana or elsewhere

1.19 Which of the following statements regarding this intersection do you agree with? Check all that apply.

- ☐ Diverging diamonds are too confusing for drivers
- ☐ Driving on the left-hand side of the road in this scenario is unsafe
- ☐ People will drive the wrong way through diverging diamonds
- ☐ People will avoid diverging diamonds
- ☐ Pedestrians and Bicyclists **can't utilize** diverging diamonds safely.
- ☐ Pedestrians and Bicyclists **can utilize** diverging diamonds safely.
- ☐ Diverging diamonds will cause **more crashes** than a traditional diamond interchange
- ☐ Diverging diamonds will cause **fewer crashes** than a traditional diamond interchange
- ☐ Diverging diamonds **increase travel time** compared with a traditional diamond interchange
- ☐ Diverging diamonds **reduce travel time** compared with a traditional diamond interchange
- ☐ Diverging diamonds might work somewhere else, but they **won't work** in my local community
- ☐ Diverging diamonds might work somewhere else, and **I think they would work** in my local community.

1.20 What is your general opinion on potential implementation of a Diverging Diamond Interchange in your area?

- o I would be strongly opposed to it
- o I would be somewhat opposed to it
- o I would be neutral
- o I would be somewhat in favor of it
- o I would be strongly in favor of it

1.21 On a scale of 1-5, where 5 would be most confident and 1 would be least confident, how confident are you that if you were to encounter this intersection while driving that you could safely navigate it?

- o 1

- 2
- 3
- 4
- 5

Media Effectiveness

You have just seen four different new intersection designs that were presented using four different media types: (1) a diagram with arrows, (2) a two-page flyer, (3) a 2-3 minute YouTube video, and (4) a short simulation, not necessarily in that order.

1.22 Please rate each media type from one to five using the slider (not shown in static version) based on how effective they were in helping you to understand the intersection design they presented. ***(5 being the most effective and 1 being the least effective)***

___ Arrow Diagram
___ Two-Page Flyer
___ Video
___ Short Simulation

1.23 For the media type you rated most highly in the previous question, consider why you rated it that way. Please select and rank the most important reasons below in regards to how heavily they factored in your decision. You must choose at least one reason. If you have reasons not listed, you may write in up to three additional reasons.

___ I prefer dynamic (video) media.
___ I prefer static (print) media.
___ The media provided enough information to satisfy me
___ The media required an appropriate amount of time to view
___ INSERT ANSWER
___ INSERT ANSWER
___ INSERT ANSWER

1.24 Please provide any additional comments in the box below.

Information Sources

1.25 From what source(s) do you regularly receive information regarding INDOT projects and activities? Please rank which of the following sources you utilize most frequently. You may choose up to 5.

- ☐ Facebook/Twitter/ Other Social Media platforms
- ☐ Newspaper
- ☐ Radio
- ☐ Television
- ☐ Word of Mouth
- ☐ INDOT Website
- ☐ Public Officials/Public Meetings
- ☐ U.S. Mail/Email
- ☐ Other:_____

1.26 In which of the following ways would you most like for INDOT to provide you with information regarding INDOT projects and activities? Please rank the following options.

- ☐ Facebook/Twitter/ Other Social Media platforms
- ☐ Newspaper
- ☐ Radio
- ☐ Television
- ☐ INDOT Website
- □ INDOT App
- ☐ Public Officials/Public Meetings
- ☐ U.S. Mail/Email
- ☐ Other:_____

1.27 From what source(s) do you regularly receive information regarding real-time travel conditions? Please rank which of the following sources you utilize most frequently. You may choose up to 5.

- □ Electronic message boards along highways
- □ Motorist assistance telephone hotline
- □ Social networks (Facebook, Twitter, etc.)
- □ INDOT Website
- □ INDOT App
- □ Radio
- □ Television
- □ E-mail
- □ Text messages
- □ Other Navigation App (Google Maps, Waze, etc.)
- □ Other:_____

Section 2: Attitudes and Preferences towards INDOT Services

NOTE: Please answer the following question in reference to *state-owned* highways, which include state roads (SR), US Highways, and interstates, but not county roads or city-owned streets.

Respondent Agreement

2.1 Please indicate the extent of your agreement with the following statements:

	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
A. INDOT clearly and frequently communicates regarding expected road work in my community including nature and anticipated duration.					
B. INDOT reaches out to my community regarding what work should be done and relevant aspects of projects.					
C. Official (signed/posted) detours are easy to follow.					

D. INDOT minimizes traffic delay on freeways during construction activities.					
E. I understand what I am supposed to do (merge, shift lanes) in work zones based on signs at the zone.					
F. Signs in work zone are easy to understand.					
G. Signs that display your speed in school and work zones reduce speeding.					
H. Interchanges in rural areas are well-lit.					
I. Interchanges in urban areas are well-lit.					
J. Urban roadways are well-lit.					
K. Rural roadways are well-lit					

Visibility

2.2 Please rate the average visibility of the following roadway elements in the roadway conditions listed.

	Generally poor	Generally fair	Generally good
A. Roadway striping at night.			
B. Roadway striping in rainy weather.			
C. Raised pavement markers (in-pavement reflectors highlighting roadway striping) showing yellow centerlines or lane lines at night.			
D. Raised pavement markers (in-pavement reflectors highlighting roadway striping) showing yellow centerlines or lane lines in rainy weather.			
E. Road signs at night.			
F. Road signs in rainy weather.			
G. Road signs in snowy weather.			
H. Work zone signs, barrels, and cones at night.			
I. Work zone signs, barrels, and cones in rainy weather.			
J. Work zone signs, barrels, and cones in snowy weather.			
K. Road workers and work equipment at night.			
L. Road workers and work equipment in rainy weather.			
M. Please, select 'Generally Good' for this option.			
N. Road workers and work equipment in snowy weather.			
O. Large overhead signs are clearly visible and legible at night.			

Choice Scenarios

2.3 Please indicate which situation you would prefer if you had to commute a long distance each day.

*Both options below have the **same travel time**, but Option A has the greater distance.*

A. Drive on a roadway that has high speeds, with exits spaced several miles apart, such as a freeway or expressway. Having few exits means that you will have to drive for a longer amount of time on streets with slower speeds and more frequent stops at traffic signals to reach your destination.
B. Drive on a roadway at speeds that are lower than in Option A, because there are intersections with county roads every mile. But having more intersections means that you will drive for a shorter amount of time on streets with slower speeds and frequent stops at traffic signals to reach your destination.

2.4 A state highway bridge along your commute route is to be rehabilitated. Which construction scenario do you prefer?

- The road is fully closed for 4 months due to the construction work – other roads must be used.
- The road is partially closed, and an on-site detour is built such that you do not drive out of your way; work takes 6 months, and due to restrictions traveling through the area is slower than usual

2.5 A major interchange along your usual commute highway is in dire need of maintenance work. Which construction scenario do you prefer?

- The entire interchange (including the highway itself) is closed for 1.5 years while construction takes place. Other roads must be used.
- The interchange is partially closed – individual lanes and ramps are closed or restricted; work takes 2.5 years, and travel through the area is much slower than usual.

2.6 What is your average commute time (in minutes)?

2.7 Assuming that you are travelling to work, please rate your level of frustration regarding each scenario.

	Not frustrated at all	Mildly Frustrated	Extremely Frustrated
A. My trip to work always takes **(user provided)** minutes. There is always some congestion in predictable locations.			
B. My trip to work takes **(user time – 25%)** minutes roughly half the time, and **(user time +25%)** minutes the other half of the time. Sometimes there is congestion, sometimes there is not congestion, and not always in the same spot.			

Speeding and Signing

2.8 What do you think average speed on Indiana's roads is? Please choose a speed range for each of the following locations.

	50-55 mph	56-60 mph	61-65 mph	66 – 70 mph	71-75 mph	76 – 80 mph	81-85 mph	86 - 90 mph	91+ mph
A. Urban Interstates									
B. Rural Interstates									
C. Urban State Highways									
D. Rural State Highways									

2.9 Variable Speed Limits (VSL) display safe speeds for different travel conditions by adjusting posted speed limits based on real-time traffic, roadway, and/or weather conditions, including for work zones. Presently the state does not use VSLs but is considering doing so. How likely would you be to obey a variable speed limit compared to a fixed posted speed limit?

- o Very unlikely
- o Not likely
- o Neutral
- o Likely
- o Very likely

2.10 What does the sign pictured below mean to you?

- o 50 MPH is the legal speed limit
- o 50 MPH is the safe speed
- o 50 MPH is the slowest speed I should drive
- o The safe speed is actually 60 MPH (or more)

2.11 You are currently traveling at 55 MPH and encounter the sign pictured below. What does this sign mean to you?

- There's a curve ahead but I do not need to slow down
- There's a curve ahead and I should slow down slightly (to 50 MPH) in order to navigate it safely
- There's a curve ahead and I should slow down moderately (to 45 MPH) in order to navigate it safely
- There's a curve ahead and I should slow down significantly (to 35 MPH) in order to navigate it safely
- There's a curve ahead and I am required by law to slow down to 35 MPH

2.12 You are approaching a work zone while driving on the interstate at 70 MPH. Signs indicate that the left lane will be closed ahead, and you encounter the sign pictured below. What action will you plan to take?

- I will do nothing, and continue into the work zone traveling the same speed
- I will slow down slightly (to 65 MPH) and continue into the zone
- I will slow down moderately (to 60 MPH) and continue into the zone
- I will slow down significantly (to 55 MPH) and continue into the zone
- I will slow down to the work zone speed limit (50 MPH) and continue into the zone

2.13 You are approaching a work zone while driving on the interstate at 70 MPH. Signs indicate that the left lane will be closed ahead, and you encounter the following pair of signs. Looking ahead, there seems to be activity at the work zone. What action will you plan to take?

- o I will do nothing, and continue into the work zone traveling the same speed
- o I will slow down slightly (to 65 MPH) and continue into the zone
- o I will slow down moderately (to 60 MPH) and continue into the zone
- o I will slow down significantly (to 55 MPH) and continue into the zone
- o I will slow down to the work zone speed limit (50 MPH) and continue into the zone

2.14 You are approaching a work zone while driving on the interstate at 70 MPH. Signs indicate that the left lane will be closed ahead, and you encounter the pair of signs pictured below. What action will you plan to take?

- o I will do nothing, and continue into the work zone traveling the same speed
- o I will slow down slightly (to 65 MPH) and continue into the zone
- o I will slow down moderately (to 60 MPH) and continue into the zone
- o I will slow down significantly (to 55 MPH) and continue into the zone
- o I will slow down to the work zone speed limit (50 MPH) and continue into the zone

Section 3: Respondents' Travel Characteristics and Patterns

Please answer the following questions considering your typical behavior ***prior to any restrictions related to the COVID-19 pandemic.***

3.1 How many personal vehicles does your household own?

0_____ 1_____ 2_____ 3_____ > 4 _____

3.2 How many miles approximately did you drive your personal vehicle (owned by your household) last year?

I do not own a personal vehicle_____ <5,000 miles_____ 5,000-9,999 miles_____ 10,000-14,999 miles_____ 15,000-19,999 miles_____ 20,000-24,999 miles_____ >25,000 miles _____ I do not know_____

3.3 Thinking about how far you typically drive, how often on average do you travel…?

	Never	Less often than every 6 months	Every 6 months	Every 3 months	Once a month	Once every two weeks	Once a week	2-3 times a week	4-7 times a week
A. Distances near to where I live (up to 10 miles)									
B. Medium distances (10-50 miles)									
C. Longer distances (more than 50 miles)									

3.4 How often on average do you travel on the following types of roadway?

	Never	Every 6 months or less	Every 3 months	Once a month	Once every two weeks	Once a week	2-3 times a week	4-7 times a week
A. Interstate								
B. Four-Lane Urban Road								
C. Four-Lane Rural Road								
D. Two-Lane Rural Road								

Section 4: Socio-Demographic Questions

4.1 What is your employment situation?
Work full time ____ Work part time____ Homemaker____ Student____ Retired____
Other: ____

4.2 What is your approximate annual household income before taxes?
Under $25,000____ $25,000 - $49,999____ $50,000 - $74,999____ $75,000 - $99,999____
$100,000 - $149,999____ $150,000 or more____
I do not wish to disclose this information____

4.3 What is your highest level of education?
Grade school or less____ Some high school____ High school graduate____
Technical training beyond high school____ Some college____ College graduate____
Graduate or professional school____

4.4 Do you have a valid Indiana driver's license?

A. Yes
B. No, but I have/have previously had a valid license issued in another US state or another country
C. No, I have never had a driver's license issued in the US or elsewhere

If you chose C, please proceed to question 4.8. Otherwise, please continue with question 4.5

4.5 How many years have you been driving? (if less than 1, enter 0) ____

4.6 Please rate your driving ability on the scale provided below:

- Very Poor
- Below Average
- Average
- Above Average
- Excellent

4.7 How many crashes/collisions have you experienced in the past 3 years while *driving* a vehicle? A crash or collision occurs when the vehicle strikes any object, including other vehicles, persons, trees, poles, fences, a ditch, and any other roadside object. Do not include incidents involving animals. ____

4.8 How many years have you resided in Indiana? (If less than 1, enter 0) ____

4.9 What is your ZIP Code? ___

APPENDIX B: MEDIA USED ON THE SURVEY

All of the media used on the survey instrument are shown here, except for material related to the restricted crossing U-turn, which is shown in Section 3.1.2.

Ramp Meter

Figure B.1 Ramp Meter Image (used with permission from the Arizona Department of Transportation). Site photographed is along Arizona State Route 51 in the Phoenix area.

Roundabout

Figure B.2 Roundabout Diagram (used with permission from the Indiana Department of Transportation (Indiana Department of Transportation, n.d.-b)

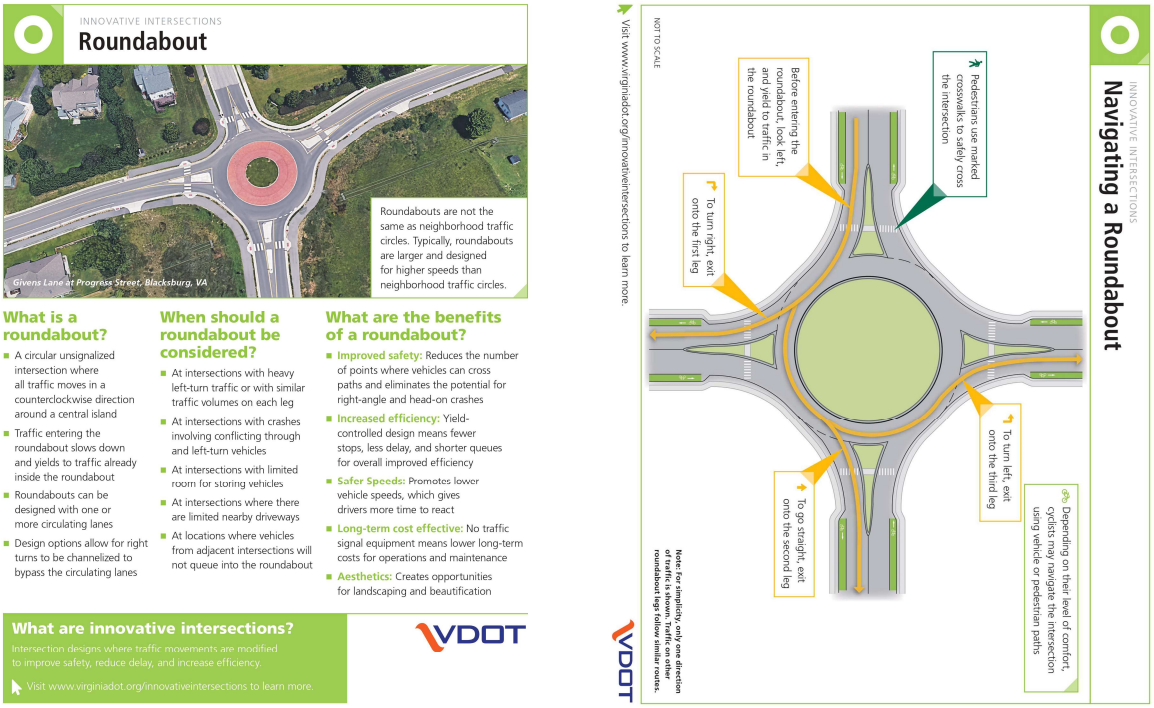


Figure B.3 Roundabout Flyer (used with permission from the Virginia Department of Transportation)

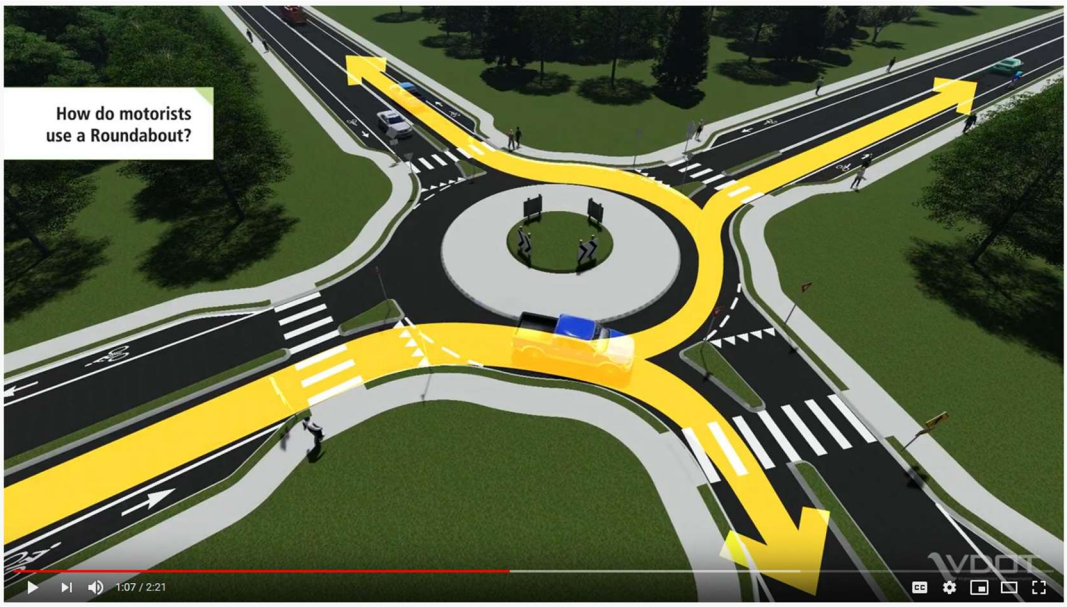


Figure B.4 Roundabout Video Screen Capture (used with permission from the Virginia Department of Transportation)

Displaced Left Turn (DLT)

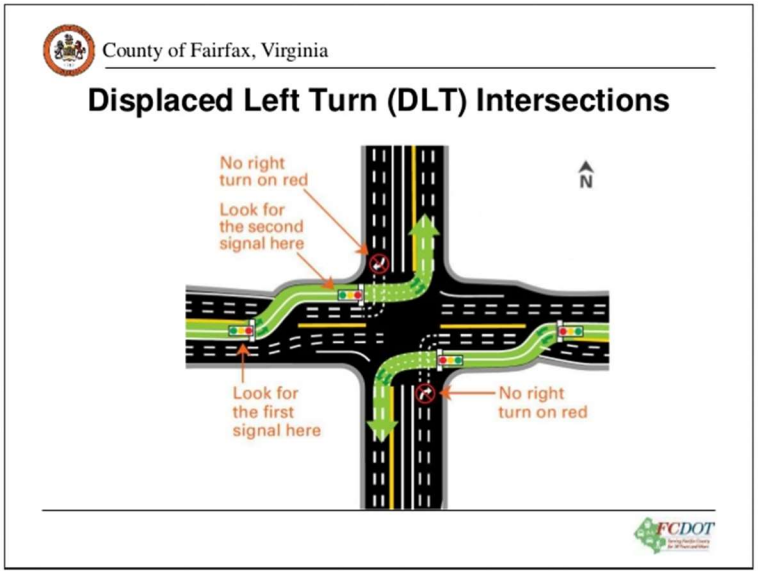


Figure B.5 Displaced Left Turn Diagram (used with permission from the Fairfax County, Virginia Department of Transportation)

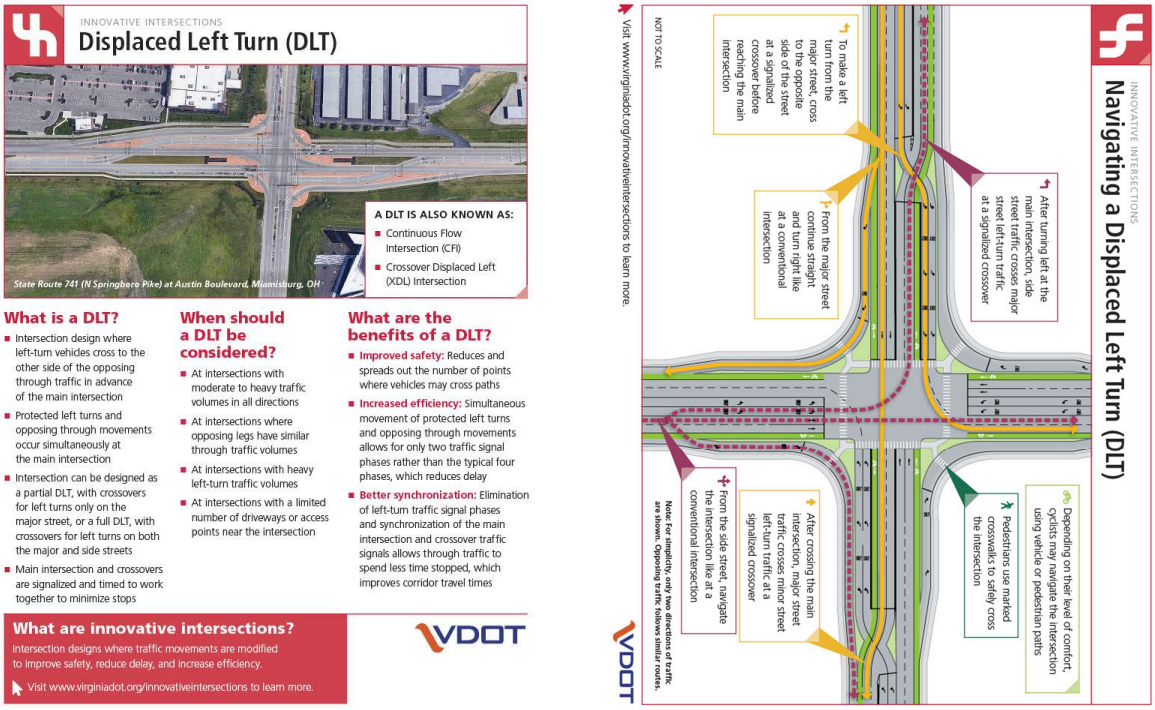


Figure B.6 Displaced Left Turn Flyer (used with permission from the Virginia Department of Transportation)

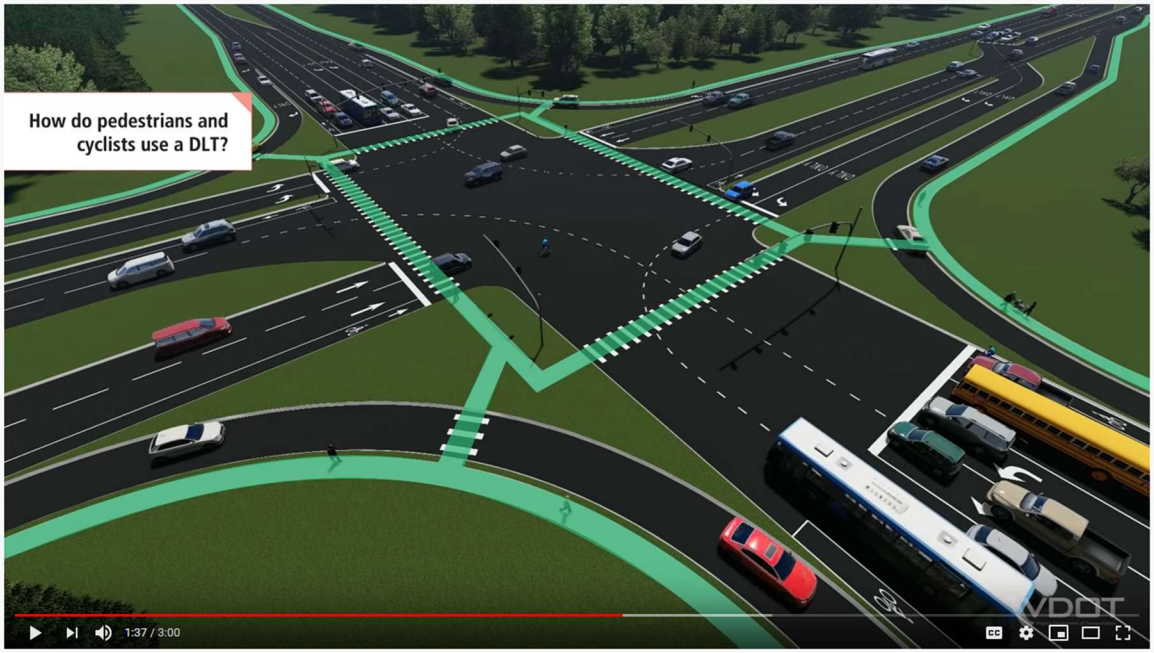


Figure B.7 Displaced Left Turn Video Screen Capture (used with permission from the Virginia Department of Transportation)

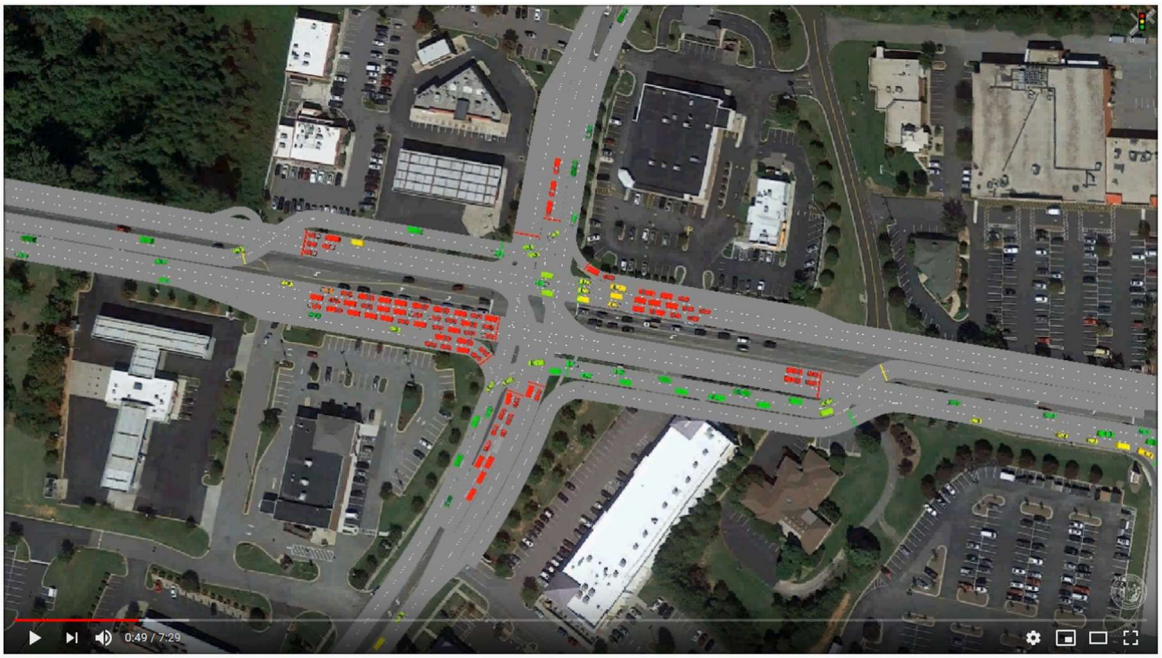


Figure B.8 Displaced Left Turn Simulation Screen Capture (used with permission from the North Carolina Department of Transportation (North Carolina Department of Transportation, 2016))

Note: Although the video is 7:29 long, participants were not required to watch more than the first minute.

Diverging Diamond Interchange (DDI)

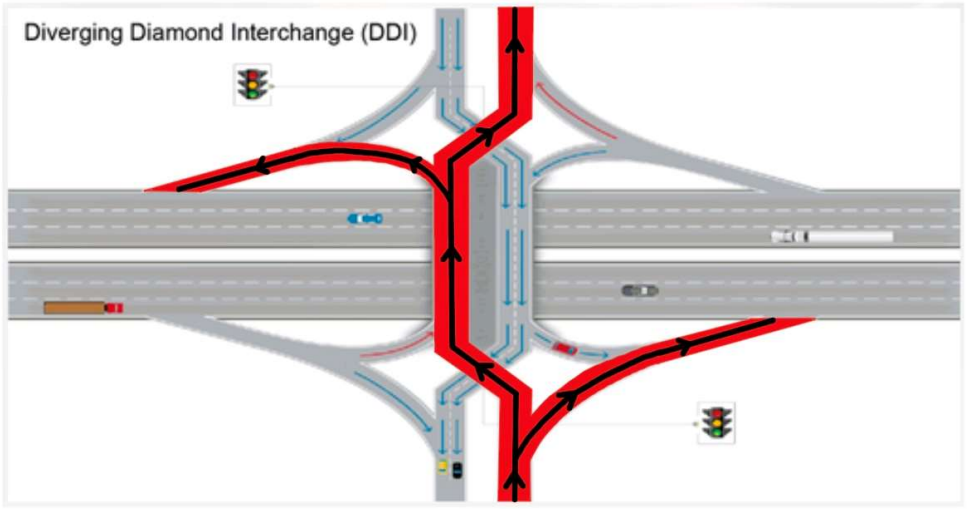


Figure B.9 Diverging Diamond Interchange Diagram (adapted from a diagram published by the Wisconsin Department of Transportation (Wisconsin Department of Transportation, n.d.))

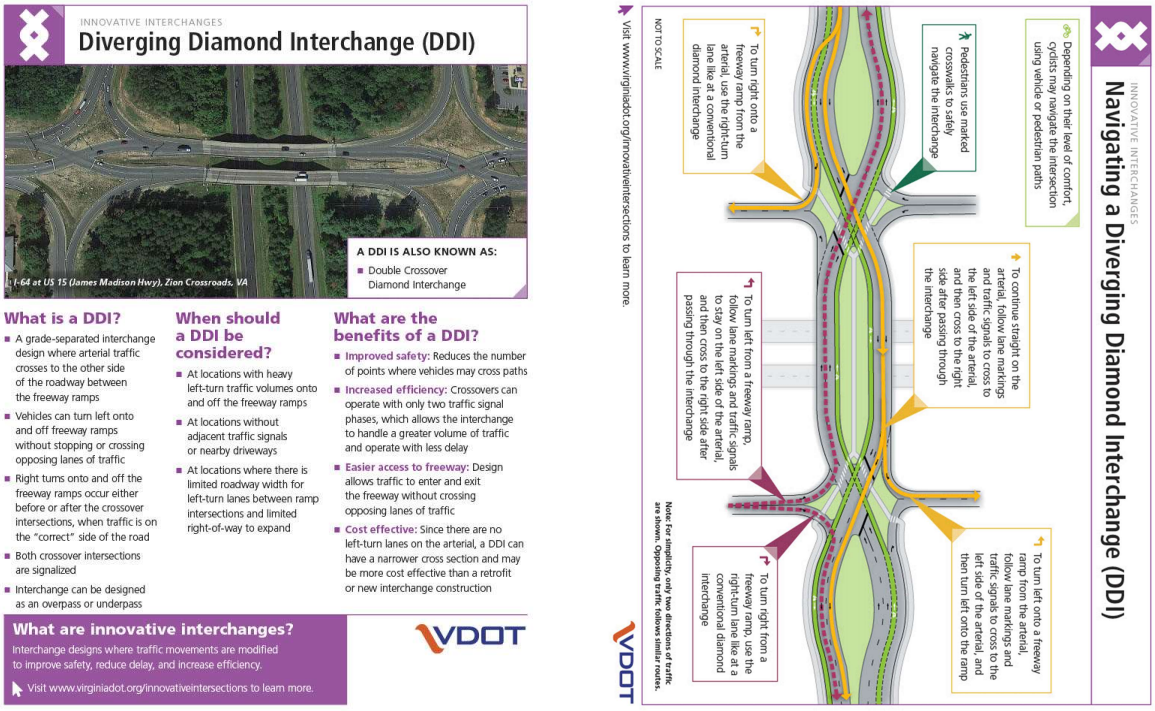


Figure B.10 Diverging Diamond Interchange Flyer (used with permission from the Virginia Department of Transportation)

Figure B.11 Diverging Diamond Interchange Video Simulation (used with permission from the Virginia Department of Transportation)

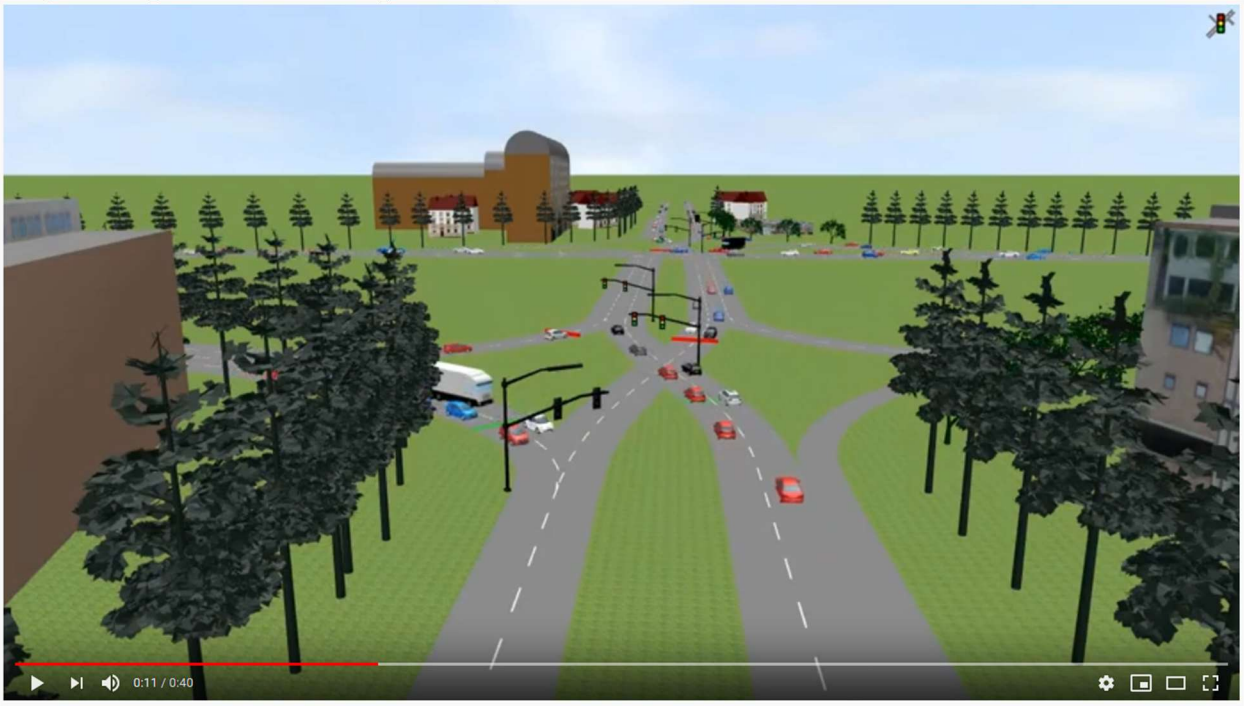


Figure B.12 Diverging Diamond Interchange Simulation Video (created at Purdue University)

APPENDIX C: SUMMARY OF SURVEY RESPONSES

Variable	Description	Response Frequency (%)
Ramp Meter		
Ramp Meter Awareness	I have never seen something like this before / I have seen pictures or videos of this environment but never in real life / I have used freeway ramps with these signals in other states	43/16/41
Ramp meters waste drivers' time	1 if agree, 0 otherwise	12
People will avoid ramp meters	1 if agree. 0 otherwise	21
Ramp meters reduce highway efficiency	1 if agree, 0 otherwise	17
Ramp meters improve highway efficiency	1 if agree, 0 otherwise	47
These meters might work somewhere else but they won't work here	1 if agree, 0 otherwise	25
These meters might work somewhere else and they will work here	1 if agree, 0 otherwise	25
Ramp Meter Acceptance	Strongly Oppose / Somewhat Oppose / Neutral / Somewhat in Favor / Strongly in Favor	13/17/38/23/9
Roundabout		
Roundabout Awareness	I have never seen something like this before / I have seen pictures or videos of this environment but never in real life / I have used intersections like this before	9/6/85
Single lane roundabouts are too confusing.	1 if agree, 0 otherwise	10
Multilane roundabouts are too confusing.	1 if agree, 0 otherwise	41
People avoid roundabouts.	1 if agree, 0 otherwise	29
In a multilane roundabout, I yield to traffic in the lane I wish to enter.	1 if agree, 0 otherwise	38
In a multilane roundabout, I yield to all traffic in the roundabout.	1 if agree, 0 otherwise	40
Large vehicles cannot utilize roundabouts.	1 if agree, 0 otherwise	33
Large vehicles can utilize roundabouts.	1 if agree, 0 otherwise	23

Roundabouts cause more crashes than a traditional signalized intersection.	1 if agree, 0 otherwise	15
Roundabouts cause fewer crashes than a traditional signalized intersection.	1 if agree, 0 otherwise	33
Roundabouts increase travel time compared with a traditional signalized intersection.	1 if agree, 0 otherwise	10
Roundabouts reduce travel time compared with a traditional signalized intersection	1 if agree, 0 otherwise	40
Roundabouts might work somewhere else, but they won't work in my local community.	1 if agree, 0 otherwise	12
Roundabouts might work somewhere else, but they will work in my local community.	1 if agree, 0 otherwise	33
Single Lane Roundabout Acceptance	Strongly Oppose / Somewhat Oppose / Neutral / Somewhat in Favor / Strongly in Favor	10/12/30/27/20
Multilane Roundabout Acceptance	Strongly Oppose / Somewhat Oppose / Neutral / Somewhat in Favor / Strongly in Favor	15/21/27/25/13
Single Lane Roundabout Confidence	Least Confident 1 / 2 / 3 / 4 / 5 Most Confident	5/5/14/18/58
Multilane Roundabout Confidence	Least Confident 1 / 2 / 3 / 4 / 5 Most Confident	10/10/21/25/34
Restricted Crossing U-Turn		
Restricted Crossing U-Turn Awareness	I have never ever seen something like this before / I have seen pictures or videos of this environment but never in real life / I have used intersections like this before	43/16/40
Restricted crossing U-turns are too confusing for drivers.	1 if agree, 0 otherwise	36
People will avoid restricted crossing U-turns.	1 if agree, 0 otherwise	29
Large vehicles cannot utilize restricted crossing U-turns.	1 if agree, 0 otherwise	25
Large vehicles can utilize restricted crossing U-turns.	1 if agree, 0 otherwise	18
Restricted crossing U-turns will cause more crashes than a two-way stop-controlled intersection.	1 if agree, 0 otherwise	20
Restricted crossing U-turns will cause fewer crashes than a two-way stop-controlled intersection.	1 if agree, 0 otherwise	27
Restricted crossing U-turns increase travel time compared	1 if agree, 0 otherwise	20

with a two-way stop-controlled intersection.		
Restricted crossing U-turns reduce travel time compared with a two-way stop-controlled intersection.	1 if agree, 0 otherwise	22
Restricted crossing U-turns might work somewhere else, but they won't work here.	1 if agree, 0 otherwise	21
Restricted crossing U-turns might work somewhere else, and I think they would work here.	1 if agree, 0 otherwise	24
Restricted Crossing U-turn Acceptance	Strongly Oppose / Somewhat Oppose / Neutral / Somewhat in Favor / Strongly in Favor	15/23/36/18/8
Restricted crossing U-turn confidence	Least Confident 1 / 2 / 3 / 4 / 5 Most Confident	10/14/28/23/26
Displaced Left Turn		
Displaced left turn awareness	I have never seen something like this before / I have seen pictures or videos of this environment but never in real life / I have used intersections like this before in Indiana or elsewhere	66/14/20
Displaced left turns are too confusing for drivers.	1 if agree, 0 otherwise	50
People will avoid displaced left turns.	1 if agree, 0 otherwise	31
Displaced left turns will cause more crashes than a traditional signalized intersection.	1 if agree, 0 otherwise	28
Displace left turns will cause fewer crashes than a traditional signalized intersection.	1 if agree, 0 otherwise	23
Displaced left turns increase travel time compared with a traditional signalized intersection.	1 if agree, 0 otherwise	16
Displaced left turns reduce travel time compared with a traditional signalized intersection.	1 if agree, 0 otherwise	22
Displaced left turns might work somewhere else, but they won't work here.	1 if agree, 0 otherwise	25
Displaced left turns might work somewhere else, and I think they would work here.	1 if agree, 0 otherwise	21
Displaced Left Turn Acceptance	Strongly Oppose / Somewhat Oppose / Neutral / Somewhat in Favor / Strongly in Favor	21/23/36/14/6

Displaced Left Turn Confidence	Least Confident 1 / 2 / 3 / 4 / 5 Most Confident	16/16/30/21/18
Diverging Diamond Interchange		
Diverging Diamond Awareness	I have never seen something like this before / I have seen pictures or videos of this environment but never in real life / I have used intersections like this before in Indiana or elsewhere	61/15/24
Diverging diamonds are too confusing for drivers.	1 if agree, 0 otherwise	39
Driving on the left-hand side of the road in this scenario is unsafe.	1 if agree, 0 otherwise	18
People will drive the wrong way through diverging diamonds.	1 if agree, 0 otherwise	36
People will avoid diverging diamonds.	1 if agree, 0 otherwise	28
Pedestrians and bicyclists cannot use diverging diamonds safely.	1 if agree, 0 otherwise	21
Pedestrians and bicyclists can use diverging diamonds safely.	1 if agree, 0 otherwise	15
Diverging diamonds will cause more crashes than a traditional diamond interchange.	1 if agree, 0 otherwise	21
Diverging diamonds will cause fewer crashes than a traditional diamond interchange.	1 if agree, 0 otherwise	22
Diverging diamonds increase travel time compared with a traditional diamond interchange.	1 if agree, 0 otherwise	11
Diverging diamonds reduce travel time compared with a traditional diamond interchange.	1 if agree, 0 otherwise	21
Diverging diamonds might work somewhere else, but they won't work here.	1 if agree, 0 otherwise	25
Diverging diamonds might work somewhere else, and I think they would work here.	1 if agree, 0 otherwise	21
Diverging Diamond Acceptance	Strongly Oppose / Somewhat Oppose / Neutral / Somewhat in Favor / Strongly in Favor	22/24/32/15/7
Diverging Diamond Confidence	Least Confident 1 / 2 / 3 / 4 / 5 Most Confident	17/16/28/19/21
Media Type Effectiveness		
Arrow Diagram Effectiveness	Least Effective 1 / 2 / 3 / 4 / 5 Most Effective	6/21/36/25/12

Flyer Effectiveness	Least Effective 1 / 2 / 3 / 4 / 5 Most Effective	14/30/36/15/5
Video Effectiveness	Least Effective 1 / 2 / 3 / 4 / 5 Most Effective	2/5/13/31/49
Simulation Effectiveness	Least Effective 1 / 2 / 3 / 4 / 5 Most Effective	3/9/18/38/32
Media Effectiveness Reason Ranking: Prefers Dynamic Media	Ranked as Reason Number 1/2/3/4/5/6/7	65/11/9/5/0/0/0
Media Effectiveness Reason Ranking: Prefers Static Media	Ranked as Reason Number 1/2/3/4/5/6/7	9/15/12/31/0/0/0
Media Effectiveness Reason Ranking: Media Provided Enough Information to Satisfy	Ranked as Reason Number 1/2/3/4/5/6/7	18/41/19/6/0/0/0
Media Effectiveness Reason Ranking: Media Required Appropriate Amount of Time to View	Ranked as Reason Number 1/2/3/4/5/6/7	7/25/25/15/0/0/0
Media Effectiveness Reason Ranking: User Answer #1	Ranked as Reason Number 1/2/3/4/5/6/7	1/1/1/1/1/1/0
Media Effectiveness Reason Ranking: User Answer #2	Ranked as Reason Number 1/2/3/4/5/6/7	0/0/0/0/1/1/0
Media Effectiveness Reason Ranking: User Answer #3	Ranked as Reason Number 1/2/3/4/5/6/7	0/0/0/0/0/0/2
Current Sources for INDOT Project and Activity Information		
Current Sources: Social Media	First Choice/Second Choice/Third Choice	30/9/8
Current Sources: Newspaper	First Choice/Second Choice/Third Choice	12/13/8
Current Sources: Radio	First Choice/Second Choice/Third Choice	6/16/11
Current Sources: Television	First Choice/Second Choice/Third Choice	25/20/11
Current Sources: Word of Mouth	First Choice/Second Choice/Third Choice	10/14/14
Current Sources: INDOT Website	First Choice/Second Choice/Third Choice	9/6/6
Current Sources: Public Officials or Public Meetings	First Choice/Second Choice/Third Choice	1/2/3
Current Sources: U.S. Mail or Email	First Choice/Second Choice/Third Choice	3/6/6
Current Sources: Other	First Choice/Second Choice/Third Choice	4/1/1
Desired Sources for INDOT Project and Activity Information		
Desired Sources: Social Media	First Choice/Second Choice/Third Choice	29/8/8
Desired Sources: Newspaper	First Choice/Second Choice/Third Choice	9/11/9
Desired Sources: Radio	First Choice/Second Choice/Third Choice	6/15/11
Desired Sources: Television	First Choice/Second Choice/Third Choice	25/21/10
Desired Sources: INDOT Website	First Choice/Second Choice/Third Choice	10/11/10
Desired Sources: INDOT App	First Choice/Second Choice/Third Choice	5/6/4
Desired Sources: Public Officials or Public Meetings	First Choice/Second Choice/Third Choice	1/3/4

Desired Sources: U.S. Mail or Email	First Choice/Second Choice/Third Choice	15/10/11
Desired Sources: Other	First Choice/Second Choice/Third Choice	1/0/1
Current Sources for Real Time Roadway Information		
Real-Time Sources: Dynamic Highway Signs	First Choice/Second Choice/Third Choice	25/13/7
Real-Time Sources: Telephone Hotline	First Choice/Second Choice/Third Choice	1/3/1
Real-Time Sources: Social Media	First Choice/Second Choice/Third Choice	12/8/7
Real-Time Sources: INDOT Website	First Choice/Second Choice/Third Choice	6/4/5
Real-Time Sources: INDOT App	First Choice/Second Choice/Third Choice	1/3/1
Real-Time Sources: Radio		10/16/9
Real-Time Sources: Television	First Choice/Second Choice/Third Choice	15/12/8
Real-Time Sources: Word of Mouth	First Choice/Second Choice/Third Choice	4/7/11
Real-Time Sources: E-mail	First Choice/Second Choice/Third Choice	2/2/3
Real-Time Sources: Text Message	First Choice/Second Choice/Third Choice	1/3/2
Real-Time Sources: Other Navigation App (Google Maps, Waze, etc.)	First Choice/Second Choice/Third Choice	22/10/7
Real-Time Sources: Other	First Choice/Second Choice/Third Choice	1/1/1
Respondent Agreement		
INDOT clearly and frequently communicates regarding expected road work in my community including nature and anticipated duration.	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree	9/16/27/36/12
INDOT reaches out to my community regarding what work should be done and relevant aspects of projects.	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree	11/20/36/26/7
Official (signed/posted) detours are easy to follow.	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree	5/14/19/43/19
INDOT minimizes traffic delay on freeways during construction activities.	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree	14/21/27/29/9
I understand what I am supposed to do (merge, shift lanes) in work zones based on signs at the zone.	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree	2/5/14/40/39
Signs in work zone are easy to understand.	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree	2/7/16/39/36
Signs that display your speed in school and work zones reduce speeding.	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree	4/9/17/38/32
Interchanges in rural areas are well-lit.	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree	14/23/32/23/8

Interchanges in urban areas are well-lit.	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree	3/9/26/41/21
Urban roadways are well-lit.	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree	4/12/25/40/19
Rural roadways are well-lit	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree	25/30/24/15/6
Traffic Control Device Visibility		
Roadway striping at night	Generally Poor/ Generally Fair/ Generally Good	17/53/30
Roadway striping in rainy weather	Generally Poor/ Generally Fair/ Generally Good	37/45/18
Raised pavement markers (in-pavement reflectors highlighting roadway striping) showing yellow centerlines or lane lines at night	Generally Poor/ Generally Fair/ Generally Good	12/47/41
Raised pavement markers (in-pavement reflectors highlighting roadway striping) showing yellow centerlines or lane lines in rainy weather	Generally Poor/ Generally Fair/ Generally Good	17/49/34
Road signs at night	Generally Poor/ Generally Fair/ Generally Good	14/46/40
Road signs in rainy weather	Generally Poor/ Generally Fair/ Generally Good	20/51/29
Road signs in snowy weather	Generally Poor/ Generally Fair/ Generally Good	26/52/22
Work zone signs, barrels, and cones at night	Generally Poor/ Generally Fair/ Generally Good	11/44/45
Work zone signs, barrels, and cones in rainy weather	Generally Poor/ Generally Fair/ Generally Good	12/50/38
Work zone signs, barrels, and cones in snowy weather	Generally Poor/ Generally Fair/ Generally Good	18/50/32
Road workers and work equipment at night	Generally Poor/ Generally Fair/ Generally Good	17/46/37
Road workers and work equipment in rainy weather	Generally Poor/ Generally Fair/ Generally Good	19/34/27
Please select 'Generally Good' for this question	Generally Poor/ Generally Fair/ Generally Good	0/0/100
Road workers and work equipment in snowy weather	Generally Poor/ Generally Fair/ Generally Good	18/55/27
Large overhead signs are clearly visible and legible at night	Generally Poor/ Generally Fair/ Generally Good	6/36/58
Accessibility Scenarios		
Accessibility/Mobility Tradeoff Scenario	Drive on freeway and local roads for longer distance (higher mobility) / Drive on highway with intersections spaced a mile apart for shorter distance (higher accessibility)	56/44

State Highway Bridge Full/Partial Closure Scenario	Full closure for 4 months with detour / Partial closure for 6 months with delay	37/63
Major Interchange Full/Partial Closure Scenario	Full closure for 1.5 years with detour / Partial closure for 2.5 years with delays	42/58
Average Commute Time	Mean = 23.19 minutes Standard Deviation = 21.43 minutes	
Constant Commute (provided commute) Frustration	Not frustrated at all/ Mildly frustrated/ Extremely frustrated	54/41/5
Variable Commute (provided commute ± 25%) Frustration	Not frustrated at all/ Mildly frustrated/ Extremely frustrated	32/50/18
Perceived Indiana Highway Speeds		
Perceived Average Speed: Urban Interstates	50-55 / 56-60 / 61-65 /66-70 / 71-75 / 76-80 / 81-85 / 86-90 / 91+ MPH	29/20/20/20/9/3/0/0/0
Perceived Average Speed: Rural Interstates	50-55 / 56-60 / 61-65 /66-70 / 71-75 / 76-80 / 81-85 / 86-90 / 91+ MPH	21/15/15/28/14/5/2/0/0
Perceived Average Speed: Urban State Highways	50-55 / 56-60 / 61-65 /66-70 / 71-75 / 76-80 / 81-85 / 86-90 / 91+ MPH	27/21/21/20/7/3/1/0/0
Perceived Average Speed: Rural State Highways	50-55 / 56-60 / 61-65 /66-70 / 71-75 / 76-80 / 81-85 / 86-90 / 91+ MPH	24/21/23/17/10/3/1/1/0
Traffic Sign Meanings and Planned Actions		
Variable Speed Limit Obedience Likelihood	Very unlikely / Not likely / Neutral / Likely / Very likely	3/7/24/37/29
Standard 50 MPH Speed Limit Sign Meaning	legal speed limit / safe speed / slowest speed I should drive / safe speed is at least 10 MPH higher	90/5/3/1
Curve Advisory Sign Meaning	Curve ahead but I do not need to slow down / Curve ahead and I should slow down slightly (to 50 MPH) to navigate it safely / Curve ahead and I should slow down moderately (to 45 MPH) to navigate it safely / Curve ahead and I should slow down significantly (to 35 MPH) in order to navigate it safely / Curve ahead and I am required by law to slow down to 35 MPH	1/2/6/64/28
Work Zone 50 MPH Speed Limit Sign Planned Action	Continue at 70 MPH / Slow down to 65 MPH / Slow down to 60 MPH / Slow down to 55 MPH / Slow down to 50 MPH (work zone limit).	0/1/3/9/86
Work Zone 50 MPH Speed Limit Sign + Workers Present Sign Planned Action	Continue at 70 MPH / Slow down to 65 MPH / Slow down to 60 MPH / Slow down to 55 MPH / Slow down to 50 MPH (work zone limit).	(0/1/2/8/89)
Work Zone 50 MPH Speed Limit Sign + Radar "Your Speed is Sign" Planned Action	Continue at 70 MPH / Slow down to 65 MPH / Slow down to 60 MPH / Slow down to 55 MPH / Slow down to 50 MPH (work zone limit).	(0/1/2/10/87)
Travel Behavior		
Household vehicle ownership	0 / 1 / 2 / 3 / > 4 vehicles	5/34/40/14/8

Annual Mileage	I do not own a personal vehicle / <5,000 miles / 5,000-9,999 miles / 10,000-14,999 miles / 15,000-19,999 miles / 20,000-24,999 miles / >25,000 miles / I do not know	5/20/23/23/12/5/6/6
Trip Frequency: Less than 10 miles	Never/ less than every 6 months/every 6 months/ every 3 months/ once a month/ once every two weeks /once a week/ 2-3 times a week/ 4-7 times a week	3/4/2/2/3/3/10/24/49
Trip Frequency: Between 10-50 miles	Never/ less than every 6 months/every 6 months/ every 3 months/ once a month/ once every two weeks /once a week/ 2-3 times a week/ 4-7 times a week	2/4/3/5/13/14/19/20/20
Trip Frequency: More than 50 miles	Never/ less than every 6 months/every 6 months/ every 3 months/ once a month/ once every two weeks /once a week/ 2-3 times a week/ 4-7 times a week	7/19/12/16/23/11/6/3/3
Trip Frequency: Interstate	Never/ less than every 6 months/every 6 months/ every 3 months/ once a month/ once every two weeks /once a week/ 2-3 times a week/ 4-7 times a week	6/13/5/10/15/12/11/13/15
Trip Frequency: Four-Lane Urban Road	Never/ less than every 6 months/every 6 months/ every 3 months/ once a month/ once every two weeks /once a week/ 2-3 times a week/ 4-7 times a week	9/10/5/7/12/8/9/18/22
Trip Frequency: Four-Lane Rural Road	Never/ less than every 6 months/every 6 months/ every 3 months/ once a month/ once every two weeks /once a week/ 2-3 times a week/ 4-7 times a week	15/16/6/9/15/10/9/10/10
Trip Frequency: Two-Lane Rural Road	Never/ less than every 6 months/every 6 months/ every 3 months/ once a month/ once every two weeks /once a week/ 2-3 times a week/ 4-7 times a week	5/7/4/7/9/8/11/17/32
Trip Frequency: Two-Lane Urban Road	Never/ less than every 6 months/every 6 months/ every 3 months/ once a month/ once every two weeks /once a week/ 2-3 times a week/ 4-7 times a week	2/2/2/3/7/5/10/20/49
Socio-Demographics and Driver History		
Age	18-24 / 25-34 / 35-44 / 45-54 / 55-64/ 65 +	18/17/17/18/15/16
Gender	Male/Female	49/51
Employment Status	Work full time / Work part time / Homemaker / Student / Retired / Other	43/12/9/6/19/11
Annual Pre-Tax Income	(Under $25,000 / $25,000 -$49,999 / $50,000 -$74,999 / $75,000 -$99,999 / $100,000 -$149,999 / $150,000 or more / I do not wish to disclose this information)	21/25/21/17/12/5
Educational Attainment	(Grade school or less / Some high school / High school graduate / Technical training beyond high school / Some college /	1/3/22/6/23/31/15

	College graduate / Graduate or professional school)	
Valid Indiana Driver's License Possession	Yes / No, but I used to have a license or am licensed in another state or country / No, I have never had a driver's license	92/3/5
Length of Driver History	0-10 / 11-20 / 21-30 / 31-40 / 41-50 / 50+ Years	21/17/17/18/15/12
Self-Perceived Driving Ability	Very Poor / Below Average / Average / Above Average / Excellent	0/1/23/39/37
Three Year Crash History	0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 Crashes	83/13/2/1/0/0/0/0/0/0
Indiana Residence Length	Mean = 33.79 years Standard Deviation = 20.02 years	

APPENDIX D: VARIABLE DESCRIPTION

Table D.1 Variable Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum	Cases	Missing Values
RB_REC	1.758759	.604642	0.0	2.0	999	0
RBSL_ACC	2.36036	1.214587	0.0	4.0	999	0
RBML_ACC	1.985986	1.252574	0.0	4.0	999	0
RBSL_CON	3.193193	1.15168	0.0	4.0	999	0
RBML_CON	2.643644	1.29634	0.0	4.0	999	0
RC_REC	.825826	.904062	0.0	2.0	999	0
RC_ACC	1.791792	1.134578	0.0	4.0	999	0
RC_CON	2.406406	1.272886	0.0	4.0	999	0
DL_REC	.53954	.804663	0.0	2.0	999	0
DL_ACC	1.613614	1.143446	0.0	4.0	999	0
DL_CON	2.083083	1.29903	0.0	4.0	999	0
DD_REC	.634635	.844433	0.0	2.0	999	0
DD_ACC	1.622623	1.188087	0.0	4.0	999	0
DD_CON	2.105105	1.355596	0.0	4.0	999	0
OVER55	.311311	.463262	0.0	1.0	999	0
UNDER35	.342342	.474731	0.0	1.0	999	0
GENDER	.489489	.50014	0.0	1.0	999	0
MORE_HS	.686687	.464073	0.0	1.0	999	0
UNI_PLUS	.457457	.498436	0.0	1.0	999	0
GRAD_SKO	.145145	.352424	0.0	1.0	999	0
OVER50K	.497497	.500244	0.0	1.0	999	0
SM_USER	.296296	.456852	0.0	1.0	999	0
EXC_DRIV	.35035	.477319	0.0	1.0	999	0
ABILITY	2.021021	.883243	0.0	3.0	999	0
U10K_MI	.435435	.496062	0.0	1.0	999	0
SHT_TRIP	3.062062	1.112937	1.0	4.0	999	0
LNG_TRIP	3.157157	1.689982	1.0	6.0	999	0
LNG_MONT	.454454	.498171	0.0	1.0	999	0
INT_FREQ	3.806807	2.083842	1.0	7.0	999	0
AA_INTFR	.510511	.50014	0.0	1.0	999	0
FRLAN_RU	4.065065	2.27621	1.0	8.0	999	0
FLRU_MNT	.534535	.499056	0.0	1.0	999	0
FRLAN_UR	4.193193	2.250743	1.0	7.0	999	0
TOLAN_RU	4.758759	2.153633	1.0	7.0	999	0
DD_DIST	.911176	.717815	0.0	2.466923	999	0
RB_VID	.215215	.411177	0.0	1.0	999	0
RC_DIA	.254254	.435659	0.0	1.0	999	0
RC_FLY	.239239	.426833	0.0	1.0	999	0
DL_DIA	.267267	.442755	0.0	1.0	999	0
DL_SIM	.218218	.413243	0.0	1.0	999	0
DD_VID	.271271	.444838	0.0	1.0	999	0
DD_SIM	.252252	.434523	0.0	1.0	999	0
PREC_DL4	.339954	.136078	.113435	.765239	999	0
PREC_DD4	.394627	.128007	.122676	.731223	999	0

Table D.2 Independent Variable Correlation Matrix

Cor.Mat.	OVER55	UNDER35	GENDER	MORE_HS	UNI_PLUS	GRAD_SKO	OVER50K	SM_USER
OVER55	1.00000	-.48508	-.00100	.09061	.09430	.14644	.00985	-.32264
UNDER35	-.48508	1.00000	-.00171	-.13575	-.14588	-.14757	-.12719	.38654
GENDER	-.00100	-.00171	1.00000	-.03363	-.03898	.02856	.09501	-.04775
MORE_HS	.09061	-.13575	-.03363	1.00000	.62025	.27833	.21459	-.13356
UNI_PLUS	.09430	-.14588	-.03898	.62025	1.00000	.44874	.28791	-.09860
GRAD_SKO	.14644	-.14757	.02856	.27833	.44874	1.00000	.19815	-.13046
OVER50K	.00985	-.12719	.09501	.21459	.28791	.19815	1.00000	-.09759
SM_USER	-.32264	.38654	-.04775	-.13356	-.09860	-.13046	-.09759	1.00000

Cor.Mat.	OVER55	UNDER35	GENDER	MORE_HS	UNI_PLUS	GRAD_SKO	OVER50K	SM_USER
EXC_DRIV	.00472	-.11860	.12457	.08441	.11746	.02501	.10859	-.05837
ABILITY	.10154	-.23464	.13546	.17987	.17160	.05779	.19628	-.10981
U10K_MI	.19438	-.11879	-.09664	.07526	.01218	-.01225	-.07838	-.07467
SHT_TRIP	.00913	-.07818	.00837	.18901	.23416	.08175	.14066	-.11306
LNG_TRIP	-.12271	.05402	.10806	.09479	.12274	.08784	.20136	.02139
LNG_MONT	-.13605	.06176	.09158	.06174	.09812	.06908	.15736	.06376
INT_FREQ	-.09956	.02945	.21293	.12385	.14981	.08188	.23744	.00125
AA_INTFR	-.06819	.02703	.20974	.11565	.14750	.09082	.21337	-.00049

Cor.Mat.	EXC_DRIV	ABILITY	U10K_MI	SHT_TRIP	LNG_TRIP	LNG_MONT	INT_FREQ	AA_INTFR
EXC_DRIV	1.00000	.81437	-.03979	.08729	.04595	.05875	.11748	.08949
ABILITY	.81437	1.00000	.02711	.17706	.09646	.08074	.16009	.12312
U10K_MI	-.03979	.02711	1.00000	.01452	-.23948	-.22985	-.19770	-.18203
SHT_TRIP	.08729	.17706	.01452	1.00000	.25905	.20932	.26786	.23285
LNG_TRIP	.04595	.09646	-.23948	.25905	1.00000	.86365	.40782	.37444
LNG_MONT	.05875	.08074	-.22985	.20932	.86365	1.00000	.35106	.33471
INT_FREQ	.11748	.16009	-.19770	.26786	.40782	.35106	1.00000	.87828
AA_INTFR	.08949	.12312	-.18203	.23285	.37444	.33471	.87828	1.00000

Cor.Mat.	OVER55	UNDER35	GENDER	MORE_HS	UNI_PLUS	GRAD_SKO	OVER50K	SM_USER
FRLAN_RU	-.03918	-.01878	.13835	.06295	.07530	.01195	.10266	-.04265
FLRU_MNT	-.04005	-.02035	.09881	.04893	.08346	.03129	.10169	-.04493
FRLAN_UR	.04701	-.10791	.16425	.19135	.17838	.11620	.19577	-.12784
TOLAN_RU	-.12250	.02108	.06416	-.00953	-.01844	-.04359	.08733	.01365
DD_DIST	.00422	.02545	-.08591	-.03575	-.08572	-.03005	-.07505	.07176
RB_VID	-.03120	.04310	-.01579	-.04536	-.01151	-.03600	-.02417	.02292
RC_DIA	-.00036	-.00947	.01228	.01775	-.02397	-.03829	.04430	-.00131
RC_FLY	-.00711	.03551	.03761	-.01577	-.00157	-.07787	-.06055	-.01446

Cor.Mat.	EXC_DRIV	ABILITY	U10K_MI	SHT_TRIP	LNG_TRIP	LNG_MONT	INT_FREQ	AA_INTFR
FRLAN_RU	.08229	.13339	-.11652	.19696	.29689	.24076	.33009	.25861
FLRU_MNT	.05011	.09496	-.10330	.15670	.28166	.25521	.30752	.23841
FRLAN_UR	.10668	.18294	-.05747	.34322	.33552	.27640	.47647	.39030
TOLAN_RU	.08718	.12646	-.13324	.25583	.24774	.22463	.25440	.19353
DD_DIST	-.04468	-.03032	.00661	-.01234	.00709	.02375	-.09532	-.07324
RB_VID	-.02208	-.00419	-.05708	-.02265	-.00258	-.00835	.01583	.01092
RC_DIA	.02415	.01734	-.01669	-.04911	-.06521	-.05278	.01112	-.01228
RC_FLY	.00131	.00791	-.02872	.03199	.01867	.02067	.02047	.03280

Cor.Mat.	FRLAN_RU	FLRU_MNT	FRLAN_UR	TOLAN_RU	DD_DIST	RB_VID	RC_DIA	RC_FLY
FRLAN_RU	1.00000	.84526	.53090	.45780	-.05852	-.00855	.00755	.01078
FLRU_MNT	.84526	1.00000	.47532	.40258	-.05742	.00525	.03792	.00116
FRLAN_UR	.53090	.47532	1.00000	.24941	-.12220	.00808	.00197	.01546
TOLAN_RU	.45780	.40258	.24941	1.00000	.01716	.04511	.04835	.00508

DD_DIST	-.05852	-.05742	-.12220	.01716	1.00000	.00808	-.06560	-.02475
RB_VID	-.00855	.00525	.00808	.04511	.00808	1.00000	.09137	.14024
RC_DIA	.00755	.03792	.00197	.04835	-.06560	.09137	1.00000	-.32744
RC_FLY	.01078	.00116	.01546	.00508	-.02475	.14024	-.32744	1.00000

Cor.Mat.	OVER55	UNDER35	GENDER	MORE_HS	UNI_PLUS	GRAD_SKO	OVER50K	SM_USER
DL_DIA	.01895	-.02577	-.03481	-.07483	-.00972	.03369	-.00829	-.03523
DL_SIM	-.00977	.00699	.01111	-.00887	.00620	.00247	.02688	.02339
DD_VID	-.00664	.00107	-.01194	.01897	-.02246	-.04688	.00981	.00840
DD_SIM	.02762	.00354	.01682	-.01513	-.04293	-.04303	-.07546	-.01851
PREC_DL4	-.42808	.68035	.33325	-.15129	-.13103	-.10961	-.01966	.60044
PREC_DD4	-.30735	.48381	.17988	.29429	.24099	.06430	.17241	.13549

Cor.Mat.	EXC_DRIV	ABILITY	U10K_MI	SHT_TRIP	LNG_TRIP	LNG_MONT	INT_FREQ	AA_INTFR
DL_DIA	-.01680	.00099	.05812	.01104	-.01066	-.01971	-.02326	-.01496
DL_SIM	-.00191	.00664	-.06318	-.00769	-.00755	-.01008	-.00103	.00828
DD_VID	-.02334	-.00433	.00907	.02061	-.01278	-.04593	.00795	.02095
DD_SIM	-.05454	-.05299	.04309	-.00754	.00327	.02535	-.00810	-.00760
PREC_DL4	-.02141	-.11252	-.39187	-.27623	.21050	.21210	.34877	.36457
PREC_DD4	.41011	.29709	-.37608	.14386	.28149	.25591	.54067	.56309

Cor.Mat.	FRLAN_RU	FLRU_MNT	FRLAN_UR	TOLAN_RU	DD_DIST	RB_VID	RC_DIA	RC_FLY
DL_DIA	-.09582	-.08489	-.07901	-.06787	.02621	.11304	-.35265	.06428
DL_SIM	.05946	.04602	.02681	.07497	-.04417	.14792	.12563	.12978
DD_VID	-.00063	-.01290	-.03038	.00353	-.04896	-.31951	.13493	.05365
DD_SIM	-.01560	.01062	-.00480	-.02378	.04642	.11646	.01020	.13891
PREC_DL4	.32614	.27241	.10405	.16043	-.01586	.04514	.01527	.02818
PREC_DD4	.19845	.16893	.26074	.14560	-.43649	.01597	.03484	.04537

Cor.Mat.	DL_DIA	DL_SIM	DD_VID	DD_SIM	PREC_DL4	PREC_DD4
DL_DIA	1.00000	-.31908	.08939	.14921	-.07871	-.07217
DL_SIM	-.31908	1.00000	.11917	-.30686	.04590	.03484
DD_VID	.08939	.11917	1.00000	-.35437	-.00322	.02152
DD_SIM	.14921	-.30686	-.35437	1.00000	-.01103	-.05521
PREC_DL4	-.07871	.04590	-.00322	-.01103	1.00000	.56447
PREC_DD4	-.07217	.03484	.02152	-.05521	.56447	1.00000

APPENDIX E: FULL MODEL SPECIFICATION AND MARGINAL EFFECTS

Awareness Models

Table E.1 Restricted Crossing U-Turn Awareness Model

```
------------------------------------------------------------------------------
Binomial Probit Model
Dependent variable                AWAR_RC
Log likelihood function       -659.49452
Restricted log likelihood     -692.23330
Chi squared [  6](P= .000)      65.47756
Significance level               .00000
McFadden Pseudo R-squared       .0472944
Estimation based on N =    999, K =   7
Inf.Cr.AIC  =   1333.0 AIC/N =    1.334
--------+---------------------------------------------------------------------
        |                 Standard            Prob.      95% Confidence
 AWAR_RC|  Coefficient       Error       z    |z|>Z*         Interval
--------+---------------------------------------------------------------------
        |Index function for probability.....................................
Constant|    -.42923***      .09964    -4.31  .0000     -.62452   -.23394
AA_INTFR|     .16719**       .08430     1.98  .0473      .00197    .33241
  OVER55|    -.23157**       .10183    -2.27  .0230     -.43116   -.03198
 UNDER35|     .23810**       .10165     2.34  .0192      .03886    .43734
  GENDER|     .27993***      .08277     3.38  .0007      .11770    .44216
 SM_USER|     .25164***      .09763     2.58  .0100      .06028    .44300
 OVER50K|     .18920**       .08379     2.26  .0239      .02498    .35342
--------+---------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 17, 2021 at 10:08:23 AM
------------------------------------------------------------------------------
```

Table E.2 Displaced Left Turn Awareness Model

```
--------------------------------------------------------------------------------
Binomial Probit Model
Dependent variable                AWAR_DL
Log likelihood function       -599.29201
Restricted log likelihood     -640.61970
Chi squared [  7](P= .000)      82.65539
Significance level                .00000
McFadden Pseudo R-squared       .0645121
Estimation based on N =    999, K =   8
Inf.Cr.AIC  =   1214.6 AIC/N =    1.216
--------+-----------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
 AWAR_DL|  Coefficient       Error       z    |z|>Z*         Interval
--------+-----------------------------------------------------------------------
        |Index function for probability.....................................
Constant|    -.66554***      .15425    -4.31  .0000     -.96786   -.36322
 UNDER35|     .38059***      .09398     4.05  .0001      .19640    .56478
AA_INTFR|     .20822**       .09180     2.27  .0233      .02830    .38814
 U10K_MI|    -.16035*        .08749    -1.83  .0668     -.33183    .01113
 SM_USER|     .32034***      .09766     3.28  .0010      .12894    .51174
FRLAN_RU|     .04948**       .01938     2.55  .0107      .01149    .08747
  GENDER|     .19181**       .08659     2.22  .0267      .02210    .36153
SHT_TRIP|    -.10801***      .03917    -2.76  .0058     -.18479   -.03124
--------+-----------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 17, 2021 at 10:08:23 AM
--------------------------------------------------------------------------------
```

Table E.3 Diverging Diamond Interchange Awareness Model

```
------------------------------------------------------------------------------
Binomial Probit Model
Dependent variable                AWAR_DD
Log likelihood function       -634.96605
Restricted log likelihood     -670.00255
Chi squared [  6](P= .000)     70.07299
Significance level               .00000
McFadden Pseudo R-squared      .0522931
Estimation based on N =    999, K =   7
Inf.Cr.AIC  =   1283.9 AIC/N =    1.285
--------+---------------------------------------------------------------------
        |                  Standard            Prob.      95% Confidence
 AWAR_DD|  Coefficient       Error       z    |z|>Z*         Interval
--------+---------------------------------------------------------------------
        |Index function for probability.....................................
Constant|    -.56481***      .11922    -4.74  .0000     -.79848   -.33115
AA_INTFR|     .28363***      .08433     3.36  .0008      .11834    .44892
 DD_DIST|    -.19292***      .05792    -3.33  .0009     -.30644   -.07941
 U10K_MI|    -.17164**       .08519    -2.01  .0439     -.33860   -.00467
EXC_DRIV|     .28080***      .08695     3.23  .0012      .11037    .45122
 UNDER35|     .39540***      .08809     4.49  .0000      .22275    .56804
 MORE_HS|     .22412**       .09141     2.45  .0142      .04496    .40328
--------+---------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 17, 2021 at 10:08:22 AM
------------------------------------------------------------------------------
```

Acceptance and Confidence Models

Table E.4 Multilane Roundabout Bivariate Acceptance and Confidence Model

```
---------------------------------------------------------------------------
Bivariate Ordered Probit Model
Dependent variable                BivOrdPr
Log likelihood function       -2782.90674
Restricted log likelihood     -2965.09828
Chi squared [ 21](P= .000)     364.38308
Significance level                .00000
McFadden Pseudo R-squared       .0614454
Estimation based on N =    999, K =  21
Inf.Cr.AIC  =   5607.8 AIC/N =    5.613
--------+------------------------------------------------------------------
RBML_ACC|                  Standard            Prob.      95% Confidence
RBML_CON|  Coefficient       Error       z    |z|>Z*         Interval
--------+------------------------------------------------------------------
        |Index function for Probability Model for RBML_ACC..................
Constant|     .56585***      .07847     7.21  .0000      .41205    .71964
AA_INTFR|     .20166***      .06506     3.10  .0019      .07415    .32916
  GENDER|     .21986***      .06887     3.19  .0014      .08489    .35483
UNI_PLUS|     .24543***      .06940     3.54  .0004      .10942    .38145
 UNDER35|     .21898***      .05978     3.66  .0002      .10181    .33616
EXC_DRIV|     .14362**       .06556     2.19  .0285      .01512    .27212
  RB_VID|     .16343**       .07921     2.06  .0391      .00819    .31867
        |Index function for Probability Model for RBML_CON..................
Constant|     .25038**       .10824     2.31  .0207      .03823    .46254
 ABILITY|     .23449***      .03584     6.54  .0000      .16425    .30472
INT_FREQ|     .06991***      .01734     4.03  .0001      .03593    .10389
  GENDER|     .34690***      .07065     4.91  .0000      .20842    .48538
LNG_TRIP|     .04832***      .01835     2.63  .0085      .01235    .08429
UNI_PLUS|     .14651**       .07233     2.03  .0428      .00475    .28828
  RB_VID|     .20084**       .08435     2.38  .0173      .03553    .36616
        |Threshold Parameters for Probability Model for RBML_ACC.............
  MU(01)|     .67612***      .04261    15.87  .0000      .59261    .75962
  MU(02)|    1.37941***      .05254    26.25  .0000     1.27643   1.48240
  MU(03)|    2.23202***      .06723    33.20  .0000     2.10025   2.36379
        |Threshold Parameters for Probability Model for RBML_CON.............
LMDA(01)|     .49937***      .04857    10.28  .0000      .40416    .59457
LMDA(02)|    1.18108***      .05995    19.70  .0000     1.06359   1.29857
LMDA(03)|    1.86010***      .06729    27.64  .0000     1.72821   1.99198
        |Disturbance Correlation = RHO(1,2)..................................
RHO(1,2)|     .63196***      .02205    28.67  .0000      .58875    .67517
--------+------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 16, 2021 at 06:40:54 PM
```

Table E.5 Multilane Roundabout Acceptance Marginal Effects

```
-------------------------------------------------------------------------------
Marginal effects for ordered probability model
M.E.s for dummy variables are Pr[y|x=1]-Pr[y|x=0]
Names for dummy variables are marked by *.
--------+----------------------------------------------------------------------
        |     Partial                            Prob.      95% Confidence
RBML_ACC|      Effect    Elasticity      z    |z|>Z*         Interval
--------+----------------------------------------------------------------------
        |--------------[Partial effects on Prob[Y=00] at means]--------------
*AA_INTF|    -.03567**      -.26501    -2.26  .0235     -.06654   -.00480
 *GENDER|    -.05225***     -.38822    -3.35  .0008     -.08281   -.02169
*UNI_PLU|    -.05890***     -.43763    -3.83  .0001     -.08903   -.02877
*UNDER35|    -.06558***     -.48728    -4.44  .0000     -.09452   -.03665
*EXC_DRI|    -.03332**      -.24755    -2.16  .0309     -.06357   -.00307
 *RB_VID|    -.03459**      -.25698    -2.08  .0378     -.06722   -.00195
        |--------------[Partial effects on Prob[Y=01] at means]--------------
*AA_INTF|    -.02270**      -.11179    -2.28  .0224     -.04218   -.00322
 *GENDER|    -.03339***     -.16445    -3.38  .0007     -.05274   -.01405
*UNI_PLU|    -.03816***     -.18793    -3.83  .0001     -.05769   -.01864
*UNDER35|    -.04513***     -.22226    -4.22  .0000     -.06612   -.02415
*EXC_DRI|    -.02212**      -.10895    -2.09  .0369     -.04290   -.00135
 *RB_VID|    -.02388*       -.11759    -1.94  .0530     -.04806    .00031
        |--------------[Partial effects on Prob[Y=02] at means]--------------
*AA_INTF|    -.00076        -.00274     -.49  .6270     -.00380    .00229
 *GENDER|    -.00136        -.00492     -.60  .5512     -.00582    .00310
*UNI_PLU|    -.00215        -.00778     -.81  .4163     -.00732    .00303
*UNDER35|    -.00541        -.01963    -1.51  .1321     -.01246    .00163
*EXC_DRI|    -.00169        -.00612     -.88  .3764     -.00543    .00205
 *RB_VID|    -.00277        -.01005     -.98  .3267     -.00831    .00277
        |--------------[Partial effects on Prob[Y=03] at means]--------------
*AA_INTF|     .02825**       .10902     2.26  .0239      .00374    .05276
 *GENDER|     .04134***      .15954     3.31  .0009      .01689    .06578
*UNI_PLU|     .04671***      .18025     3.76  .0002      .02236    .07105
*UNDER35|     .05265***      .20319     4.29  .0000      .02858    .07671
*EXC_DRI|     .02668**       .10296     2.13  .0329      .00217    .05119
 *RB_VID|     .02794**       .10784     2.04  .0415      .00107    .05481
        |--------------[Partial effects on Prob[Y=04] at means]--------------
*AA_INTF|     .03088**       .24234     2.25  .0244      .00399    .05776
 *GENDER|     .04566***      .35839     3.28  .0010      .01839    .07293
*UNI_PLU|     .05250***      .41207     3.68  .0002      .02451    .08050
*UNDER35|     .06348***      .49826     3.94  .0001      .03190    .09507
*EXC_DRI|     .03045**       .23900     2.04  .0418      .00113    .05977
 *RB_VID|     .03330*        .26133     1.87  .0621     -.00169    .06828
--------+----------------------------------------------------------------------
z, prob values and confidence intervals are given for the partial effect
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 16, 2021 at 06:40:50 PM
-------------------------------------------------------------------------------
```

Table E.6 Multilane Roundabout Confidence Marginal Effects

```
------------------------------------------------------------------------------
Marginal effects for ordered probability model
M.E.s for dummy variables are Pr[y|x=1]-Pr[y|x=0]
Names for dummy variables are marked by *.
--------+---------------------------------------------------------------------
        |     Partial                            Prob.      95% Confidence
RBML_CON|      Effect    Elasticity      z    |z|>Z*         Interval
--------+---------------------------------------------------------------------
        |--------------[Partial effects on Prob[Y=00] at means]--------------
 ABILITY|    -.03388***     -.94610    -5.57  .0000     -.04581   -.02195
INT_FREQ|    -.00912***     -.47957    -3.28  .0010     -.01456   -.00368
 *GENDER|    -.05150***     -.71160    -4.81  .0000     -.07248   -.03052
LNG_TRIP|    -.01088***     -.47470    -3.27  .0011     -.01740   -.00436
*UNI_PLU|    -.01998*       -.27613    -1.93  .0531     -.04024    .00027
 *RB_VID|    -.02576**      -.35590    -2.41  .0159     -.04670   -.00482
        |--------------[Partial effects on Prob[Y=01] at means]--------------
 ABILITY|    -.02542***     -.56809    -5.75  .0000     -.03409   -.01675
INT_FREQ|    -.00684***     -.28796    -3.32  .0009     -.01088   -.00280
 *GENDER|    -.03828***     -.42339    -5.03  .0000     -.05319   -.02337
LNG_TRIP|    -.00816***     -.28504    -3.31  .0009     -.01300   -.00333
*UNI_PLU|    -.01506*       -.16654    -1.94  .0526     -.03029    .00017
 *RB_VID|    -.02041**      -.22576    -2.30  .0213     -.03779   -.00304
        |--------------[Partial effects on Prob[Y=02] at means]--------------
 ABILITY|    -.02936***     -.27629    -5.39  .0000     -.04003   -.01869
INT_FREQ|    -.00790***     -.14005    -3.24  .0012     -.01268   -.00313
 *GENDER|    -.04424***     -.20599    -4.81  .0000     -.06229   -.02620
LNG_TRIP|    -.00943***     -.13863    -3.24  .0012     -.01514   -.00372
*UNI_PLU|    -.01753*       -.08160    -1.91  .0559     -.03549    .00044
 *RB_VID|    -.02531**      -.11786    -2.14  .0326     -.04853   -.00210
        |--------------[Partial effects on Prob[Y=03] at means]--------------
 ABILITY|     .00563**       .04147     2.09  .0364      .00036    .01090
INT_FREQ|     .00151*        .02102     1.86  .0626     -.00008    .00311
 *GENDER|     .00810**       .02954     1.99  .0461      .00014    .01606
LNG_TRIP|     .00181*        .02081     1.86  .0635     -.00010    .00372
*UNI_PLU|     .00313         .01141     1.47  .1424     -.00105    .00731
 *RB_VID|     .00195         .00711      .93  .3542     -.00217    .00607
        |--------------[Partial effects on Prob[Y=04] at means]--------------
 ABILITY|     .08303***      .48192     5.62  .0000      .05407    .11199
INT_FREQ|     .02234***      .24428     3.29  .0010      .00904    .03565
 *GENDER|     .12592***      .36164     4.90  .0000      .07551    .17634
LNG_TRIP|     .02667***      .24180     3.29  .0010      .01076    .04258
*UNI_PLU|     .04944*        .14198     1.92  .0544     -.00093    .09981
 *RB_VID|     .06954**       .19970     2.20  .0279      .00755    .13152
--------+---------------------------------------------------------------------
z, prob values and confidence intervals are given for the partial effect
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 16, 2021 at 06:40:51 PM
------------------------------------------------------------------------------
```

Table E.7 Restricted Crossing U-Turn Bivariate Acceptance and Confidence Model

```
--------------------------------------------------------------------------------
Bivariate Ordered Probit Model
Dependent variable                BivOrdPr
Log likelihood function       -2807.93220
Restricted log likelihood     -2972.10044
Chi squared [ 20](P= .000)      328.33648
Significance level                .00000
McFadden Pseudo R-squared       .0552364
Estimation based on N =    999, K =  20
Inf.Cr.AIC  =   5655.9 AIC/N =    5.662
--------+-----------------------------------------------------------------------
  RC_ACC|                  Standard            Prob.      95% Confidence
  RC_CON|  Coefficient       Error       z    |z|>Z*         Interval
--------+-----------------------------------------------------------------------
        |Index function for Probability Model for RC_ACC.....................
Constant|     .86788***      .06877    12.62  .0000      .73309   1.00267
LNG_MONT|     .16365**       .06751     2.42  .0154      .03133    .29597
GRAD_SKO|     .14498*        .08016     1.81  .0705     -.01213    .30209
  RC_FLY|    -.17557**       .08101    -2.17  .0302     -.33434   -.01680
 UNDER35|     .17549***      .06198     2.83  .0046      .05401    .29697
EXC_DRIV|     .11626*        .06881     1.69  .0911     -.01860    .25112
        |Index function for Probability Model for RC_CON.....................
Constant|     .76489***      .09126     8.38  .0000      .58602    .94376
EXC_DRIV|     .35924***      .07046     5.10  .0000      .22113    .49735
  GENDER|     .30316***      .05818     5.21  .0000      .18913    .41718
TOLAN_RU|     .04744***      .01368     3.47  .0005      .02063    .07426
LNG_MONT|     .19052***      .06904     2.76  .0058      .05520    .32584
  RC_DIA|     .26872***      .06632     4.05  .0001      .13873    .39872
  RC_FLY|    -.16551*        .08584    -1.93  .0538     -.33375    .00273
        |Threshold Parameters for Probability Model for RC_ACC...............
  MU(01)|     .72812***      .04366    16.68  .0000      .64255    .81369
  MU(02)|    1.68380***      .05698    29.55  .0000     1.57212   1.79548
  MU(03)|    2.46925***      .07393    33.40  .0000     2.32435   2.61416
        |Threshold Parameters for Probability Model for RC_CON...............
LMDA(01)|     .62415***      .05025    12.42  .0000      .52567    .72263
LMDA(02)|    1.44597***      .06015    24.04  .0000     1.32807   1.56387
LMDA(03)|    2.06816***      .06701    30.86  .0000     1.93682   2.19951
        |Disturbance Correlation = RHO(1,2)..................................
RHO(1,2)|     .59646***      .02259    26.40  .0000      .55218    .64073
--------+-----------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 16, 2021 at 06:40:59 PM
--------------------------------------------------------------------------------
```

Table E.8 Restricted Crossing U-Turn Acceptance Marginal Effects

```
--------------------------------------------------------------------------------
Marginal effects for ordered probability model
M.E.s for dummy variables are Pr[y|x=1]-Pr[y|x=0]
Names for dummy variables are marked by *.
--------+-----------------------------------------------------------------------
        |     Partial                              Prob.      95% Confidence
  RC_ACC|      Effect    Elasticity      z    |z|>Z*          Interval
--------+-----------------------------------------------------------------------
        |--------------[Partial effects on Prob[Y=00] at means]--------------
*LNG_MON|    -.03761**      -.25525    -2.42  .0155     -.06806   -.00716
*GRAD_SK|    -.04728**      -.32095    -2.49  .0127     -.08446   -.01011
 *RC_FLY|     .04196**       .28479     2.09  .0364      .00265    .08127
*UNDER35|    -.04029**      -.27347    -2.55  .0109     -.07131   -.00927
*EXC_DRI|    -.02731*       -.18535    -1.72  .0857     -.05845    .00384
        |--------------[Partial effects on Prob[Y=01] at means]--------------
*LNG_MON|    -.02391**      -.10462    -2.40  .0163     -.04342   -.00440
*GRAD_SK|    -.03407**      -.14910    -2.20  .0278     -.06442   -.00372
 *RC_FLY|     .02411**       .10549     2.30  .0214      .00357    .04464
*UNDER35|    -.02660**      -.11639    -2.44  .0148     -.04798   -.00522
*EXC_DRI|    -.01773*       -.07756    -1.67  .0951     -.03854    .00309
        |--------------[Partial effects on Prob[Y=02] at means]--------------
*LNG_MON|     .00972**       .02652     2.25  .0244      .00126    .01818
*GRAD_SK|     .00801***      .02186     2.80  .0051      .00240    .01362
 *RC_FLY|    -.01316*       -.03591    -1.79  .0742     -.02761    .00129
*UNDER35|     .00943**       .02574     2.49  .0127      .00202    .01685
*EXC_DRI|     .00674*        .01838     1.76  .0792     -.00078    .01426
        |--------------[Partial effects on Prob[Y=03] at means]--------------
*LNG_MON|     .02908**       .16008     2.38  .0173      .00513    .05304
*GRAD_SK|     .03932**       .21639     2.29  .0221      .00564    .07299
 *RC_FLY|    -.03063**      -.16855    -2.18  .0289     -.05810   -.00315
*UNDER35|     .03185**       .17527     2.44  .0145      .00630    .05739
*EXC_DRI|     .02138*        .11767     1.68  .0927     -.00354    .04630
        |--------------[Partial effects on Prob[Y=04] at means]--------------
*LNG_MON|     .02271**       .29920     2.35  .0190      .00373    .04169
*GRAD_SK|     .03403**       .44832     2.04  .0410      .00138    .06668
 *RC_FLY|    -.02228**      -.29347    -2.30  .0214     -.04125   -.00330
*UNDER35|     .02561**       .33738     2.35  .0187      .00427    .04695
*EXC_DRI|     .01691         .22283     1.63  .1031     -.00342    .03725
--------+-----------------------------------------------------------------------
z, prob values and confidence intervals are given for the partial effect
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 16, 2021 at 06:40:55 PM
--------------------------------------------------------------------------------
```

Table E.9 Restricted Crossing U-Turn Confidence Marginal Effects

```
------------------------------------------------------------------------------
Marginal effects for ordered probability model
M.E.s for dummy variables are Pr[y|x=1]-Pr[y|x=0]
Names for dummy variables are marked by *.
--------+---------------------------------------------------------------------
        |     Partial                            Prob.      95% Confidence
  RC_CON|      Effect    Elasticity      z    |z|>Z*         Interval
--------+---------------------------------------------------------------------
        |--------------[Partial effects on Prob[Y=00] at means]--------------
*EXC_DRI|    -.05281***     -.55308    -5.16  .0000     -.07287   -.03275
 *GENDER|    -.05231***     -.54783    -4.73  .0000     -.07397   -.03064
TOLAN_RU|    -.00894***     -.44567    -3.47  .0005     -.01399   -.00389
*LNG_MON|    -.02916***     -.30538    -2.67  .0075     -.05055   -.00777
 *RC_DIA|    -.03553***     -.37212    -3.15  .0016     -.05762   -.01344
 *RC_FLY|     .02989**       .31303     2.00  .0450      .00067    .05911
        |--------------[Partial effects on Prob[Y=01] at means]--------------
*EXC_DRI|    -.04838***     -.34683    -5.10  .0000     -.06696   -.02980
 *GENDER|    -.04514***     -.32363    -4.93  .0000     -.06309   -.02719
TOLAN_RU|    -.00778***     -.26535    -3.52  .0004     -.01211   -.00344
*LNG_MON|    -.02553***     -.18306    -2.68  .0073     -.04419   -.00688
 *RC_DIA|    -.03305***     -.23697    -2.99  .0028     -.05471   -.01140
 *RC_FLY|     .02442**       .17504     2.15  .0318      .00213    .04670
        |--------------[Partial effects on Prob[Y=02] at means]--------------
*EXC_DRI|    -.04050***     -.13593    -4.31  .0000     -.05892   -.02207
 *GENDER|    -.03372***     -.11317    -4.48  .0000     -.04847   -.01896
TOLAN_RU|    -.00578***     -.09237    -3.35  .0008     -.00917   -.00240
*LNG_MON|    -.01936**      -.06497    -2.56  .0104     -.03416   -.00456
 *RC_DIA|    -.02812***     -.09440    -2.60  .0094     -.04935   -.00690
 *RC_FLY|     .01605**       .05389     2.39  .0167      .00290    .02921
        |--------------[Partial effects on Prob[Y=03] at means]--------------
*EXC_DRI|     .02584***      .10953     4.58  .0000      .01477    .03691
 *GENDER|     .02738***      .11604     4.24  .0000      .01471    .04004
TOLAN_RU|     .00478***      .09632     3.19  .0014      .00184    .00771
*LNG_MON|     .01535***      .06506     2.58  .0098      .00370    .02700
 *RC_DIA|     .01741***      .07377     3.21  .0013      .00678    .02803
 *RC_FLY|    -.01655*       -.07013    -1.92  .0550     -.03345    .00036
        |--------------[Partial effects on Prob[Y=04] at means]--------------
*EXC_DRI|     .11584***      .50111     4.72  .0000      .06778    .16390
 *GENDER|     .10379***      .44897     4.74  .0000      .06083    .14674
TOLAN_RU|     .01773***      .36493     3.48  .0005      .00774    .02771
*LNG_MON|     .05870***      .25392     2.64  .0083      .01508    .10232
 *RC_DIA|     .07930***      .34305     2.81  .0050      .02399    .13461
 *RC_FLY|    -.05381**      -.23279    -2.20  .0277     -.10172   -.00591
--------+---------------------------------------------------------------------
z, prob values and confidence intervals are given for the partial effect
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 16, 2021 at 06:40:56 PM
------------------------------------------------------------------------------
```

Table E.10 Displaced Left Turn Bivariate Acceptance and Confidence Model

```
--------------------------------------------------------------------------------
Bivariate Ordered Probit Model
Dependent variable                BivOrdPr
Log likelihood function       -2737.60113
Restricted log likelihood     -2974.27141
Chi squared [ 18](P= .000)     473.34055
Significance level                .00000
McFadden Pseudo R-squared       .0795725
Estimation based on N =    999, K =  18
Inf.Cr.AIC  =   5511.2 AIC/N =    5.517
--------+-----------------------------------------------------------------------
  DL_ACC|                  Standard            Prob.      95% Confidence
  DL_CON|  Coefficient       Error       z    |z|>Z*         Interval
--------+-----------------------------------------------------------------------
        |Index function for Probability Model for DL_ACC.....................
Constant|     .52201***      .08832     5.91  .0000      .34891    .69511
GRAD_SKO|     .24857***      .07220     3.44  .0006      .10706    .39007
EXC_DRIV|     .13199*        .06865     1.92  .0545     -.00256    .26654
  DL_DIA|    -.36371***      .07660    -4.75  .0000     -.51384   -.21357
PREC_DL4|     .89194***      .20146     4.43  .0000      .49709   1.28680
        |Index function for Probability Model for DL_CON.....................
Constant|     .72984***      .07009    10.41  .0000      .59247    .86722
  GENDER|     .28026***      .05660     4.95  .0000      .16932    .39121
EXC_DRIV|     .38639***      .06917     5.59  .0000      .25082    .52196
AA_INTFR|     .23368***      .05544     4.21  .0000      .12501    .34235
  DL_DIA|    -.28305***      .07776    -3.64  .0003     -.43545   -.13065
  DL_SIM|     .12715*        .06928     1.84  .0665     -.00863    .26294
        |Threshold Parameters for Probability Model for DL_ACC...............
  MU(01)|     .65419***      .04001    16.35  .0000      .57578    .73260
  MU(02)|    1.65649***      .05638    29.38  .0000     1.54599   1.76699
  MU(03)|    2.41149***      .07625    31.62  .0000     2.26203   2.56094
        |Threshold Parameters for Probability Model for DL_CON...............
LMDA(01)|     .59116***      .04318    13.69  .0000      .50654    .67578
LMDA(02)|    1.39565***      .05510    25.33  .0000     1.28765   1.50365
LMDA(03)|    2.04609***      .06529    31.34  .0000     1.91813   2.17405
        |Disturbance Correlation = RHO(1,2)..................................
RHO(1,2)|     .68599***      .01901    36.09  .0000      .64874    .72325
--------+-----------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 16, 2021 at 06:41:04 PM
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```

Table E.11 Displaced Left Turn Acceptance Marginal Effects

```
--------------------------------------------------------------------------------
Marginal effects for ordered probability model
M.E.s for dummy variables are Pr[y|x=1]-Pr[y|x=0]
Names for dummy variables are marked by *.
--------+-----------------------------------------------------------------------
        |     Partial                              Prob.      95% Confidence
  DL_ACC|      Effect    Elasticity      z    |z|>Z*          Interval
--------+-----------------------------------------------------------------------
        |--------------[Partial effects on Prob[Y=00] at means]--------------
*GRAD_SK|    -.08398***     -.41269    -3.86  .0001     -.12664   -.04132
*EXC_DRI|    -.03766**      -.18506    -1.96  .0497     -.07527   -.00004
 *DL_DIA|     .10927***      .53695     4.46  .0000      .06123    .15731
PREC_DL4|    -.32466***     -.54237    -4.59  .0000     -.46328   -.18605
        |--------------[Partial effects on Prob[Y=01] at means]--------------
*GRAD_SK|    -.04198***     -.18039    -3.13  .0018     -.06830   -.01567
*EXC_DRI|    -.01546*       -.06642    -1.87  .0608     -.03162    .00070
 *DL_DIA|     .03409***      .14647     5.45  .0000      .02182    .04635
PREC_DL4|    -.12733***     -.18601    -4.49  .0000     -.18294   -.07173
        |--------------[Partial effects on Prob[Y=02] at means]--------------
*GRAD_SK|     .02632***      .07143     4.78  .0000      .01552    .03712
*EXC_DRI|     .01510**       .04099     2.01  .0444      .00038    .02983
 *DL_DIA|    -.05074***     -.13769    -3.99  .0001     -.07567   -.02581
PREC_DL4|     .13530***      .12482     4.21  .0000      .07235    .19825
        |--------------[Partial effects on Prob[Y=03] at means]--------------
*GRAD_SK|     .05597***      .39682     3.31  .0009      .02288    .08906
*EXC_DRI|     .02261*        .16028     1.90  .0574     -.00071    .04592
 *DL_DIA|    -.05758***     -.40821    -4.63  .0000     -.08194   -.03321
PREC_DL4|     .19045***      .45902     4.34  .0000      .10437    .27652
        |--------------[Partial effects on Prob[Y=04] at means]--------------
*GRAD_SK|     .04367***      .80530     2.86  .0042      .01374    .07359
*EXC_DRI|     .01541*        .28410     1.84  .0655     -.00099    .03180
 *DL_DIA|    -.03504***     -.64616    -4.91  .0000     -.04902   -.02106
PREC_DL4|     .12625***      .79147     4.33  .0000      .06910    .18340
--------+-----------------------------------------------------------------------
z, prob values and confidence intervals are given for the partial effect
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 16, 2021 at 06:41:00 PM
--------------------------------------------------------------------------------
```

Table E.12 Displaced Left Turn Confidence Marginal Effects

```
------------------------------------------------------------------------------
Marginal effects for ordered probability model
M.E.s for dummy variables are Pr[y|x=1]-Pr[y|x=0]
Names for dummy variables are marked by *.
--------+---------------------------------------------------------------------
        |     Partial                              Prob.      95% Confidence
  DL_CON|      Effect    Elasticity      z    |z|>Z*          Interval
--------+---------------------------------------------------------------------
        |--------------[Partial effects on Prob[Y=00] at means]--------------
 *GENDER|    -.07688***     -.58243    -4.94  .0000     -.10737   -.04639
*EXC_DRI|    -.08088***     -.61270    -5.63  .0000     -.10904   -.05272
*AA_INTF|    -.04810***     -.36435    -3.10  .0019     -.07848   -.01771
 *DL_DIA|     .06453***      .48883     3.16  .0016      .02447    .10458
 *DL_SIM|    -.03620**      -.27423    -2.10  .0359     -.07001   -.00239
        |--------------[Partial effects on Prob[Y=01] at means]--------------
 *GENDER|    -.04346***     -.27106    -5.09  .0000     -.06021   -.02672
*EXC_DRI|    -.04949***     -.30866    -5.40  .0000     -.06744   -.03154
*AA_INTF|    -.02714***     -.16927    -3.15  .0016     -.04402   -.01027
 *DL_DIA|     .03290***      .20521     3.57  .0004      .01483    .05098
 *DL_SIM|    -.02211**      -.13790    -1.97  .0493     -.04415   -.00007
        |--------------[Partial effects on Prob[Y=02] at means]--------------
 *GENDER|    -.00984**      -.03156    -2.39  .0169     -.01791   -.00176
*EXC_DRI|    -.01685***     -.05408    -2.92  .0035     -.02818   -.00553
*AA_INTF|    -.00580**      -.01862    -2.00  .0453     -.01149   -.00012
 *DL_DIA|     .00249         .00800      .83  .4043     -.00337    .00835
 *DL_SIM|    -.00711       -.02282    -1.41  .1598     -.01703    .00280
        |--------------[Partial effects on Prob[Y=03] at means]--------------
 *GENDER|     .04582***      .20653     4.67  .0000      .02658    .06507
*EXC_DRI|     .04822***      .21736     5.22  .0000      .03012    .06633
*AA_INTF|     .02887***      .13012     3.04  .0024      .01025    .04749
 *DL_DIA|    -.03810***     -.17172    -3.14  .0017     -.06185   -.01434
 *DL_SIM|     .02188**       .09862     2.07  .0385      .00116    .04260
        |--------------[Partial effects on Prob[Y=04] at means]--------------
 *GENDER|     .08437***      .48456     4.81  .0000      .05000    .11873
*EXC_DRI|     .09900***      .56864     4.94  .0000      .05972    .13829
*AA_INTF|     .05217***      .29967     3.08  .0020      .01901    .08534
 *DL_DIA|    -.06183***     -.35512    -3.54  .0004     -.09605   -.02760
 *DL_SIM|     .04354*        .25010     1.90  .0575     -.00138    .08847
--------+---------------------------------------------------------------------
z, prob values and confidence intervals are given for the partial effect
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 16, 2021 at 06:41:01 PM
------------------------------------------------------------------------------
```

Table E.13 Diverging Diamond Interchange Bivariate Acceptance and Confidence Model

```
--------------------------------------------------------------------------------
Bivariate Ordered Probit Model
Dependent variable                BivOrdPr
Log likelihood function       -2733.87414
Restricted log likelihood     -3004.59076
Chi squared [ 19](P= .000)     541.43325
Significance level                .00000
McFadden Pseudo R-squared       .0901010
Estimation based on N =    999, K =  19
Inf.Cr.AIC  =   5505.7 AIC/N =    5.511
--------+-----------------------------------------------------------------------
  DD_ACC|                  Standard            Prob.      95% Confidence
  DD_CON|  Coefficient       Error       z    |z|>Z*         Interval
--------+-----------------------------------------------------------------------
        |Index function for Probability Model for DD_ACC.....................
Constant|     .04745         .11378      .42  .6767     -.17556    .27046
  DD_VID|     .24862***      .07742     3.21  .0013      .09688    .40035
  DD_SIM|    -.16322***      .06297    -2.59  .0095     -.28665   -.03980
FLRU_MNT|     .12213**       .05486     2.23  .0260      .01460    .22965
PREC_DD4|    1.64424***      .26357     6.24  .0000     1.12765   2.16083
        |Index function for Probability Model for DD_CON.....................
Constant|    -.20986         .13349    -1.57  .1159     -.47149    .05178
FRLAN_UR|     .04068***      .01269     3.20  .0014      .01580    .06556
TOLAN_RU|     .05543***      .01258     4.41  .0000      .03077    .08009
EXC_DRIV|     .18902***      .05981     3.16  .0016      .07179    .30624
  GENDER|     .25244***      .05384     4.69  .0000      .14691    .35796
  DD_VID|     .27610***      .07699     3.59  .0003      .12519    .42700
PREC_DD4|    1.40375***      .30672     4.58  .0000      .80258   2.00491
        |Threshold Parameters for Probability Model for DD_ACC..............
  MU(01)|     .67408***      .03940    17.11  .0000      .59685    .75130
  MU(02)|    1.55817***      .05536    28.15  .0000     1.44967   1.66666
  MU(03)|    2.30838***      .07457    30.95  .0000     2.16221   2.45454
        |Threshold Parameters for Probability Model for DD_CON..............
LMDA(01)|     .58728***      .04238    13.86  .0000      .50422    .67034
LMDA(02)|    1.34194***      .05484    24.47  .0000     1.23445   1.44942
LMDA(03)|    1.89393***      .06268    30.21  .0000     1.77108   2.01679
        |Disturbance Correlation = RHO(1,2)..................................
RHO(1,2)|     .72162***      .01756    41.11  .0000      .68722    .75603
--------+-----------------------------------------------------------------------
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 16, 2021 at 06:41:09 PM
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```

Table E.14 Diverging Diamond Interchange Acceptance Marginal Effects

```
------------------------------------------------------------------------------
Marginal effects for ordered probability model
M.E.s for dummy variables are Pr[y|x=1]-Pr[y|x=0]
Names for dummy variables are marked by *.
--------+---------------------------------------------------------------------
        |     Partial                              Prob.      95% Confidence
  DD_ACC|      Effect    Elasticity      z    |z|>Z*          Interval
--------+---------------------------------------------------------------------
        |--------------[Partial effects on Prob[Y=00] at means]--------------
 *DD_VID|    -.06483***     -.31013    -3.09  .0020     -.10600   -.02365
 *DD_SIM|     .05457**       .26109     2.14  .0325      .00455    .10459
*FLRU_MN|    -.04430**      -.21195    -2.25  .0247     -.08296   -.00565
PREC_DD4|    -.46312***     -.87435    -5.95  .0000     -.61560   -.31064
        |--------------[Partial effects on Prob[Y=01] at means]--------------
 *DD_VID|    -.02789***     -.11297    -2.74  .0061     -.04784   -.00794
 *DD_SIM|     .01830**       .07413     2.42  .0155      .00349    .03312
*FLRU_MN|    -.01655**      -.06704    -2.27  .0232     -.03084   -.00226
PREC_DD4|    -.17579***     -.28096    -5.66  .0000     -.23670   -.11487
        |--------------[Partial effects on Prob[Y=02] at means]--------------
 *DD_VID|     .02064***      .06300     3.32  .0009      .00846    .03282
 *DD_SIM|    -.02106**      -.06428    -1.98  .0473     -.04186   -.00025
*FLRU_MN|     .01602**       .04889     2.18  .0292      .00162    .03041
PREC_DD4|     .16621***      .20022     5.07  .0000      .10197    .23045
        |--------------[Partial effects on Prob[Y=03] at means]--------------
 *DD_VID|     .03941***      .26082     2.86  .0042      .01241    .06641
 *DD_SIM|    -.03000**      -.19853    -2.22  .0265     -.05650   -.00349
*FLRU_MN|     .02541**       .16818     2.23  .0256      .00310    .04772
PREC_DD4|     .26745***      .69851     5.46  .0000      .17147    .36344
        |--------------[Partial effects on Prob[Y=04] at means]--------------
 *DD_VID|     .03267***      .49966     2.67  .0076      .00870    .05664
 *DD_SIM|    -.02182**      -.33376    -2.33  .0198     -.04017   -.00347
*FLRU_MN|     .01943**       .29710     2.23  .0255      .00238    .03647
PREC_DD4|     .20525***     1.23876     5.39  .0000      .13063    .27986
--------+---------------------------------------------------------------------
z, prob values and confidence intervals are given for the partial effect
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 16, 2021 at 06:41:05 PM
------------------------------------------------------------------------------
```

Table E.15 Diverging Diamond Interchange Confidence Marginal Effects

```
------------------------------------------------------------------------------
Marginal effects for ordered probability model
M.E.s for dummy variables are Pr[y|x=1]-Pr[y|x=0]
Names for dummy variables are marked by *.
--------+---------------------------------------------------------------------
        |     Partial                              Prob.      95% Confidence
  DD_CON|      Effect    Elasticity      z    |z|>Z*          Interval
--------+---------------------------------------------------------------------
        |--------------[Partial effects on Prob[Y=00] at means]--------------
FRLAN_UR|    -.01182***     -.33319    -3.17  .0015     -.01912   -.00451
TOLAN_RU|    -.01000***     -.32001    -2.66  .0078     -.01737   -.00263
*EXC_DRI|    -.04647***     -.31255    -2.76  .0057     -.07945   -.01350
 *GENDER|    -.06472***     -.43525    -4.04  .0001     -.09610   -.03334
 *DD_VID|    -.06059***     -.40748    -3.93  .0001     -.09080   -.03038
PREC_DD4|    -.29782***     -.79039    -4.26  .0000     -.43484   -.16079
        |--------------[Partial effects on Prob[Y=01] at means]--------------
FRLAN_UR|    -.00637***     -.15754    -3.18  .0015     -.01030   -.00244
TOLAN_RU|    -.00539***     -.15131    -2.66  .0077     -.00936   -.00143
*EXC_DRI|    -.02622***     -.15461    -2.66  .0078     -.04554   -.00690
 *GENDER|    -.03479***     -.20513    -4.11  .0000     -.05138   -.01819
 *DD_VID|    -.03584***     -.21135    -3.65  .0003     -.05509   -.01659
PREC_DD4|    -.16060***     -.37372    -4.29  .0000     -.23404   -.08715
        |--------------[Partial effects on Prob[Y=02] at means]--------------
FRLAN_UR|    -.00130**      -.01843    -1.97  .0487     -.00260   -.00001
TOLAN_RU|    -.00110*       -.01770    -1.84  .0660     -.00228    .00007
*EXC_DRI|    -.00705*       -.02378    -1.82  .0686     -.01463    .00054
 *GENDER|    -.00732**      -.02469    -2.20  .0278     -.01383   -.00080
 *DD_VID|    -.01200**      -.04050    -2.28  .0226     -.02232   -.00169
PREC_DD4|    -.03284**      -.04372    -2.18  .0289     -.06230   -.00337
        |--------------[Partial effects on Prob[Y=03] at means]--------------
FRLAN_UR|     .00560***      .12095     3.01  .0026      .00195    .00924
TOLAN_RU|     .00474**       .11617     2.55  .0106      .00110    .00837
*EXC_DRI|     .02179***      .11235     2.68  .0074      .00585    .03774
 *GENDER|     .03037***      .15657     3.78  .0002      .01462    .04612
 *DD_VID|     .02804***      .14457     3.70  .0002      .01320    .04289
PREC_DD4|     .14104***      .28692     3.87  .0001      .06957    .21250
        |--------------[Partial effects on Prob[Y=04] at means]--------------
FRLAN_UR|     .01389***      .30440     3.14  .0017      .00522    .02257
TOLAN_RU|     .01176***      .29236     2.65  .0081      .00305    .02047
*EXC_DRI|     .05795***      .30276     2.60  .0094      .01423    .10166
 *GENDER|     .07645***      .39945     3.98  .0001      .03881    .11409
 *DD_VID|     .08039***      .42003     3.49  .0005      .03519    .12559
PREC_DD4|     .35022***      .72210     4.21  .0000      .18724    .51319
--------+---------------------------------------------------------------------
z, prob values and confidence intervals are given for the partial effect
***, **, * ==>  Significance at 1%, 5%, 10% level.
Model was estimated on Mar 16, 2021 at 06:41:06 PM
------------------------------------------------------------------------------
```