RESEARCH & DEVELOPMENT

Economic Impact of SuperStreets

Donald C. Barnes, PhD
Adam T. Jones, PhD
Lizzette Perez Lespier, PhD
Peter Schuhmann, PhD
Manoj Vanajakumari, PhD
Ethan D. Watson, PhD
Cameron School of Business
University of North Carolina Wilmington

NCDOT Project 2020-47

FHWA/NC/2020-47

June 2022

The Economic Impact of Reduced-Conflict Intersections in North Carolina

FINAL REPORT

Prepared by:

Donald C. Barnes

Adam T. Jones

Lizzette Pérez Lespier

Peter Schuhmann

Manoj Vanajakumari

Ethan D. Watson

A report sponsored by:

THE NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

August 2022

Technical Report Documentation Page

1. Report No. **FHWA/NC/2020-47**	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Economic Impact of SuperStreets		5. Report Date June 2022
		6. Performing Organization Code
7. Author(s) **Dr. Donald C. Barnes, Dr. Adam T. Jones, Dr. Lizzette Perez Lespier, Dr. Peter Schuhmann, Dr. Manoj Vanajakumari, Dr. Ethan D. Watson**		8. Performing Organization Report No.
9. Performing Organization Name and Address **University of North Carolina Wilmington** **Cameron School of Business** **601 S. College Rd** **Wilmington, NC 28403-5945**		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address North Carolina Department of Transportation Research and Development Unit 1020 Birch Ridge Drive Raleigh, North Carolina 27610		13. Type of Report and Period Covered **Final Report** **September 2019 to June 2022**
		14. Sponsoring Agency Code **RP2020-47**
Supplementary Notes:		

16. Abstract

This research examined the economic impact of reduced conflict intersection (RCI) design otherwise known as restricted crossing U-turn intersections. The analysis involved a multifaceted approach using remote sensing radiance data to analyze economic activity adjacent to RCI improvements, a business survey to assess business perceptions of RCIs, a residential real estate analysis, and resident survey. The remote sensing analysis utilizing a multi-group interrupted time series analysis yielded mixed results with most models resulting in a null effect. However, two locations were suggestive of a positive and significant effect on economic activity for development adjacent to the RCI compared to a control location. However, analysis of two of the three industrial parks studied show evidence of decreased economic activity following the installation of the RCI. The business survey indicated that businesses with a large number of customers and that are busiest later in the day are more likely to believe RCIs make their business easier to reach. Industrial users were less likely to agree that RCIs make their businesses easier to reach and more likely to indicate a safety concern around their facilities. Analysis of residential real estate sale prices yielded mixed results and indicate that RCIs have potential to support home values but extended wait times at the U-Turn portion of an RCI intersection could have a negative effect. This assertion is supported by the residential survey results which show residents are willing to "pay" for safety with increased wait times but are decidedly more averse to additional time to turn left than an increase in total commute time. This difference in aversion to increased travel time indicates that residents value traffic flow; a result further supported by respondents increased willingness to make a trip for a single item if the road is not congested and make an impulse stop for a snack or coffee when traffic is light.

17. Key Words ***Reduced Conflict Intersection, restricted crossing U-turn intersection, economic impact, surveys***	18. Distribution Statement		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 203	22. Price

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

DISCLAIMER

The contents of this report reflect the views of the author(s) and not necessarily the views of the University of North Carolina System or the University of North Carolina at Wilmington. The author(s) are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of North Carolina, the North Carolina Department of Transportation, or the Federal Highway Administration at the time of publication. This report does not constitute a standard, specification, or regulation.

ACKNOWLEDGEMENTS

The research team acknowledges the North Carolina Department of Transportation for supporting and funding this project. The team extends a special thank you to Dr. Joseph Hummer for his tireless support of the project and assistance to the team.

EXECUTIVE SUMMARY

Reduced conflict intersections (RCIs) are designed to reduce the number of points where vehicle paths cross by restricting the ability of vehicles approaching an arterial road from crossing or turning left onto the arterial. Previous studies have examined the operational characteristics of RCIs, finding their use improves through traffic flow and safety profiles, and significantly reduces the number of injury crashes. While the RCI design improves the arterial street's efficiency, RCIs may increase travel time for vehicles on minor streets crossing or turning left onto the arterial road, as those vehicles now must first turn right and then U-turn to come back to their intersection of entry in the desired travel direction.

Businesses located near proposed RCI improvements often voice concerns that these aspects of the RCI design will negatively affect their businesses. Such concerns may be justified if changes in traffic flow and ease of transition through and between nearby roadways significantly affects customer access. Yet, if economic activity or specific business opportunities are primarily demand driven, an RCI is unlikely to have adverse effects on the associated commercial activity. Indeed, it may be the case that overall improvements in traffic flow result in access by a spatially broader group of consumers. In such cases, the effects of RCI implementation may show up elsewhere, such as in home prices as residents price-in the convenience or inconvenience of travelling through an intersection.

The existing literature on the economic impact of RCI intersections and other alternative intersection designs is relatively undeveloped and provides little insight to understand the potential scope and magnitude of these effects. This report attempts to fill some of these knowledge gaps by summarizing a series of empirical investigations intended to improve our understanding of the potential economic impacts of RCIs. Using data collected from businesses and households in North Carolina, our approach to understanding the potential impacts of RCIs considers two main channels for impacts: impacts on businesses and impacts on residents. We explore the "incidence" of impacts (who is affected by RCIs) as well as the direction of impacts (whether RCIs create positive or negative effects).
Specific objectives of the research project were:

- Determine if the volume of economic activity is affected positively or negatively by RCI intersection design.
- Quantify and evaluate business perceptions of RCIs to complement evaluation of economic activity near RCIs
- Determine if home prices are affected by RCI intersection design
- Quantify resident perceptions of RCIs to complement home price analysis

We address these objectives using a multifaceted approach. To examine economic activity around the RCIs we use night-time radiance data obtained from the Visible Infrared Imaging Radiometer Suite (VIIRS) to quantify the change in economic activity before and after RCI installation. The radiance results are complemented by a business survey to help understand differences in results and differing perceptions of RCIs across business types. To examine the potential effect of RCIs on residential real estate, a difference-in-difference approach is used to compare home sales prices for streets that are affected by RCI installation relative to homes on proximate control streets. The residential real estate analysis is complemented by a residential survey and discrete choice experiment to explore residents' weighting of safety versus time and their perceptions and decisions around RCI usage.

The radiance analysis of economic activity around RCIs suggests a null to slightly positive effect on commercial development and a negative effect on activity in industrial areas. The positive effect on commercial development suggests that improvements in traffic flow outweigh the additional costs of less direct routes. However, the radiance analysis suggests a negative economic impact on industrial developments. Business survey results suggest that businesses with more customers and businesses who are busiest during periods of traffic congestion believe RCIs make their businesses easier to reach, while industrial businesses were less likely to agree that RCIs make reaching their business easier and were also more likely to express safety concerns.

Results from the residential survey provide evidence in support of a positive effect on commercial development. Residents are more likely to patronize businesses when traffic flow is improved. Specifically, survey respondents suggest that they are more likely to make a trip for a single item requiring a U-turn when roads are not congested than they are to make a trip when roads are congested. In addition, the residents indicated they are more likely to stop for a snack when traffic is lighter. These responses combined with the operational characteristics research of prior studies suggest a positive effect on retail business from RCI installations.

Analysis of residential real estate prices located near RCI improvements yielded mixed results. Of the four RCI intersections examined, we discover one RCI that had a positive and significant effect on real estate prices, two RCIs produced positive but insignificant effects, and one RCI produced a negative effect. Notably, all three intersections with a positive effect (significantly positive in one case) were unsignalized U-turns. The one intersection that had a negative effect on home prices included a signalized U-turn as part of the design. This negative impact, though anecdotal, may suggest the extra time costs of waiting at the signal outweigh the benefits of improved traffic flow for nearby residents.

The real estate analysis is complemented by a discrete choice experiment included in the residential survey and reveals that residents are willing to trade off both overall commute time and time to turn left for safety improvements. Specifically, results indicate that residents are willing to trade off nearly two minutes of additional travel time for a 10% reduction in accidents, and that drivers are less averse to additional commute time than to additional time to turn left. These results provide further evidence of the importance of traffic flow and traffic safety.

RCIs are an appropriate solution when the benefits of improved traffic flow and safety outweigh the additional time costs associated with U-turns. The research findings provided in this report provide new insights into where and how the use of RCI designs may impact economic activity and NCDOT constituent satisfaction. Our results suggest that residents view the improved traffic flow provided by RCIs favorably, and that residential and business impacts are likely to be positive or relatively insignificant. The finding of negative impacts when RCIs are constructed near industrial areas or business parks accessing arterial roads from minor streets may indicate that industrial users find the U-turns more problematic and costly than other types of drivers and suggests further consideration prior to RCI implementation in industrial locations.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

Roughly 30 years after they were first suggested, states such as Virginia, Louisiana, Maryland, and Florida are beginning to use alternative intersection designs to improve the safety and efficiency of suburban arterials. In North Carolina these intersections are known as Reduced Conflict Intersections (RCIs) and redirect minor street left turn and through movement to downstream U-turn crossovers. Other names for such intersections include Restricted Crossing U-turns (RCUTs), Superstreets, Michigan Lefts, Median U-Turns (MUTs) and a host of other names. While the benefits of improved traffic flow and safety have been well established, the economic impacts and public perceptions associated with Reduced Conflict intersections (RCIs) are relatively less understood. This study seeks to examine the economic impact and public perception that RCIs may have on communities.

RCIs potentially affect several constituencies within a community. First, RCIs change traffic patterns around businesses, and may create economic impacts to businesses as customers may change their shopping patterns. Changes in traffic patterns may also affect home prices in nearby residential developments. While business owners are often anxious about access modifications, the economic impact of RCIs on business and home prices is theoretically ambiguous. In the case of commerce, increased travel times required to cross arterial roads may deter some customers from patronizing certain businesses, but improved traffic flow on the main road may reduce travel times, reduce traffic congestion, and potentially broaden the market area served by businesses through improved overall customer access.

Similarly, impacts on residents who live in areas where an RCI impedes their ability to turn left may find the intersection cumbersome, which would be reflected in lower home values. However, if residents view RCIs positively because of increased safety and traffic flow on the main road, higher home values may result. To address these potential impacts, we propose three approaches to studying the potential impact. First, we utilize satellite imagery to calculate radians (a measure of light immitted), which is shown to be correlated with economic activity. RCI implementation creates an exogenous shock to businesses access by customers, providing researchers with natural experiments that allow for the application of Difference-in-Difference methodologies to analyze potential effects. Second, we use these natural experiments of RCI implementations to examine whether the economic impact of RCIs is reflected in home values. Third, and lastly, we surveyed both businesses and residential respondents to ascertain their perceptions and attitudes regarding various RCI related information.

Research Objectives

The objective of the research presented below is to investigate the economic impact of reduced conflict intersections (RCIs). While a comprehensive coverage of all potential impacts is beyond the scope of any single report, we take a broad approach to the question and consider two different channels for economic impacts: impacts on businesses and impacts on residents. In economic parlance this idea is referred to as "incidence" or where a burden ultimately falls. If economic activity or business is demand driven, then an RCI is unlikely to affect the activity and the effects may show up elsewhere, such as home prices as residents price-in the time, safety, and cognitive costs of travelling through an intersection. Like many “shocks” to a market, the effects are likely to be spread across multiple groups in different ways, thus, we take a broader focus than the narrow activity around an intersection. Thus, the specific objectives of the research project were:

- Determine if the volume of economic activity is affected positively or negatively by RCI intersection design.
- Quantify and evaluate business perceptions of RCIs to complement evaluation of economic activity near RCIs
- Determine if home prices are affected by RCI intersection design
- Quantify resident perceptions of RCIs to complement home price analysis

Related Literature

We are not the first to consider the impact of RCIs. The literature on the improvements to safety and traffic has been previously documented. For instance, Hummer et. al (2014) examines North Carolina RCIs and reports reductions in accidents. Furthermore, they report improved travel times compared to conventional intersections. Max Moreland (2021) examined 49 RCIs installed between 2010 and 2020 in Minnesota and reports a reduction in fatal and severe accidents; however, fails to find a reduction in total crashes. Thus, Moreland reports that RCIs appear to reduce the severity of accidents. Inman and Haas (2012) examine RCIs in the state of Maryland and also find favorable safety improvements with RCI installations. They report a 30% reduction in crash rates compared to conventional intersections.

While the literature indicates that safety and traffic flow improve with RCIs, transportation officials report significant angst from constituents when RCIs are proposed and implemented (see Vu et al (2006) and Miller (2019) as examples). This may be due to perceived economic impacts from RCI installations by businesses in the area. Interestingly, Eisele and Frawley (1999) and Cunningham (2015) find that concerns of raised medians limiting access to the stores and reducing business are larger prior to installation than post installation. To date, there is relatively less written about the economic impact of RCIs. A few exceptions are a Virginia case study (Miller, 2019), and an examination of Louisiana sales tax data (Schneider, Barnes, Pfetzer, & Hutchinson, 2019). The Virginia case study uses economic modelling techniques (Maximum Potential Economic Loss and Expected Potential Economic Loss) to assess intersections and finds some evidence that sales may be hurt for some areas but helped for others. However, lacking a sufficient number of RCUTs, the study relies on a calibrated model rather than observed data. The Louisiana study (Schneider, Barnes, Pfetzer, & Hutchinson, 2019) examines taxable sales data surrounding J-turn intersections using pre-post installation means testing. In aggregate (across all parishes), they find that sales increase following the installation of the RCIs.

In addition to studies that look at RCIs, there is related literature on raised medians. Like RCIs, medians can impede access to businesses and have been the focus of previous studies. For instance, Riffkin et. al. (2013) study three matched pairs of corridors in Utah following median installations and find that sales increased with no evidence of a detrimental impact. Additionally, Cunningham et. al. (2015) use perception-based surveys to study medians in North Carolina. They survey business adjacent to seven improved corridors, and business along matched control corridors. Using means testing they find no direct evidence of negative economic impacts on treatment vs control groups.

We extend the existing research that examines the economic impact of RCIs by taking a three-part approach. In the first part, we use radiance data from satellite imagery to quantify economic activity around RCIs. While we attempt to validate this measure in this study, we are not alone in using this type of measure as a proxy of economic activity. For example, Li et al., (2022) interpreted night-time light (NTL) patterns based on remote sensed satellite images to evaluate development in different cities and found that construction land expansion was the most direct and profound driver for the increase in nighttime light. Also, Villa (Villa, 2014) used luminosity data to assess the effects of a social program in Colombia generates large positive effects on municipality level economic growth rates. Moreover, Levin & Zhang (2017), used NTL imagery for identifying urban land across large regions, and evaluating nighttime brightness of cities to explain differences in GDP per capita and GDP density, establishing correlation. We try to address causality by using a diff-in-diff methodology. Diff-in-diff are the gold standard for teasing out causality in randomized clinic trials. While we do not enjoy the benefit of being able to randomly select where RCIs are placed, their installation provides us with a natural experiment that allows us to match "treated" developments with appropriate control developments for comparison. The matched control approach extends, and largely confirms, the work of Schneider et. al. (2019) using Louisiana sales tax data for commercial development and extends the work to industrial development.

In our second part of this study, we further extend the literature by examining the economic impact to homeowners who are affected by RCI implementations. Since RCIs improve traffic in an area, our study is related to literature that has examined how traffic affects home values (Bagby, 1980; Kawamura & Mahajan, 2005). However, improved traffic flow may be offset by the additional costs of required U-turns or additional traffic maneuvers required by RCIs. Like our satellite imagery analysis, we attempt to address causality by using a diff-in-diff methodology using RCI implementations as a natural experiment.

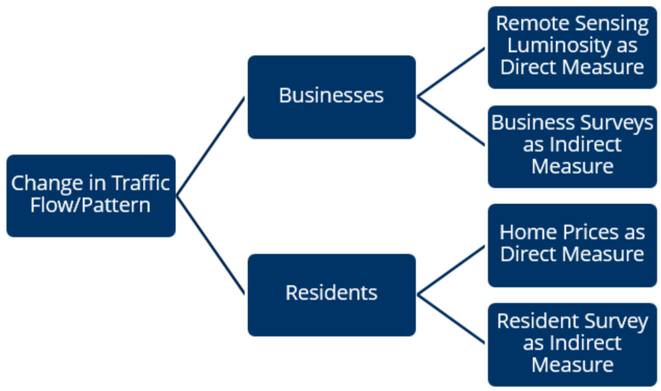
Finally, we survey both business and residents to assess perceptions of the RCI to shed light on the results from the remote sensing data analysis and real estate analysis. We parse the business surveys business size and type to identify which businesses may be least receptive and we incorporate a choice experiment into the resident survey to identify how residents tradeoff safety versus time.

Approach

Economists often discuss the idea of "incidence," who the burden ultimately falls on when analyzing taxes, and we bring the same framework to the economic impact analysis of reduced conflict intersections. Because the economic impact could fall on the supply side, businesses, the demand side, consumers, or some combination of the two. In addition, the effects could be either positive or negative. For example, if intersection improvements make businesses easier to reach the improvement could have a positive economic impact or if it makes a business more difficult to reach then it could have a negative impact. But, if the level of business activity is driven by demand, i.e., total grocery demand is a function of population, not traffic flow, then the economic impact may manifest itself in home prices as buyers capitalize commute times.

To examine the two potential manifestations, we take a dual approach, using direct data to quantify economic impacts and using survey data as an indirect approach to provide a richer picture of the direct data. Figure 1 presents the research approach.

Figure 1: Research Approach



Areas of Interest

Because of the multi-faceted approach described above, the research team took a broad approach to identifying the appropriate sites for analysis. The team started with a map of sites provided by NCDOT roughly corresponding to locations installed through 2015 with a few corridors installed after 2015 having been added to the map. Working with NCDOT regional engineers and through other exploratory endeavors, the research team added additional locations to the site inventory. Once the site inventory was complete, the research team identified approximate installation dates using different vintages of aerial imagery in Google Earth Pro. A list of RCI intersections can be found in Appendix A.

Following the development of the RCI inventory, sites were selected as "areas of interest" using the following criteria.

- Remote sensing – site installed 2015 or later with a population density of at least 500 persons per square mile in the site's census tract
- Residential survey – Site had appropriate and accessible treatment and control residential developments in close proximity to the site
- Business survey – Site had a density of businesses located near the RCIs and were in a relatively stable community (corridors outside military bases were not surveyed for this reason)
- Home Prices – site installed after 2004 and has both treatment and control residential development in close proximity to the site. i.e., one residential street connecting to an arterial road at the RCI site and another residential street connecting to the arterial road through a conventional intersection or an intersection which has not had improvements made to the intersection through which it connects.

A list of the areas of interest is presented in Table 1.

Table 1: Areas of Interest

Area	Signalized	Night Lights	Residential Survey	Business Survey	Home Prices
US 74 in Union County (SE of Charlotte)	Yes	✓		✓	
S. College Rd in New Hanover Cty (Wilmington)	Mixed		✓	✓	✓
Hwy 55-Bypass (Holly Springs)	Yes	✓	✓	✓	✓
Hwy 24 in Spout Springs (NW of Fayetteville)	Yes		✓		
Hwy 17 in Leland (SW of Wilmington)	Yes			✓	
Cliffdale Rd and Cutchen Ln in Fayetteville	Yes			✓	
NC 49 and Stough Rd in Concord	Yes	✓		✓	
US 601 and Poplar Tent Rd in Concord	Yes			✓	
US 64 and Knollwood Rd in Apex	No			✓	

Remote Sensing and Economic Activity

Correlative studies often use cross sectional data to establish a relationship between two variables, but event studies aiming to establish causation commonly require pre- and post-event data. Such data is regularly available for financial studies projects but not for other projects owing to lack of central data collection, proprietary or private data, restrictions on data use, or simply the time frame data is available. When examining completed transportation projects, the lack of pre-installation data is a major constraint. To work around the problem, we turn to remote sensing (satellite) data as proxy for economic activity.

Remote sensing data is commonly used for geographic regions where reliable economic data is not available. Proville et. al. (2017) use a long-time horizon (1992-2013), but low resolution, imagery series to establish the relationship between night-time lights and economic output (GDP) at the national level. Chen and Nordhaus (Chen & Nordhaus, 2011) use a slightly shorter time series (1992-2008) to confirm the validity of remote sensing data as a proxy for activity at sub-national levels while Ghosh et. al. (2010) make use of improving sensor resolution to examine the contribution of informal economies to total economic activity. Henderson et. al. (2012) use remote sensing data to create sub-national growth estimates for African countries. Henderson et. al. (2018) build upon the prior work and use radiance data, rather than strictly lights, to allow for more variation and demonstrate the viability of the approach to lower light areas while avoiding the problem of high-light areas maxing out the remote sensors.

Inspired by the above research, we capitalize on improving sensor resolution and use the nighttime radiance to measure the economic impact of RCI installations on economic activity adjacent to the installations. Remote sensing is the process of studying an object or area without making physical contact with it. High-flying aircraft and satellites are usually used to obtain information about the earth, objects, and land. Optical remote sensing uses visible and near-infrared reflectance of solar rays. Solar radiance gets reflected by clouds, ground, ocean, river, buildings, etc. Satellite sensors pick up the reflected energy which is further converted to machine-readable files.

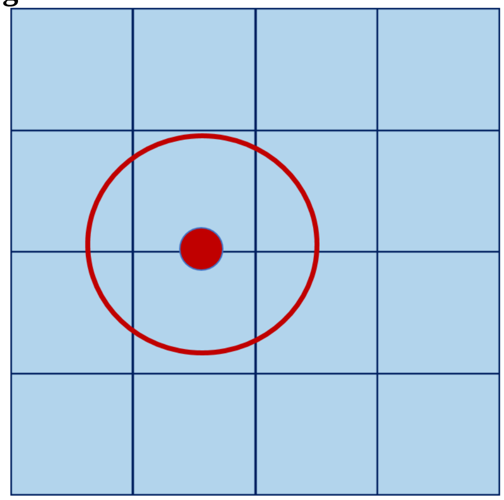
Spatial resolution refers to the details the satellite image contains. While temporal resolution refers to the frequency with which the satellite sensors revisit the same location on earth. For this project, we use images from the low-light imaging sensor, which is part of the VIIRS-DNB (Visible Infrared Imaging Radiometer Suite – Day Night Band) of the Suomi National Polar-orbiting Partnership (S-NPP) satellite. The S-NPP satellite was launched in 2011. The spatial resolution is approximately 750m. The temporal resolution is two times a day, one during the day and another during the night.

Google Earth Engine (GEE) contains a catalog of multi-petabyte satellite images. It is open and free for non-commercial use. Using an API written in Python, we access the data source. Compared to NASA earth data, using GEE helps save processing time rather than downloading the raw images, cleaning them, and processing them to glean the necessary data for analysis, thus saving valuable time and computing resources. We use the GEE product VIIRS-DNB monthly stray-light corrected image (NOAA/VIIRS/DNB/MONTHLY_V1/VCMSLCFG) for our analysis. The composite images from the repository provide monthly average radiance. The data from this product is corrected for stray light but not aurora, fires, boats, and temporal lights.

The nighttime satellite image sensors should only receive light energy from illumination from the intended sources. However, the radiance can be affected by sun rays even when the sun is under the horizon at the study area. This stray light contaminates the radiance values. The VIIRS product that we use for analysis corrects the problems caused due to stray lights. The other sources of contamination of the radiance values are aurora (polar lights), lights emitted by fishing boats, forest fires, and temporal lights (non-permanent lights like entertainment lights, strobe lights, lighthouses, festival lights)

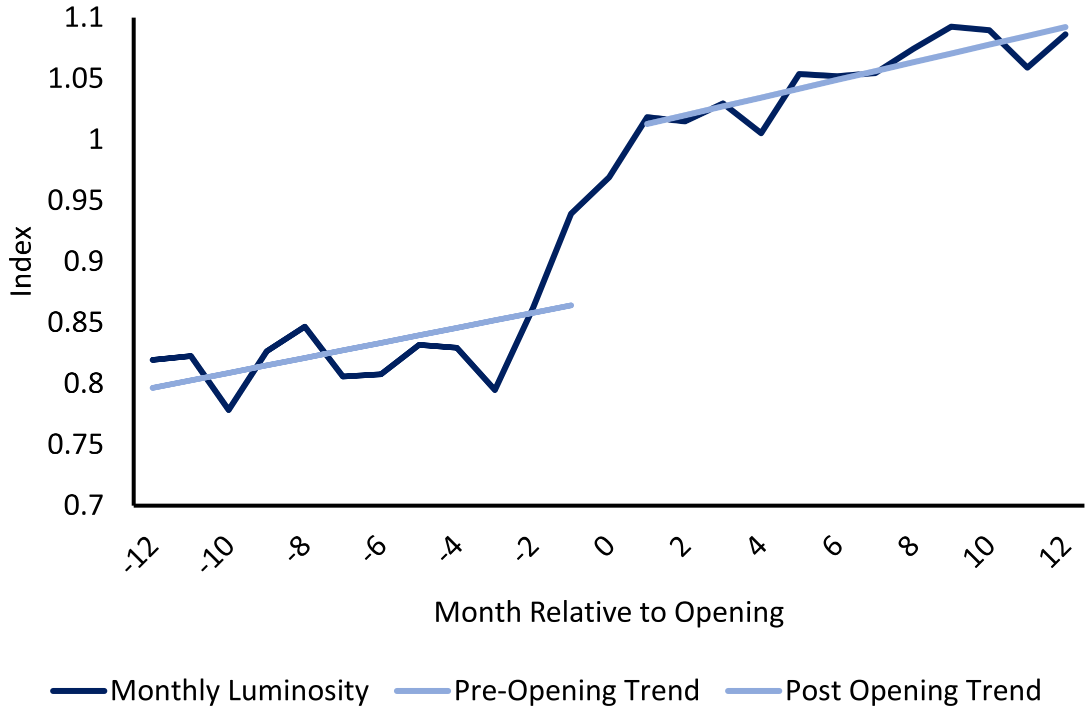
Monthly satellite data is available as an average over the month of nighttime brightness for each area, defined as a “pixel”, in the satellite imagery. This is analogous to taking a black and white photo with a digital camera and zooming in until the image pixelates out, turns into gray shaded squares, and then putting a number to how bright each square is. To get a monthly average, take the same photo each day and then average the brightness for each locationally consistent pixel across a month’s worth of photos. Each pixel in the S-NPP-CSO data is 463m square with predetermined boundaries, making small parcel analysis difficult. For reference, think of the pixel size as roughly equivalent of a Walmart Supercenter Development site. To overcome the pixel size problem, we focus on larger developments, grocery stores or larger, and use multiple measurements for each development examined. We use three approaches, a single point, a point with a 100m buffer and a point with a 500m buffer. For the single point, the data contains the radiance value of the given GPS coordinate where a development is located. However, this could lead to error as the single point may be near the edge of a pixel and lead to a radiance measure for an area adjacent to the area of interest. The two measures that include a buffer around the point trade off some locational precision for coverage certainty as the buffer increases the certainty that a measure includes pixels completely covering the parcel. The 100m and 500m buffer versions of the radiance measurement is a weighted average of the pixels where the majority of the pixel is contained within the area of interest, in our case a circle of 100m and 500m radius centered on the development. Figure 2 shows a diagram of a point with a buffer and how a grid of pixels would be averaged to provide a radiance measurement for the point.

Figure 2: Point with Buffer on Pixel Grid



To help validate the average radiance data as a valid measure of activity at the parcel level, pre- and post-opening radiance data for Walmart Neighborhood Markets and Walmart Super Centers were examined to verify a structural break at the time of opening. Walmart locations are appropriate for such an exercise as opening dates are often available and, importantly, they are typically developed on greenfield sites minimizing the confounding issue of previous land-use type. In North Carolina, there have been 46 locations where the radiance data is available (since 2014), 38 Neighborhood Markets and eight Supercenters. Figure 3 shows a graph of the seasonally adjusted, average pre and post opening radiance data, indexed to the month of opening, using a 100m buffer around the facilities coordinate point. Trend lines have been fitted for both pre and post periods with the gap between them representing the effect of the facilities opening.

Figure 3: Pre-Post Radiance of Walmart Openings



While the pre-post difference is apparent in Figure 3, the difference between the two is statistically significant at the 99% level strongly supporting the suggestion of a pre-post difference in average radiance. However, the data presented in Figure 3 shows an average radiance for all the Walmart sites. Table 2 presents the pre-post average radiance comparison for individual sites. The table compares pre and post opening radiance data for individual facilities and pre-post differences are presented as the number of facilities that had a statistically significant increase in radiance following the opening of the facility, a statistically insignificant increase, a statistically insignificant decrease, and a statistically significant decrease. In addition, the counts of facilities with significant differences are broken out as the total for all locations (and percentage of facilities), for Neighborhood Markets (and percentage of neighborhood markets), and for Super Centers (and percentage) as shown in three pairs of columns. For robustness, the analysis is conducted using three different buffer ranges: no buffer, 100m, and 500m. The data with no buffer analyzes the pixel in which a facility's coordinate point is located, the 100m and 500m buffers use a weighted average of the pixels that overlap a circle with the buffer size as a radius extending from the facility's coordinate point. The results are substantially the same for all buffer sizes except that the median increase in radiance decreases as the buffer radius increases, as one would expect since the measure is capturing a larger area diluting the effect of the facility.

Table 2: Radiance Change 12 Months Pre-Site Development to 12 Months Post Site Development

	All Locations		Neighborhood Markets		Super Centers	
	Count	%	Count	%	Count	%
No Buffer						
Sample Count	46		38		8	
Median increase in radiance	21.9%		16.6%		45.9%	
Significantly Increase	32	69.6%	24	63.2%	8	100%
Increase	10	21.7%	10	26.3%	0	0
Decrease	4	8.7%	4	10.5%	0	0
Significantly Decrease	0	0%	0	0%	0	0
100m Radius						
Sample Count	46		38		8	
Median increase in radiance	19.8%		16.1%		44.6%	
Significantly Increase	33	71.7%	25	65.8%	8	100%
Increase	9	19.6%	9	23.7%	0	0
Decrease	4	8.7%	4	10.5%	0	0
Significantly Decrease	0	0%	0	0%	0	0
500m radius						
Sample Count	46		38		8	
Median increase in radiance	+14.7		+11.3%		+27.0%	
Significantly Increase	32	69.6%	24	63.2%	8	100%
Increase	10	21.7%	10	26.3%	0	0
Decrease	4	8.7%	4	10.5%	0	0
Significantly Decrease	0	0%	0	0%	0	0

All data is seasonally adjusted to account for regular fluctuations in radiance.

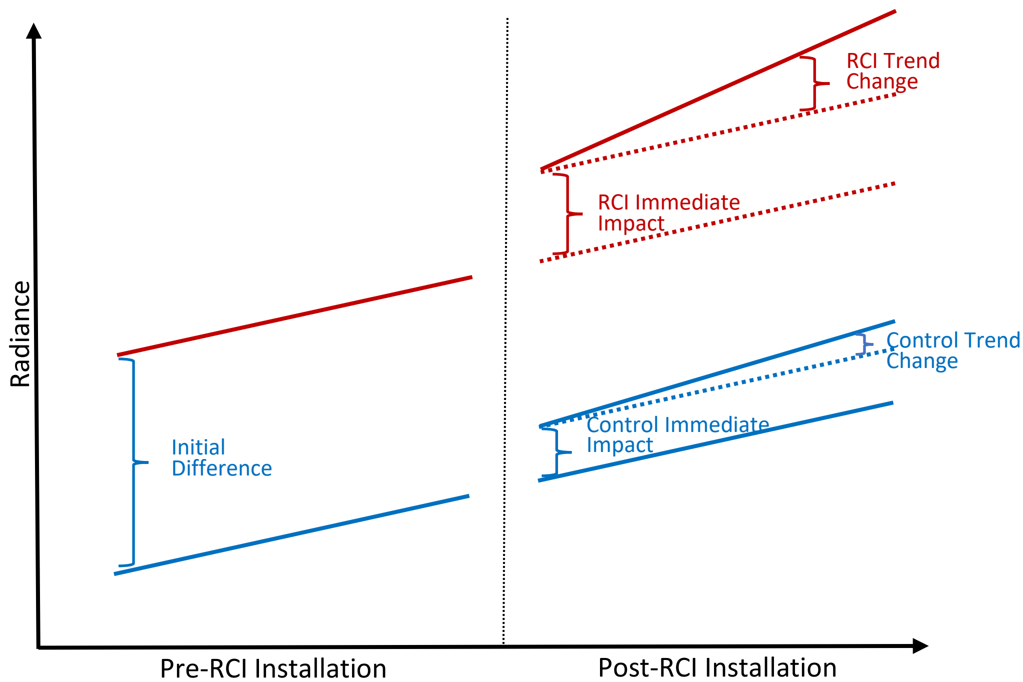
A priori, one would expect that the construction and opening of a facility would increase the radiance of a project site, an expectation that is confirmed by the increases in radiance of approximately 90% of the Walmart sites as shown in Table 2. However, not all sites saw a significant increase in radiance. For example, looking at the measure with no buffer (using only the pixel the where coordinate point is located) 10 sites' radiance increased but by an insignificant amount and 4 sites saw a decrease, also by an insignificant amount. Disaggregating the sites into neighborhood markets and super centers suggests that the insignificant results may be driven by too small a facility for the increase in radiance to consistently show up in the data. This suggestion is supported by the median increase in radiance of the neighborhood markets increased by 16.6% while radiance of the super centers increased by 45.9%. These results suggest that the neighborhood markets are not large enough to consistently register a significant increase in radiance, a suggestion further supported by the smaller median increases in radiance as the area of interest (circle around the point) or buffer range increases.

The background and empirical analysis above provide a foundation for analysis of activity surrounding road improvement sites but offers a cautionary note that analysis needs to be conducted for sizeable developments to reach consistent results and should include at least a year of pre and post radiance data to overcome noise in the data.

Intersection Improvement Analysis with Remote Sensing

One approach to examining the effect of intersection improvements is a single series, interrupted time series analysis approach. The ITS approach has a long history in program analysis and involves the analysis of a series of data examining differences in pre and post trends as well as levels of the data to see if they increased or decreased. However, because the installations of reduced conflict intersections are endogenous, meaning they are often installed in growing areas, a single series approach makes it difficult to tell whether it was the RCI that caused an affect or the growth, or some other unobserved variable. To control for the unobserved variables, we take a multi-series, interrupted time series approach to analysis, using one series at the "treated" series and the other as a control. The approach is shown visually below in Figure 4.

Figure 4: Multi-Series Interrupted Time Series



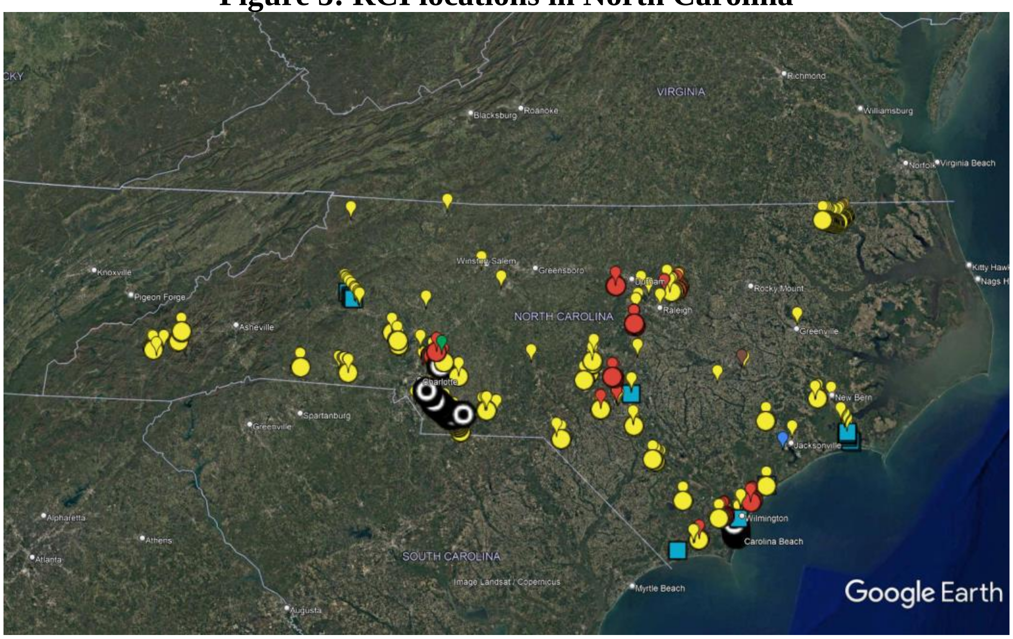
In a multi-series, interrupted time series approach, two series with parallel pre-event trends are compared to yield estimates of two effects: an initial effect and a change in trend. Our analysis focuses on the change in trend as evidence of a short-term effect and ignores the initial effect. We control for changes in the level of activity following the installation of an RCI but we are not convinced the initial effect is reliable as it could be partially driven by disruptions, or recovery, from construction. Instead, we focus on the change in trend over the two-year post-installation period to provide directional evidence of the impact on economic activity.[1]

The analysis presented below examines the two years prior to the RCI installation period and the two years following, consistent with Schneider (2019). The period of installation is dropped from the analysis to focus on the effects of the design, not the construction disruptions.

Road Improvement Site Identification

Locations used in the remote sensing analysis presented below were selected from "Reduced Conflict Intersection (RCI)" type improvements located in the state of North Carolina. Because the analysis is conducted as a pre-post examination of activity around an improvement, only improvements to existing roads and intersections were eligible for analysis as RCI street design incorporated into new roads, commonly bypasses, do not have the requisite pre-installation data needed for analysis. The UNCW research team examined a comprehensive database of RCI locations compiled from an NCDOT database as well as supplemental sites located by the UNCW Research Team. A map of the RCI locations is presented in Figure 5.

Figure 5: RCI locations in North Carolina



RCIs tend to follow one of two patterns, they are either clustered in a corridor or individual improvements. Many of the corridors were installed as part of initial construction, such as those on Hwy 401/Louisburg Rd in Wake County, or as part of expansion projects such as Hwy 601 southeast of Monroe in Union County. Individual improvements are more commonly intersection improvements or redesigns unique to the

[1] These effects should not be interpreted to be ongoing as one would expect that after an initial adjustment period a new level of equilibrium will be reached, and activity growth or decline will not continue in a linear fashion indefinitely.

individual intersection and proximate traffic flow and conditions. The set of intersections for possible study includes all “RCI type” improvements defined as improvements that require at least some traffic to do a U-turn for a change in the direction of travel (i.e., a vehicle may make a right followed by a U-turn to effectively make a left) or to cross an arterial road (a vehicle may have to turn right, make a U-turn, and then another right to continue on the original road.)

To arrive at the final two intersections and one corridor for remote sensing analysis, the research team filtered the RCIs by installation dates after 2014, and for population density greater than 500 people per square mile. Once that subset of RCI locations was identified, each was examined for suitability including the requirement of a sizeable commercial development adjacent to the RCI as well as a suitable control development in reasonable proximity. In addition, the individual circumstances of the improvement were also considered. For example, one RCI type improvement was made on Carolina Beach Rd as a median cut to allow traffic to turn left into a secondary ingress and egress point on a Walmart development. However, the improvement allowed more traffic to turn into the development but did not alter the ability of traffic to leave the development. Because the improvement was minor and did not affect the primary entrance and exits the improvement was not selected for analysis. Two intersections and one corridor were ultimately selected as appropriate locations for study, Hwy 55-Bypass and Avent Ferry Rd in Holly Springs, NC, NC49 and Stough Road in Concord, NC, a corridor of intersections on US74 in Union County, southeast of Charlotte, NC.

Matched Comparisons - Commercial Development

To examine the effects of RCI type intersection design on commercial development, four intersections were identified with RCIs installed between 2016 and 2019 allowing for a pre-post analysis of four types of business: a large multitenant center, medium sized grocery anchored center, a big box general merchandise store, and a big box home improvement store. The intersections of interest are listed in Table 3.

Table 3: Commercial Development Intersections for Analysis

Location	Intersection	Approximate Date of Improvement	Development Type
Holly Springs, NC	NC55-Bypass and Avent Ferry Rd	January 2017	Multitenant Center
Indian Trail, NC	US74 and Faith Church Rd	September 2018	Grocery Anchored Center
Indian Trail, NC	US74 and Unionville Indian Trail Rd	February 2019	Big Box General Merchandise Store
Indian Trail, NC	US74 and Wesley Chapel Stouts Rd/Sardis Church Rd	June 2018	Big Box Home Improvement Store

Multitenant

Improved Intersection: NC 55-Bypass and Avent Ferry Rd

The intersection of NC 55-Bypass and Avent Ferry Rd is located southwest of Holly Springs, NC, which is southwest of Raleigh, NC. NC 55-Bypass is a four-lane highway that skirts around the city of Holly Springs and serves as the location of suburban style commercial development including multi-tenant strip centers and big box stores while downtown Holly Springs serves as the home for more urban development with a focus on density and walkability. The NC 55-Bypass is a four-lane road with reduced conflict intersections placed at the majority of the intersections, however, not all the RCIs were built at the same time. The analysis below focuses on the intersection of Avent Ferry Rd. and NC 55-Bypass. Figure 6 presents an overview of the improved intersection's location while Figure 7 presents a visual of the improvements to the intersection's design. The intersection was improved in 2017 from a conventional intersection with left turn lanes to one with a reverse RCI design such that traffic on Avent Ferry may turn left or right but cannot proceed straight through the intersection. Thus, traffic from Holly Springs, inside the bypass, must turn, travel down the bypass and then turn again to exit the bypass in order to enter the commercial development on the outside of the bypass. It is no longer possible to go straight across the bypass and enter the commercial development on the outside. However, the unique design of the intersection means that no U-turns are required for vehicles entering the developments and the number of light cycles has been reduced. Through movement on Avent Ferry Road still requires a U-turn as with other RCIs.

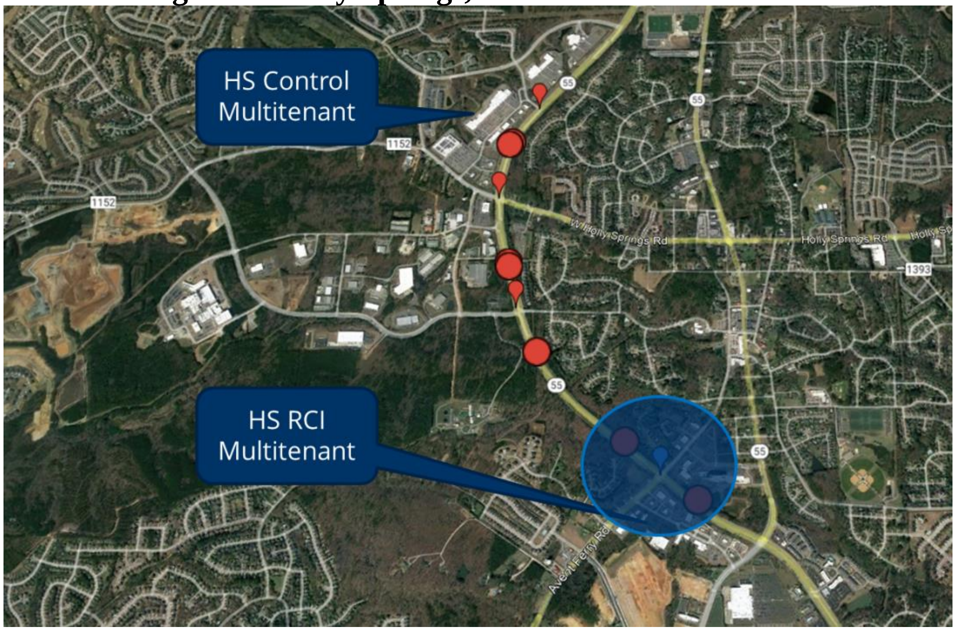
Figure 6: NC 55-Bypass and Avent Ferry Road Pre-Improvements

Figure 7: NC 55-Bypass and Avent Ferry Road Post-Improvements

Matched Developments

Using radiance data, the activity surrounding the intersection is analyzed using a matched pair comparison of multitenant developments located on the outside of NC 55-Bypass. Each has RCI design intersections in front of the developments, but one was installed prior to the analysis period and serves as a control center versus the center adjacent to the RCI installed during the sample period, the treated center. A visual representation of the centers' locations is shown in Figure 8. The "RCI" notation in location title indicates the location of interest versus the "control."

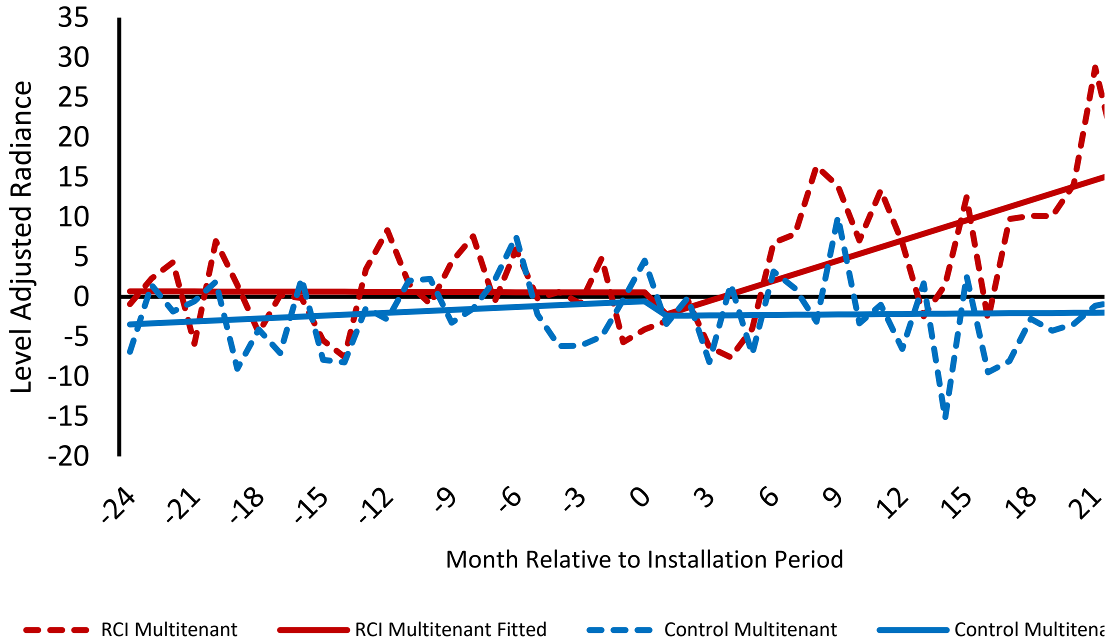
Figure 8: Holly Springs, NC Multitenant Centers



Matched Pairs Activity Comparison

Activity adjacent to the intersections of interest was compared using radiance measures for the pixel region containing each development's coordinate point. A graph of the radiance over time is shown in Figure 9. The dashed red line presents the radiance data for the HS RCI Multitenant while the solid red line is a fitted line over the two years prior and two years post installation with the installation period omitted. The fitted line is estimated and fitted to allow for different levels, intercepts, and slopes pre and post installation. The blue lines are the equivalents for the HS Control Multitenant.

Figure 9: Multitenant Pre-Post Comparison



A visual examination of Figure 9 suggests a relative increase in activity at the multitenant center adjacent to the treatment RCI following the installation. A more detailed statistical analysis indicates the growth in activity is significantly higher following the installation for the RCI multitenant center than the control multitenant center. The multi-series, interrupted time series regression results are shown in Appendix B.

When interpreting the growth at the RCI Multitenant center, one needs to be careful to consider the period of analysis and not extend the growth trend indefinitely as activity growth is likely to flatten following the initial adjustment period. Nevertheless, activity around the RCI Multitenant was, on average, 22% higher following the RCI installation.

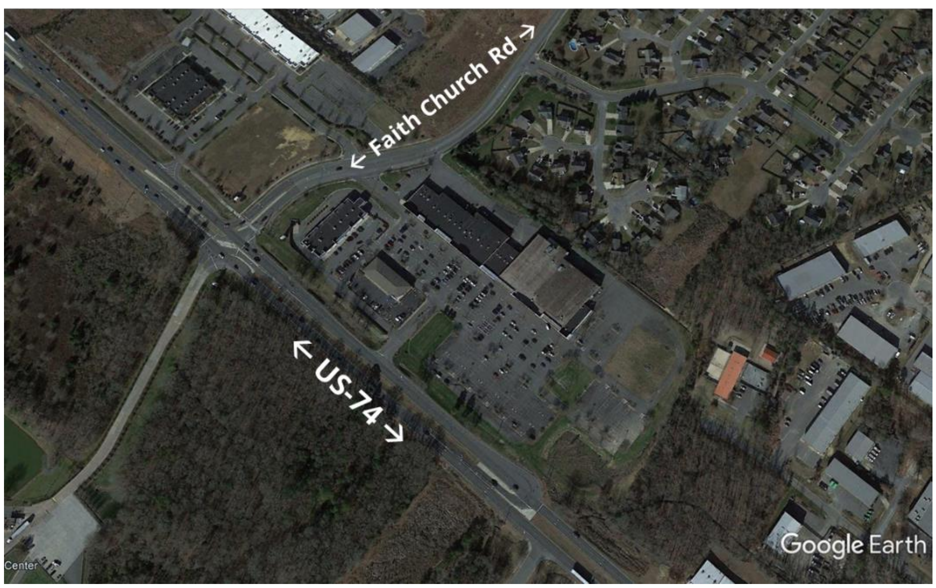
Grocery

Improved Intersection: US 74 and Faith Church Rd

The intersection of US 74 and Faith Church Rd is located in Indian Trail, NC, an area on the southeast periphery of Charlotte, NC. US 74 is a four lane, arterial with a reputation for traffic lights and congestion as drivers approach Charlotte. As part of ongoing improvements, NCDOT has redesigned several intersections along the US 74 corridor to include RCI designs. The intersection of US 74 and Faith Church Rd is a three-way intersection, for all intents and purposes, as the fourth leg of the intersection is a long driveway to a warehouse facility. The intersection was improved in 2018 to limit traffic on Faith Church Rd from turning left onto US 74 such that traffic southbound on Faith Church Rd must first turn right, and then do a U-turn to head east on US 74. A pre-improvement aerial of the intersection is presented in Figure 10 and a post improvement aerial is presented in figure 11.

Figure 10: US74 and Faith Church Rd, Pre-Improvement

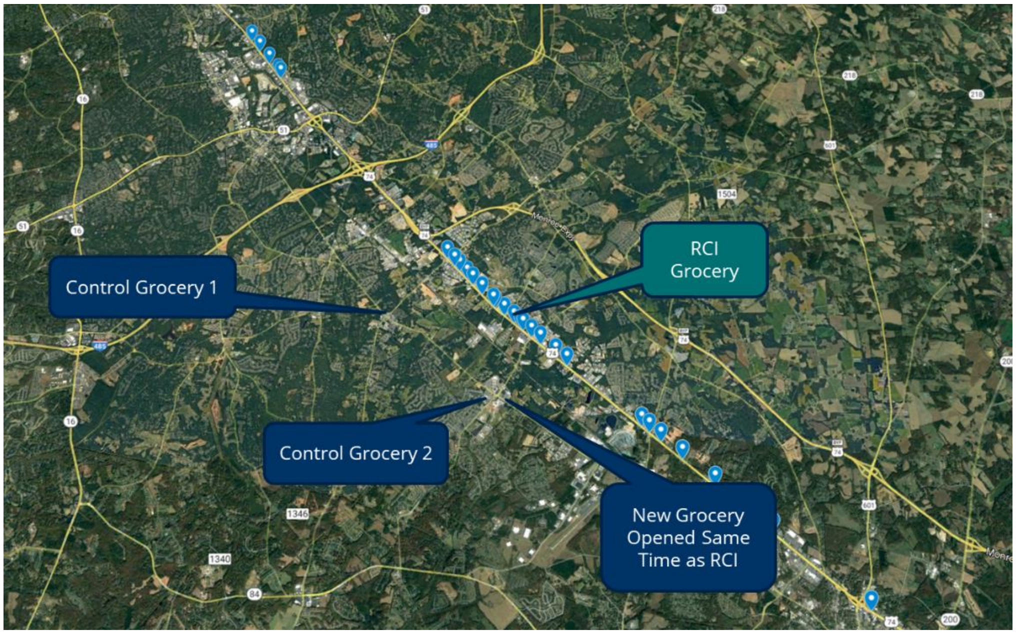
Figure 11: US74 and Faith Church Rd, Post-Improvement



Matched Developments

The commercial development located at the intersection of US 74 and Faith Church Rd is a grocery anchored center and is matched to two other grocery anchored developments as shown in Figure 12.

Figure 12: RCI Grocery Store and Control Stores along US74 Development Corridor

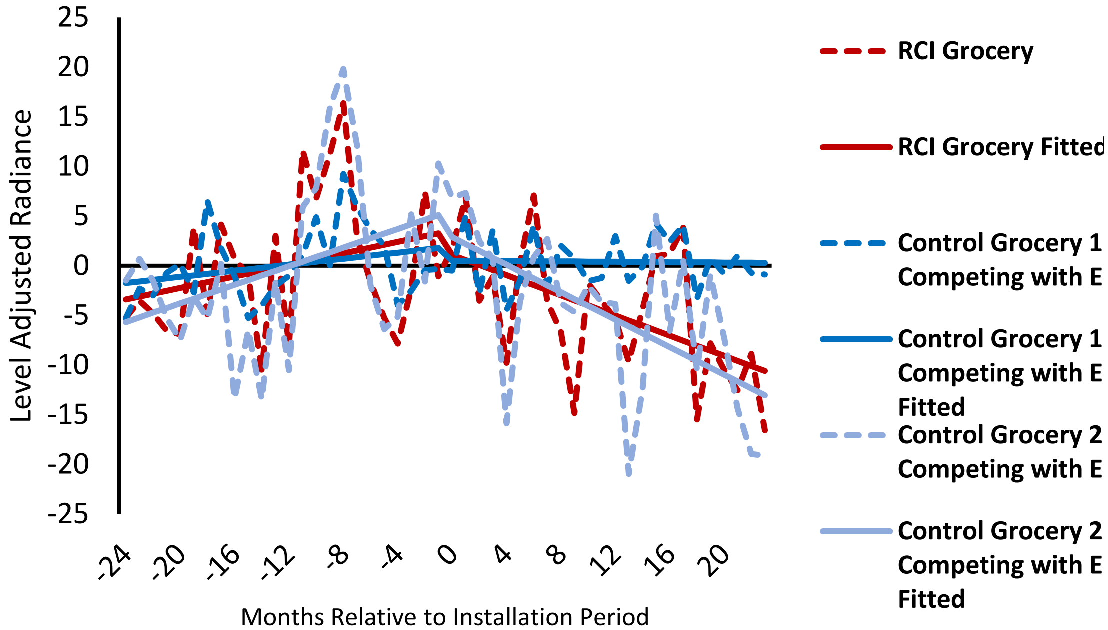


Examining Figure 12, we clearly see the corridor of RCI improvements denoted with blue pins and the RCI Grocery is located in the middle of the image. Control Grocery 1 is another store of the same grocery chain as the one located at the RCI intersection. However, comparisons of locations from the same chain may be inappropriate as the opening of a new grocery store around the time of RCI installation makes such a comparison difficult to glean any insights from. Because of the new grocery opening, a second control grocery, from a different chain but located in closer proximity to the competitor entrant and the RCI Grocery is also used in comparison.

Matched Pairs Activity Comparison

Using the radiance data for the points of intersection containing each development's coordinate point, we see the activity near the RCI Grocery declines following the period when the RCI was installed. However, this same period corresponds to the opening of an additional competitor and comparing RCI Grocery to Control Grocery 2 we see the two follow a similar pattern. Statistically, while the RCI Grocery sees negative growth compared to Control Grocery 1, the RCI is statistically no different than the Control Grocery 2 location also subject to competition from the entry of a new competitor in the market. (Full Multi group interrupted time series results are presented in Appendix B.) A graphical version of the statistical analysis is presented in Figure 13.

Figure 13: Grocery Center Pre-Post Comparison



While the decrease in RCI Grocery activity is evident in the red lines (dashed lines are measured radiance and solid lines are the fitted trend) versus Control Grocery 1, the relatively horizontal navy-blue line, the comparison of the RCI Grocery to Control Grocery 2, both of which are subject to competition from the new competitor, the trends are statistically indistinguishable. Individual trend figures and full regression results are included in Appendix B. It is worth noting, the trend for Control 2, geographically closer to the competitor, declines ever so slightly faster than the RCI Grocery, although not significantly.

We interpret these results to suggest a null effect of the RCI under weaker assumptions and an indeterminate result under stronger assumptions. If one were to assume the entrant of the competitor affects the RCI Grocery and Control Grocery 2, but has little effect on Control Grocery 1, then it is reasonable to state that the RCI had no significant effect on economic activity. If one were to assume the competitor entrant may also be competing with the Control Grocery 1 then the results would be considered indeterminate. The null effect of the RCI installation seems the most appropriate conclusion under reasonable assumptions.

Big Box General Merchandise

Improved Intersection: US74 and Unionville Indian Trail Rd

The intersection of US74 and Unionville Indian Trail Rd is located in Indian Trail, NC, an area on the southeast periphery of Charlotte, NC. US74 is a four lane, arterial highway with a reputation for traffic lights and congestion as drivers approach Charlotte. As part of ongoing improvements, NCDOT has redesigned several intersections along the US 74 corridor to include RCI designs. The intersection of US74 and Unionville Indian Trail Rd is a four-way, non-right-angle intersection. The intersection was improved in 2019 to require traffic on Unionville Indian Trail Rd to turn right onto US 74 such that traffic wishing to turn left onto, or cross over, US74 must turn right, and then do a U-turn to return to the intersection and either continue along US74 or turn right to continue on Unionville Indian Trail Rd. A pre-improvement aerial of the intersection is presented in Figure 14 and a post improvement aerial is presented in figure 15.

Figure 14: US74 and Unionville Indian Trail Rd, Pre-Improvement

Figure 15: US74 and Unionville Indian Trail Rd, Post-Improvement

Matched Developments

The commercial development located at the intersection of US74 and Unionville Indian Trail Rd is a large discount department store which we will refer to as a Big Box General Store. The store is matched to four other big-box general stores located along the US74 corridor, with the exception of Control Big Box General Store 1 which is located slightly off the corridor. The locations of the control stores are shown in Figure 16.

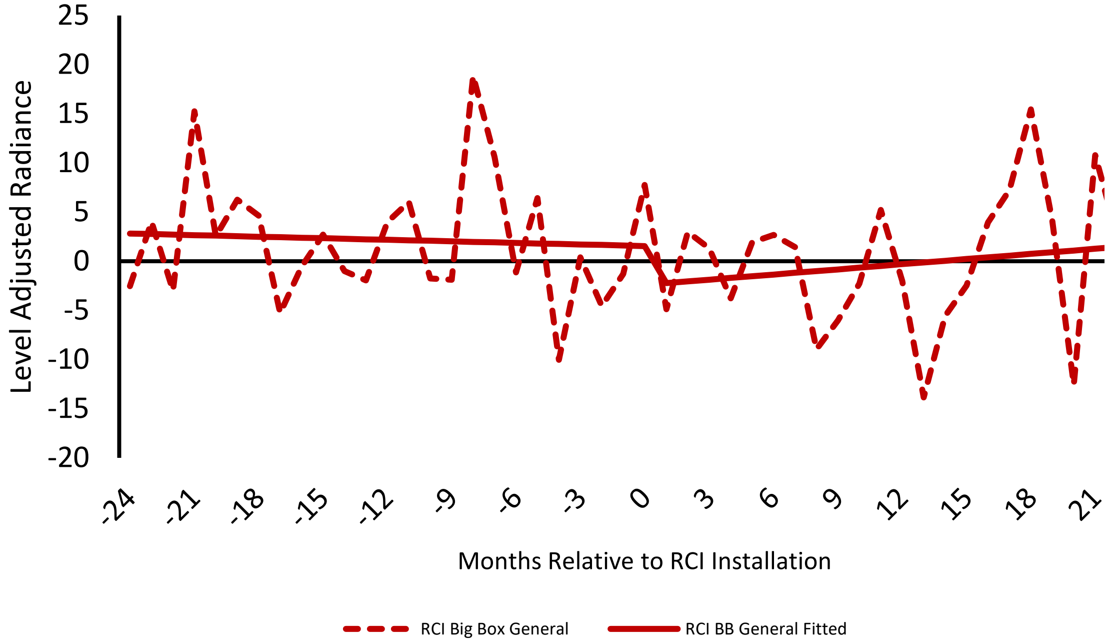
Figure 16: RCI Big Box General Store and Control Stores on US74

Examining Figure 16, we clearly see the corridor of RCI improvements denoted with the blue pins and RCI Big Box General Store is located in the middle of the image. Control Big Box General Store 1 and Control Big Box General Store 4 are stores of the same big box chain as the one located at the RCI intersection while Control Big Box General Store 2 and Control Big Box General Store 3 are locations of a competitor. It is worth noting that control stores 1 and 2 are both located considerably closer to Charlotte and may face slightly different growth dynamics than control stores 3 and 4 are further out on the periphery of the Charlotte region.

Matched Pairs Activity Comparison

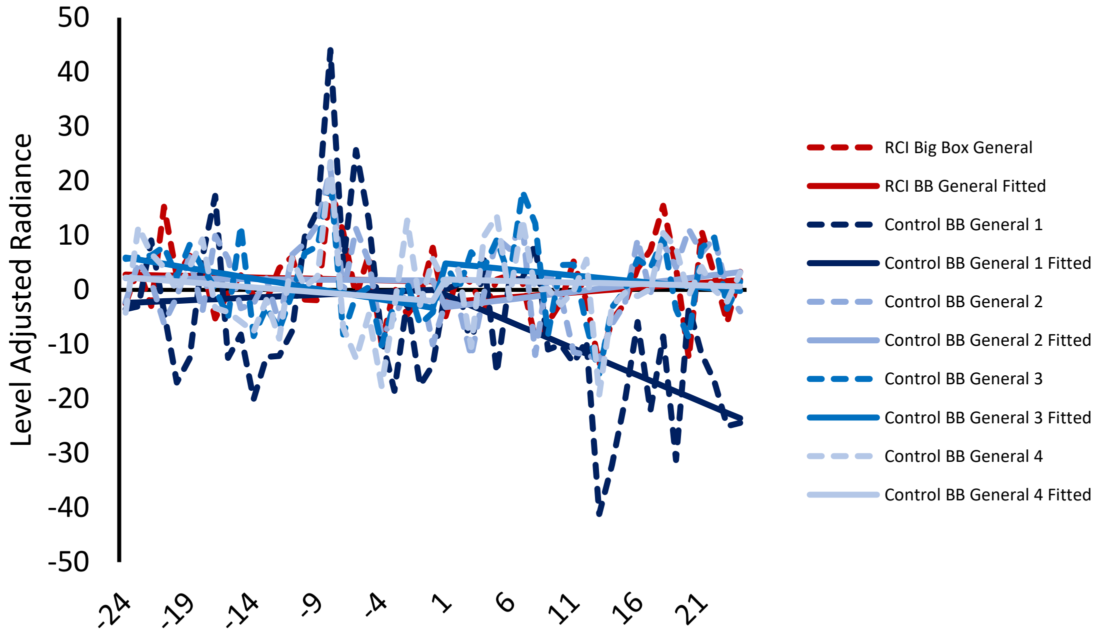
A single series examination of the radiance data for the RCI Big Box Store suggests the activity near the RCI Big Box General Store following the installation of the RCI is statistically indistinguishable from the pre installation trend, as shown in Figure 17.

Figure 17: RCI Big Box General Store Radiance



The trend changes from marginally negative pre-installation to marginally positive post installation, albeit at a slightly lower average level, but the differences are not statistically significant. However, to validate the single series result, we compare the RCI Big Box General Store to four other controls. Figure 18 presents a graph of the RCI Big Box General Store versus four other control stores. Individual RCI store v. control store figures are presented in Appendix B.

Figure 18: RCI Big Box General Merchandise v. Control Stores



While the majority of the big box stores see no change in their pre and post installation trend, for the RCI store or the control stores, Control 1 does see a significant decline in activity following the period when the RCI was installed in front of the RCI Big Box General Store but this decline does not correspond to a decline or even a significant increase in activity at the RCI Big Box General Store and the research team believes this decline to be caused by other factors. There is no statistical evidence of a change in activity for the RCI Big Box General Store following the installation of an RCI improvement. A table of regression results for the RCI location versus all four control locations is presented in Appendix B.

Big Box Home Improvement Store

Improved Intersection: US74 and Sardis Church Rd/Wesley Chapel Stouts Rd

The intersection of US74 and Sardis Church Rd (Wesley Chapel Stouts Rd south of US74) is located in Indian Trail, NC, an area on the southeast periphery of Charlotte, NC. US74 is a four lane, arterial highway with a reputation for traffic lights and congestion as drivers approach Charlotte. As part of ongoing improvements, NCDOT has redesigned several intersections along the US 74 corridor to include RCI designs. The intersection of US74 and Sardis Church Rd is a four-way, right angle intersection. The intersection was improved in 2018 to require traffic on Sardis Church to turn right onto US74 such that traffic wishing to turn left onto, or cross over, US74 must turn right, and then do a U-turn to return to the intersection and either continue along US74 or turn right to continue on Unionville Indian Trail Rd. A pre-improvement aerial of the intersection is presented in Figure 19 and a post improvement aerial is presented in Figure 20.

Figure 19: US74 and Sardis Church Rd/Wesley Chapel Stouts Rd, Pre-Improvement

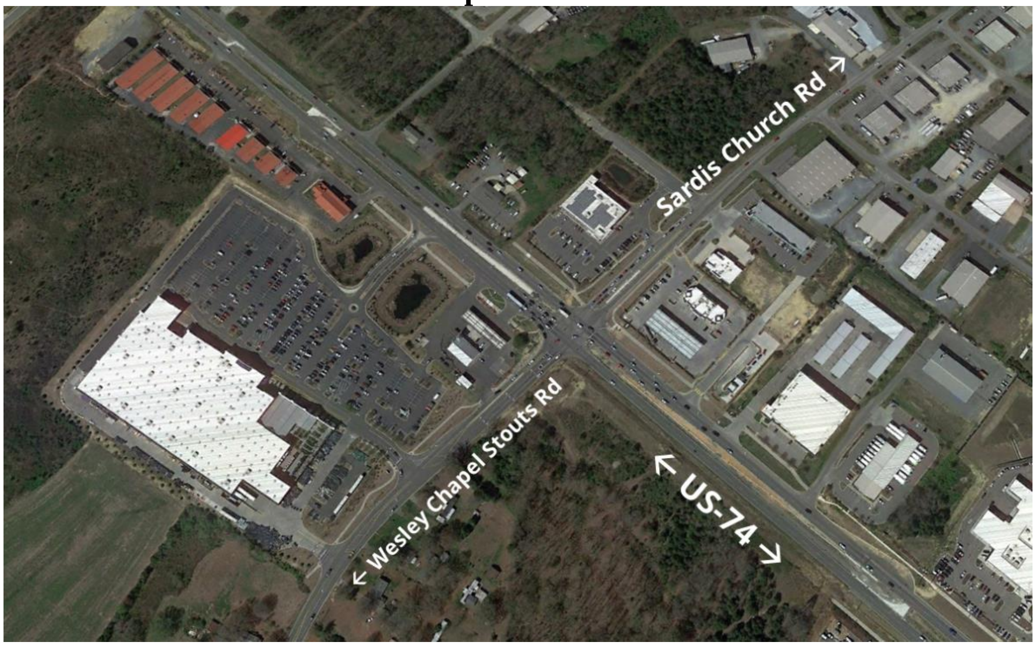


Figure 20: US74 and Sardis Church Rd/Wesley Chapel Stouts Rd, Post-Improvement

Matched Developments

A big box style home improvement store located at the intersection of US74 and Sardis Church Rd/Wesley Chapel Stouts Rd, an intersection improved with an RCI style design, is matched to three other big box home improvement stores located along the US74 corridor for comparison. The locations of the control stores are shown in Figure 21.

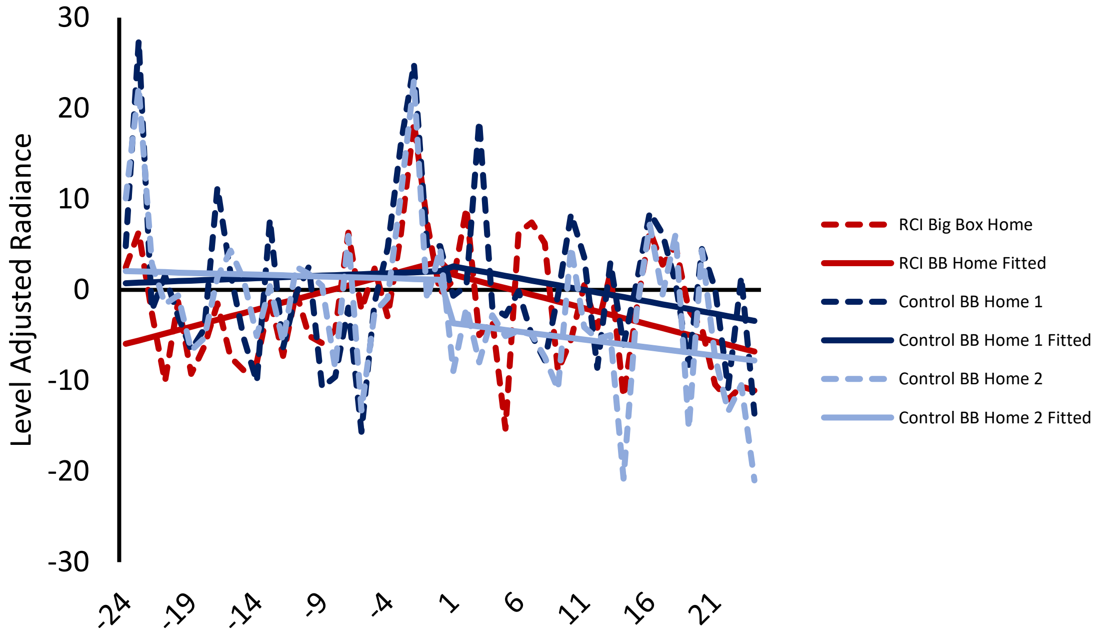
Figure 21: RCI Big Box Home Store and Control Stores on US74

Figure 21 shows the US74 corridor with RCI improvements, denoted by the blue pins, with four big-box home improvement stores located along the corridor. Control Big Box Home Stores 1 and 3 are locations of the same chain while Control Big Box Home Store 2 is a similar sized store of a competitor. In addition, the RCI Big Box Home Store was also matched to five other suburban big box home improvement stores on the southeastern quadrant of Charlotte, not shown in Figure 21.

Matched Pairs Activity Comparison

Comparisons of the RCI Big Box Home Store are confounded as the home stores have a larger draw area than some other establishments, such as grocery stores, increasing the likelihood that each store is affected by different factors within their customer bases. The Control Big Box Home Store 1, RCI Big Box Home Store, and Control Big Box Home Store 3 are evenly spread along a 12 stretch of US74 and trends in activity levels at Control 3 are likely different than at Control 1. Owing to such a large geographic distance between the locations, we include more control locations, albeit at the price of an even larger examination area. Figure 22 presents the graph of activity at RCI Big Box Home Store vs. control stores 1 and 2.

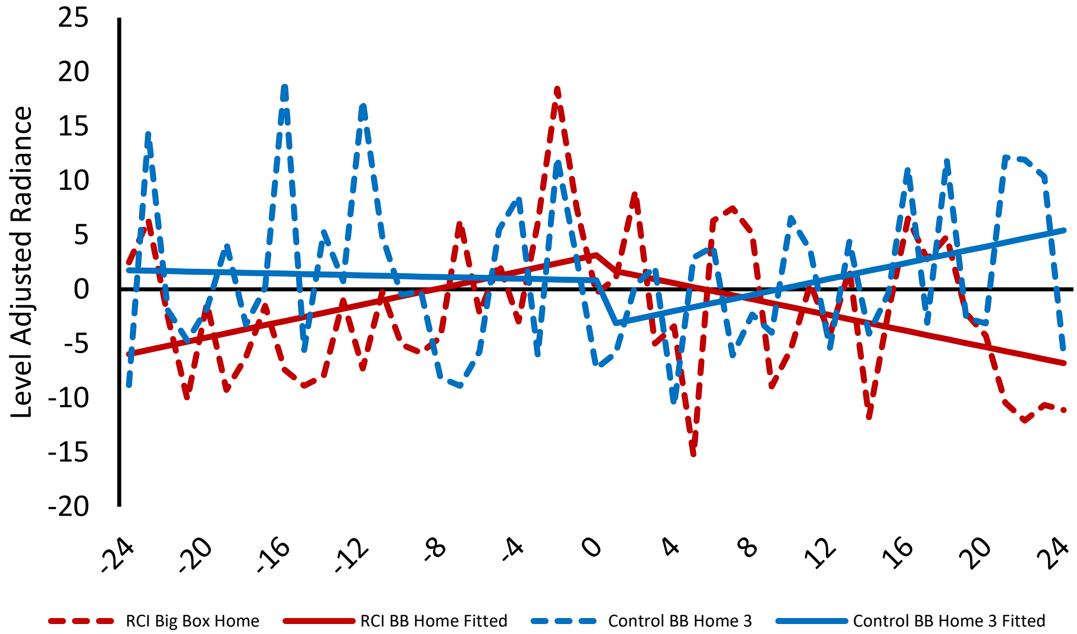
Figure 22: RCI Big Box Home Store v. Control Stores 1 and 2



Prior to the installation period, activity at control stores 1 and 2 was mostly flat but activity at RCI Big Box Home Store was increasing. The difference in pre-installation growth trend was not significant for the RCI Big Box vs control 1 but RCI Big Box had a significantly stronger growth trend than control store 2 pre-installation. Following the installation period, activity at all three stores declined, likely reflecting a slowdown in net county-to-county migration the year prior to installation. With fewer people moving into the county and building permits flat through 2019 in Union County, home improvement store activity slowed. However, the comparison of the RCI Big Box Home Store to Control Big Box Home Store 3 provides a counterfactual.

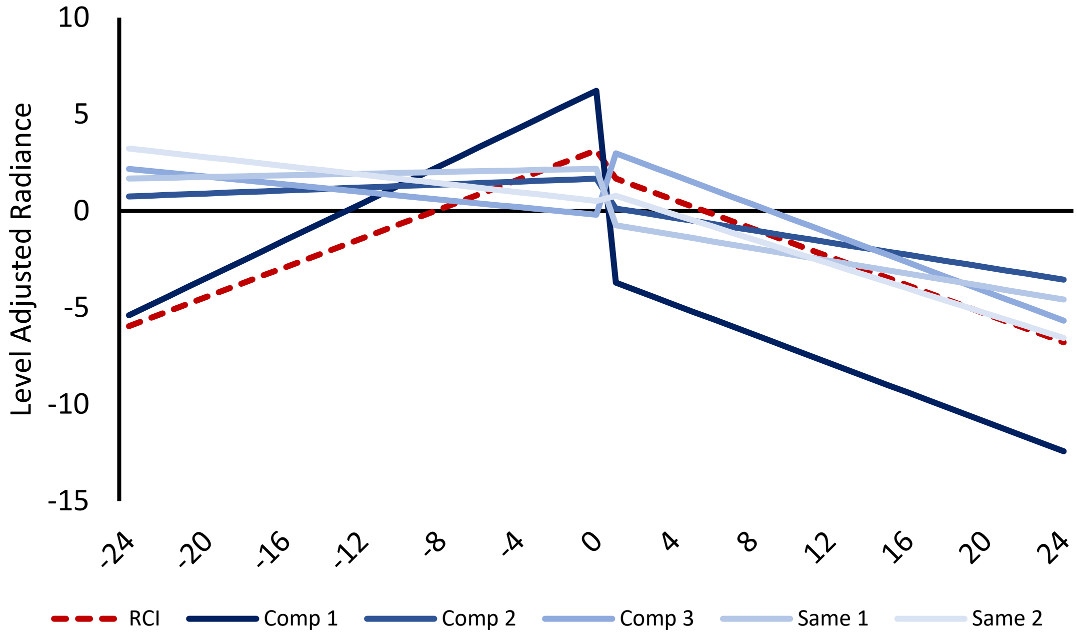
Control Big Box Home Store 3's pattern of activity runs counter to the other locations with growth picking up following the RCI installation period and at a location approximately 5 miles away, as shown in Figure 23.

Figure 23: RCI Big Box Home Store v. Control Store 3



The difference in growth trends likely reflects the outward shift geographically of development activity as additional analysis suggests that activity levels at the stores may well match the outward expansion of the Charlotte area. Thus, the research team is skeptical that the RCI had any notable impact on the home improvement store. However, to further validate that RCI Big Box Home Stores slowing sales in the 2018-2020 period we its trend versus five other home improvement stores on the southeastern corner of Charlotte. Figure 24 shows the fitted trends for these five stores versus the RCI Big Box.

Figure 24: RCI Big Box Home Store v. Other SE Charlotte Locations



Comp 1, Comp 2, and Comp 3 are all store locations of a similar but competitor chain while Same 1 and Same 2 are locations from the same chain. RCI is located along the US74 and the five comparisons are all located along other corridors on the southeast side of Charlotte.

There is no significant difference in the post period trend between the RCI Big Box Home Improvement Store and the other five suburban locations. Full regression results are presented in Appendix B. Examining the post installation period, it become more apparent that the Control Big Box Home Store 3 above is the outlier of the home stores as the other seven stores (two controls on US74 and five others from around the southeast side of Charlotte) saw activity slow in the two-year post period.

Matched Comparisons - Industrial Development

To examine the effects of RCI type intersection design on industrial development, two intersections were identified with three small industrial parks located in close proximity. The intersections of interest are listed in Table 4.

Table 4: Commercial Development Intersections for Analysis

Location	Intersection	Approximate Date of Improvement
Indian Trail, NC	US74 and Wesley Chapel Stouts Rd/Sardis Church Rd	June 2018
Concord, NC	NC49 and Stough Rd	March 2017

Industrial Parks 1 and 2

Improved Intersection: US74 and Sardis Church Rd/Wesley Chapel Stouts Rd

The intersection of US74 and Sardis Church Rd (Wesley Chapel Stouts Rd south of US74) is located in Indian Trail, NC, an area on the southeast periphery of Charlotte, NC. US74 is a four lane, arterial highway with a reputation for traffic lights and congestion as drivers approach Charlotte. As part of ongoing improvements, NCDOT has redesigned several intersections along the US 74 corridor to include RCI designs. The intersection of US74 and Sardis Church Rd is a four-way, right angle intersection. The intersection was improved in 2018 to require traffic on Sardis Church to turn right onto US74 such that traffic wishing to turn left onto, or cross over, US74 must turn right, and then do a U-turn to return to the intersection and either continue along US74 or turn right to continue on Unionville Indian Trail Rd. A pre-improvement aerial of the intersection is presented in Figure 25 and a post improvement aerial is presented in figure 26. (This intersection is the same as in Figures 19 and 20 but reframed to show the location of the business parks.)

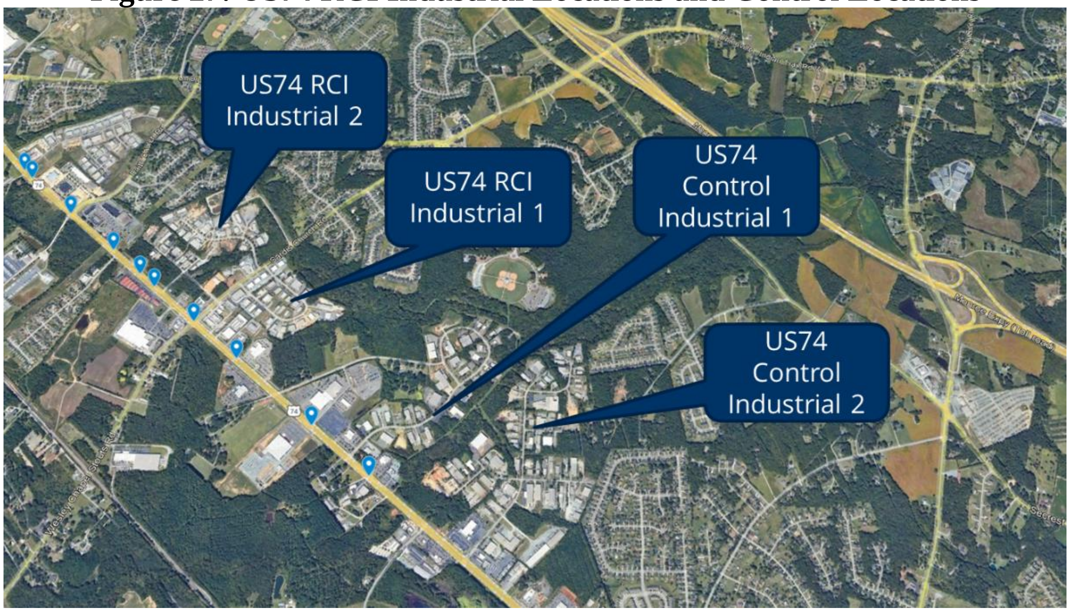
Figure 25: US74 and Sardis Church Rd, Pre-Improvement

Figure 26: US74 and Sardis Church Rd, Post-Improvement

Matched Developments

Located off Sardis Church Rd are two industrial parks, one on the east side of the road, and one on the west side of the road. Both industrial parks are in close proximity to the US74 and Sardis Church Rd intersection with the RCI restrictions on intersection movement. The two parks are matched to two other small industrial parks located just to the southeast of the industrial parks but without an RCI style intersection at their entrance. All four industrial parks contain relatively small facilities and do not appear to include any major warehousing operations where the facility is surrounding by loading docks, etc. A map of the four locations relative to each other is presented in Figure 27.

Figure 27: US74 RCI Industrial Locations and Control Locations



Matched Pairs Activity Comparison

The two industrial parks subject to the RCI treatment of their US74 intersection, US74 RCI Industrial 1 and US74 RCI Industrial 2, are each compared with the two control locations, US74 Control Industrial 1 and US74 Control Industrial 2, that use a traditional median break to access US74. Visual presentations of those comparisons are shown in Figure 28 and Figure 29.

Figure 28: US74 RCI Industrial 1 v US47 Control Industrial 1 and 2

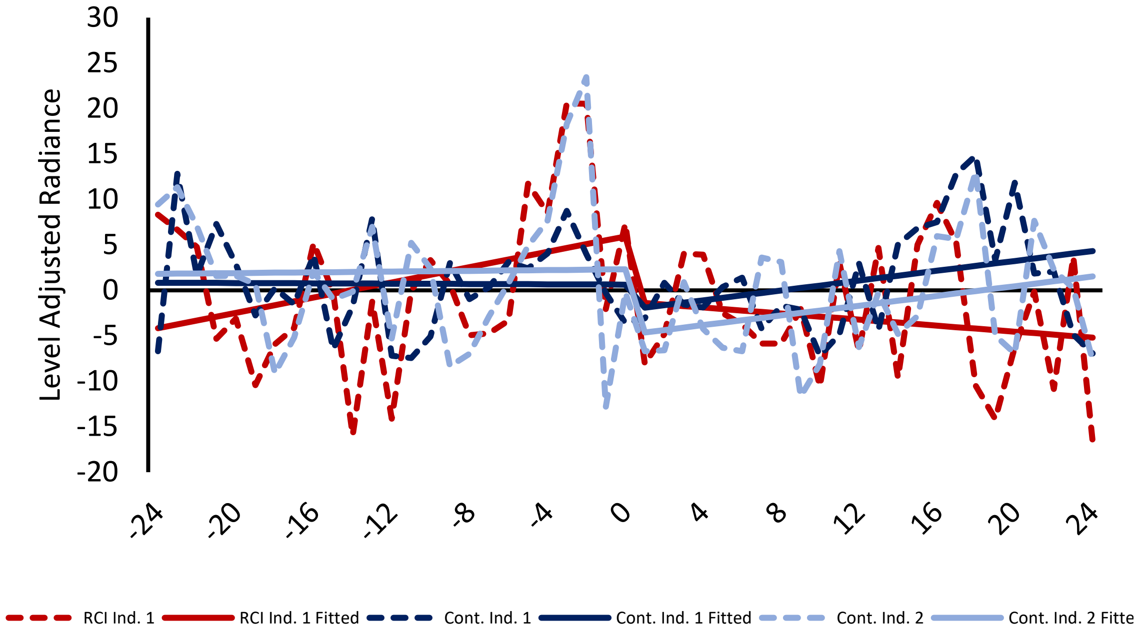
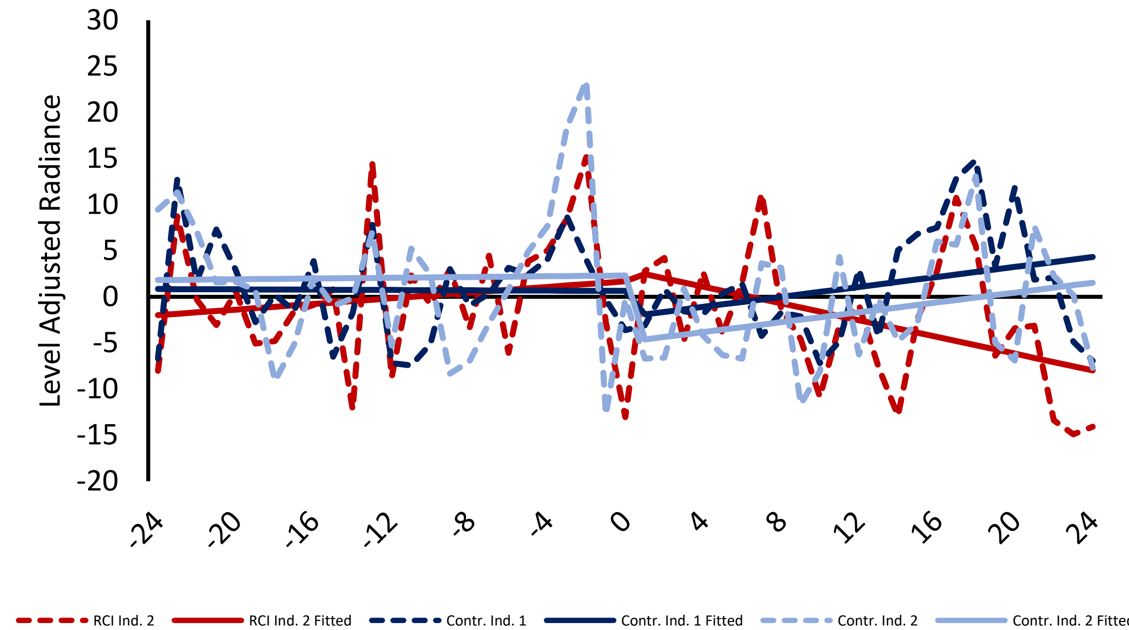


Figure 29: US74 RCI Industrial 2 v US47 Control Industrial 1 and 2



As seen for both comparisons, the treated industrial parks are negatively affected by the installation of the RCI. Activity levels in the control parks are relatively flat prior to the RCI installation and growing, insignificantly, post installation. But the industrial parks affected by the RCI installation where activity was slowly growing pre-installation both show signs of decreased activity following the installation. The pre-post change for US74 RCI Industrial 1 is significant with a p-value of 0.08 while the change for US74 RCI Industrial 2 is slightly outside the commonly accepted significance levels with a P value of 0.13. However, it is possible the results of the single series pre-posttest are being driven by other factors and a multi-series analysis is warranted.

When comparing US74 RCI Industrial 1 to US74 Control Industrial 1 and 2 the results again are negative and slightly outside the commonly accepted level for statistical significance with p-values of 0.12 and 0.11 respectively. However, for US74 RCI Industrial 2 compared to US74 Control Industrial 1 and 2 the post-installation trends are significantly different with p-values of 0.004 and 0.003 respectively.

Industrial Park 3

Improved Intersection: NC49 and Stough Road in Concord, NC

The intersection of NC49 and Stough Rd is located on a rural, four-lane arterial highway connecting the core of Charlotte, NC with Concord, NC, a town on the outskirts of the metropolitan area. The three-way intersection was improved through the addition of an RCI style design such that traffic approaching NC49 from Stough Road, where the industrial park is located, are required to turn right. Traffic wishing to make a left on NC49 must first turn right and then make a U-turn to travel northeast on NC49. Unlike some other locations in the analysis presented above, there are options to reach NC49 and travel northeast that do not require traveling through an RCI but their travel distance is longer. A pre-improvement aerial of the intersection is presented in Figure 30 and a post improvement aerial is presented in figure 31.

Figure 30: NC49 and Stough Rd, Pre-Improvement

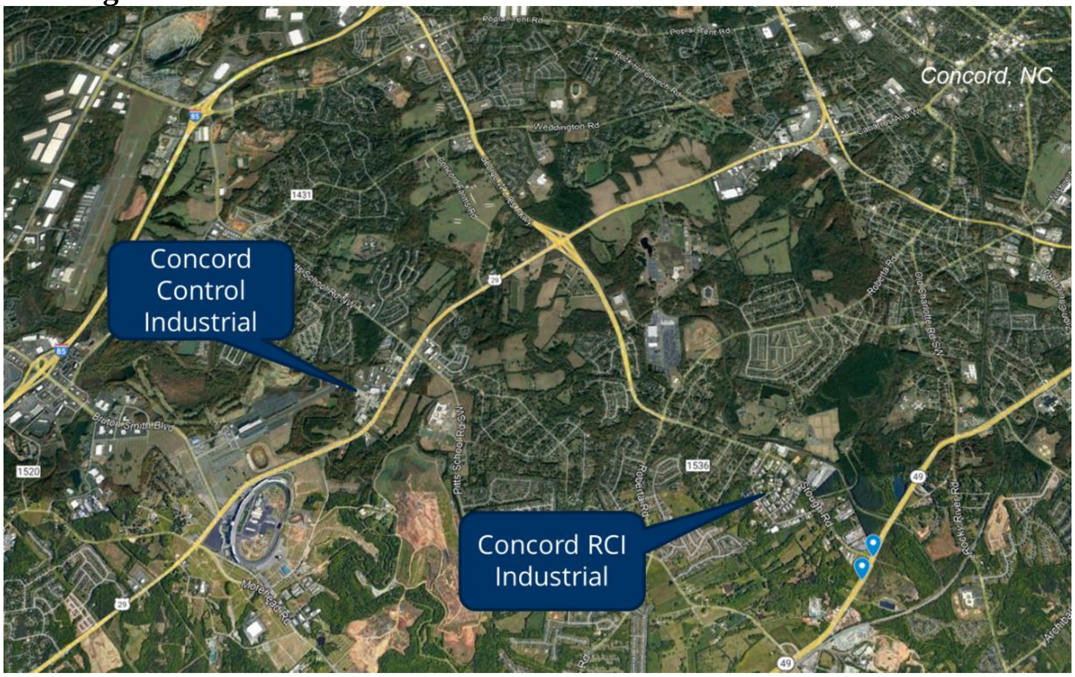
Figure 31: NC49 and Stough Rd, Post-Improvement

Matched Developments

Located off Stough Rd is a small business park and a moderately large distribution center. Because there is not another business park in close proximity that meets the parallel trends requirement for comparison, we matched the Stough Rd park to a business park located off US29, approximately 5 miles away. Both business parks contain relatively small facilities and do not appear to include any major warehousing operations where the facility is surrounding by loading docks, etc. There is a

Weyerhaeuser distribution facility across the Stough Rd from the Concord RCI Industrial location. A map of the four locations relative to each other is presented in Figure 32.

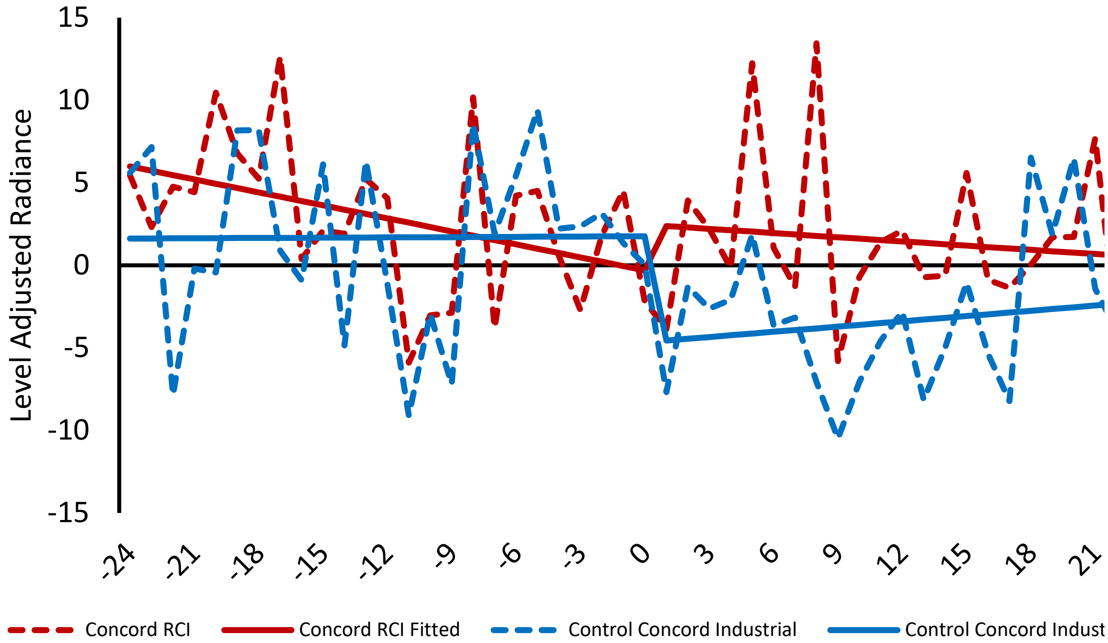
Figure 32: Concord RCI Industrial and Concord Control Industrial



Matched Pairs Activity Comparison

The Concord RCI Industrial location is problematic for analysis as a good, matched control is not available. Thus, we conduct a single series and multi-series analysis for the business park. The pre-post radiance data for the RCI location as well as the most appropriate control location are shown in Figure 33.

Figure 33: Concord RCI Industrial v Concord Control Industrial



Focusing on the single series analysis first, the red line, we see that activity appeared to be slightly slowing pre-RCI and the trend continuing post RCI installation. However, there was no statistical difference between the pre-and-post installation trend. In an attempt to confirm the single-series result, we compared the Concord RCI Industrial to the nearest business park that was close to meeting the parallel trends requirement for the multi-series analysis. While the Concord Control Industrial location did not have the same pre-RCI installation downward trend as the RCI business park it was the most reasonable control available. Even with activity at the control location being relatively flat pre-RCI installation and ever so slightly increasing after the period in which the RCI was installed at the Concord RCI Industrial location, the post installation trends were not significantly different. Regression output to accompany Figure 32 is presented in Appendix B. These results suggest the RCI installation on NC49 did not significantly affect activity in the business park.

Summary of Remote Sensing Results

Analysis of the average radiance data presented above reveals a mix of results depending on individual intersections and development type. RCIs located near commercial developments have a mild positive effect if any. This finding is consistent with Schneider's (2019) results for Louisiana and suggests that the improvements in traffic flow outweigh additional time costs of a less than direct route. The RCI type improvement on NC55-bypass is a good example, as traffic movement is restricted but the intersection is thought to still facilitate access to adjacent developments and activity increased. However, many of the commercial results are of no effect and the analysis of industrial development suggests a negative effect. A summary of the radiance analysis is found in Table 5. The mixed results are evidence that RCIs are an important tool for traffic engineers and must be matched to the activity around the intersection. The improved traffic flow around an intersection may be less beneficial to an industrial user who may well pay a higher time cost in navigating the RCIs in larger or heavier vehicles. Additional research is needed to identify and mitigate individual drivers of the negative effect on industrial users. When used thoughtfully, RCI improvements will improve traffic flow leading to the potential of increased economic activity on commercial developments.

Table 5: Summary of Radiance Results

Area	Comparison	Results
Commercial		
Area	**Comparison**	**Results**
Holly Springs, NC	RCI Multitenant v. Control Multitenant	Significantly Positive
Indian Trail, NC	RCI Grocery v. Control Grocery 1*	Indeterminate
Indian Trail, NC	RCI Grocery v. Control Grocery 2*	No Effect
Indian Trail, NC	Big Box General Merchandise v Control 1	Significantly Positive
Indian Trail, NC	Big Box General Merchandise v. Control 2	No Effect
Indian Trail, NC	Big Box General Merchandise v Control 3	No Effect
Indian Trail, NC	Big Box General Merchandise v. Control 4	No Effect
Indian Trail, NC	Big Box Home Store v. Control 1	No Effect
Indian Trail, NC	Big Box Home Store v. Control 2	No Effect
Indian Trail, NC	Big Box Home Store v. Control 3	Significantly Negative**
Indian Trail, NC	Big Box Home Store v. Competitor 1	No Effect
Indian Trail, NC	Big Box Home Store v. Competitor 2	No Effect
Indian Trail, NC	Big Box Home Store v. Competitor 3	No Effect
Indian Trail, NC	Big Box Home Store v. Same Company 1	No Effect
Indian Trail, NC	Big Box Home Store v. Same company 2	No Effect
Industrial		
Area	**Comparison**	**Results**
Indian Trail, NC	Industrial 1 v. Control 1	Insignificantly Negative***
Indian Trail, NC	Industrial 1 v. Control 2	Insignificantly Negative***
Indian Trail, NC	Industrial 2 v. Control 1	Significantly Negative
Indian Trail, NC	Industrial 2 v. Control 2	Significantly Negative
Concord, NC	Concord Ind. v. Control Concord Ind.	No Effect

* While pre-improvement trends pass the parallel trends test, the entry of a new grocery into the market likely affected the RCI grocery and Control Grocery 2, but not Control Grocery 1, thus the results for RCI Grocery vs. Control Grocery 1 are described as indeterminate.

** The negative effect compared to Control 3 appears to be an outlier as the RCI Big Box Home Store was increasing in activity until the RCI was installed. However, the RCI installation and slowing activity appears to correspond to a slowing of activity in the housing sector while Control BB Home 3 picked up in activity for at least the short period of study.

*** Results were significant at the 88% level, slightly below the more commonly accepted 90% minimum threshold. However, the negative effect is consistent with the other industrial areas examined.

Business Perceptions of Reduced Conflict Intersections

While the radiance analysis presented above focuses on direct measures of activity, the resolution limits analysis to "big box" businesses and multitenant locations. Nevertheless, the radiance results suggest a slightly positive effect for commercial development and a potentially negative effect for industrial development. Analysis of the survey responses complements the radiance analysis by shedding light on the reasons for the different results across development type. The objective of our survey was to quantify business perceptions of the RCI's effects on their businesses and customers while providing insight into the radiance results, including differences in perceptions by type and size of business.

Survey Development and Deployment

To survey businesses, we developed an electronic survey and distributed a link to the survey via a postcard mailing. The survey was broken into several sections: business characteristics, attitudes about traffic flow, perceptions of customers' traffic experience (including the RCI near the business), and business descriptives including respondent demographics (a copy of the survey is available in Appendix C).

Addresses for the mailings were sourced using Google Maps and postcards mailed in November 2021 with follow up mailings in January 2022, March 2022, and April 2022. Several variations of the postcard/entry link were used to create an indicator of businesses located within 500 meters of an RCI vs located between 500m and 1000m, as well whether ingress and egress was affected by the RCI. In the end, 310 responses were pooled for analysis.

Response Descriptives

Survey responses included a cross section of industries that were combined into broader categories for analysis (Table 6 provides the number of responses from each broad category.[2]). As one might expect, roughly half of the responses were from retail businesses or other businesses open to the public without an appointment. The broad category of "Open to the Public/Retail" includes retail, hospitality, auto repair, community service organizations, gas stations, etc.

[2] Businesses could indicate they are in more than one industry.

Table 6: Responses by Broad Industry Category

Broad Industry Group	Responses	% of Responses
Open to Public/Retail	156	50%
Industrial	19	6%
Office	72	23%
Apartments	28	8%
Education	11	4%
Medical	38	12%

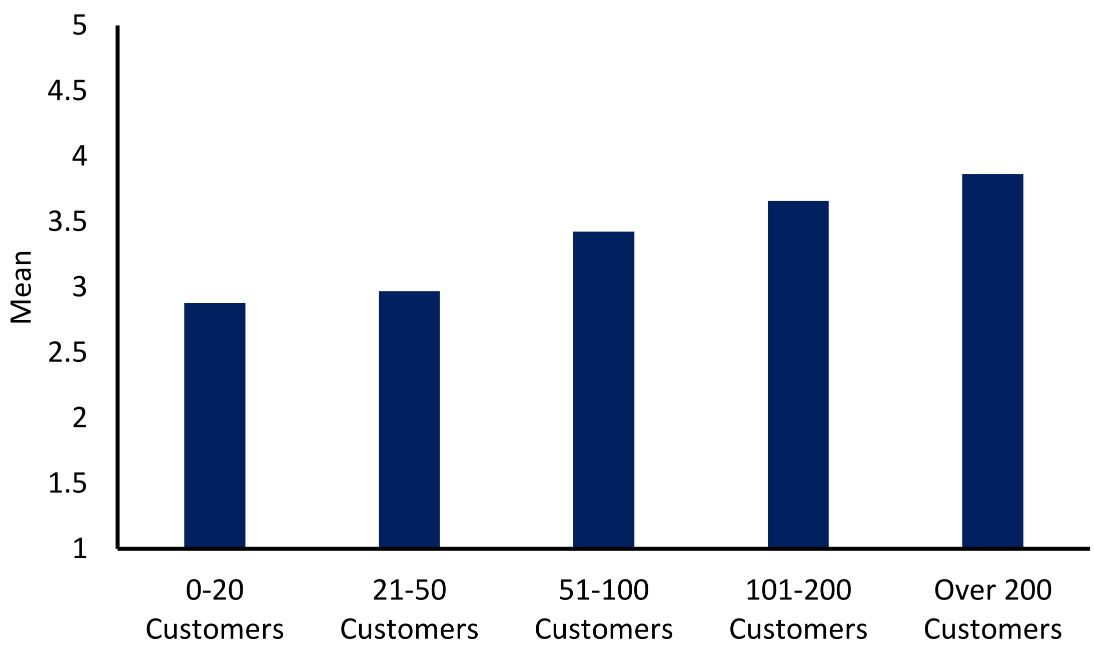
The broad category of "Open to the Public/Retail" includes retail, hospitality, auto repair, community service organizations, gas stations, etc.

In addition to a spread of industry responses, the respondents tended to be relatively senior as well with approximately 80% of responses being from Assistant managers, managers, or owners with nearly a third of respondents having been in their current position for five or more years. Further, nearly 80% of businesses classified themselves as "local" with about half of them stating they had multiple locations while nearly 20% of responses came from regional or national chains. Over half the respondents indicated their business had been in that location for five or more years. Additional descriptive data can be found in appendix D.

Survey Analysis and Results

Aside from strict descriptives we have also conducted ANOVA (Analysis of Variance) across several categorical variables. This type of analysis allows us to calculate a mean value for different categories for the purposes of comparison. Of particular interest are responses to the statement "Reduced conflict intersections (RCIs) have made it easier for customers to reach my business." Differences between respondent categories help to understand the radiance results from above. For example, the strong response of the multitenant development, which includes a grocery store, following the RCI type improvement is supported by agreement with the statement that increases as the number of customers visiting a business increase (see Figure 34).

Figure 34: Response to “RCIs have made it easier for customers to reach my business” by number of customers



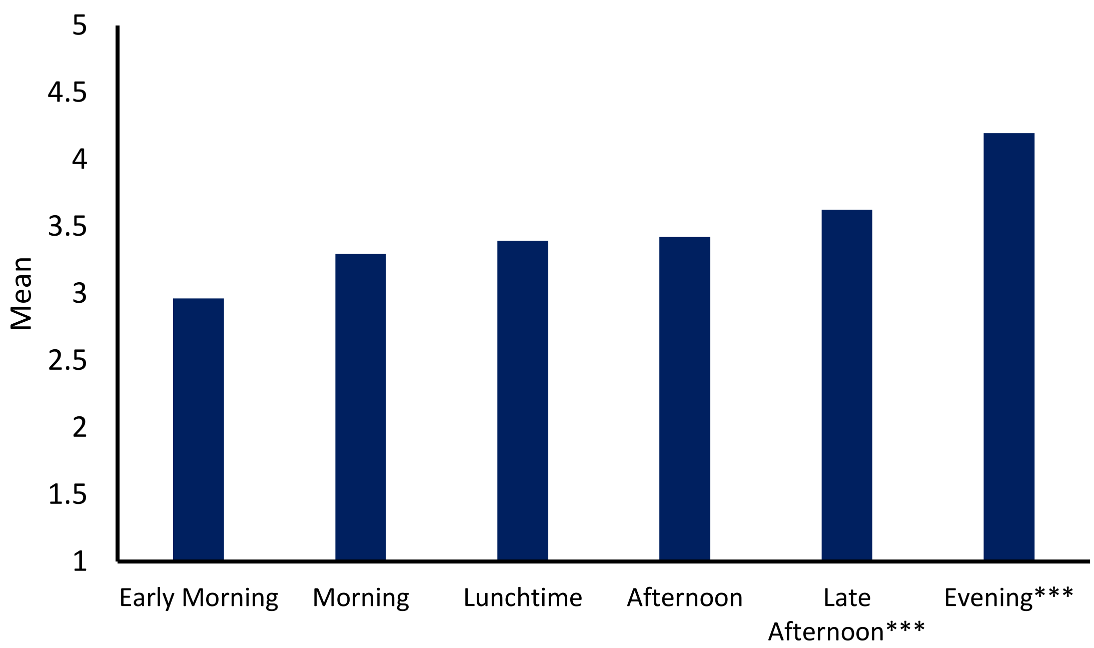
Strongly Disagree=1, Somewhat Disagree=2, Neither=3, Somewhat Agree=4, Strongly Agree=5
Statistical difference from the mean response is shown with asterisks, * indicates a 90% confidence level of a p-value of less than 0.10, ** indicates at 95% confidence level and a p-value of less than 0.05, and *** indicates a 99% confidence level and a p-value less than 0.01.

It is worth noting that this pattern could also be caused by businesses with more customers locating on corners and, thus, being favored by the RCI design over those located in the middle of the block. However, if responses are limited to only those respondents indicating they are in the middle of the block, the trend remains but positive responses flatten off after 50 customers suggesting the largest businesses believe that RCIs make the biggest difference when the business is located on a corner.[3]

Appreciation of RCI street design also increases by busiest time of day as those respondents who are busier late afternoon and evening, presumably when traffic is heavier are more likely to state that RCIs make their businesses easier to reach, significantly so for those busiest in the late afternoon and evening, as shown in Figure 35.

[3] Without a controlled experiment pinning down causality is nearly impossible as RCI designs are intentional about improving traffic flow and thus may still accommodate higher traffic businesses in the middle of the block via a median cut, etc.

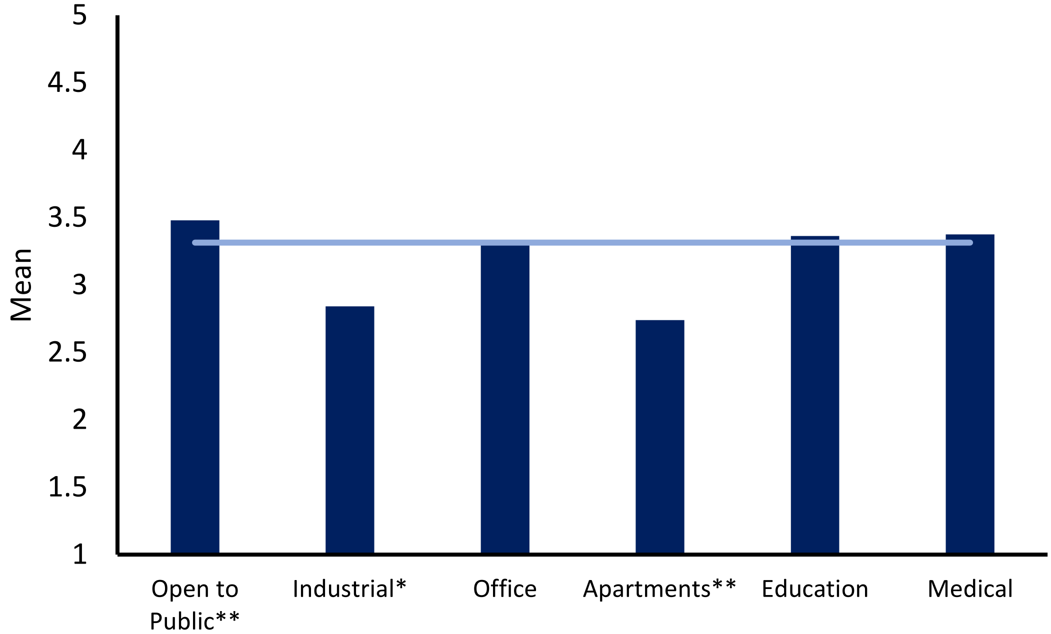
Figure 35: Response to "RCIs have made it easier for customers to reach my business" by Busiest Time of Day



Strongly Disagree=1, Somewhat Disagree=2, Neither=3, Somewhat Agree=4, Strongly Agree=5
Statistical difference from the mean response is shown with asterisks, * indicates a 90% confidence level of a p-value of less than 0.10, ** indicates at 95% confidence level and a p-value of less than 0.05, and *** indicates a 99% confidence level and a p-value less than 0.01.

However, industrial users are significantly less likely to agree with the statement that RCIs make their business easier to reach, as shown in Figure 36 by the gap between the blue bar representing the mean response for industrial users and the horizontal blue line, the sample mean response.

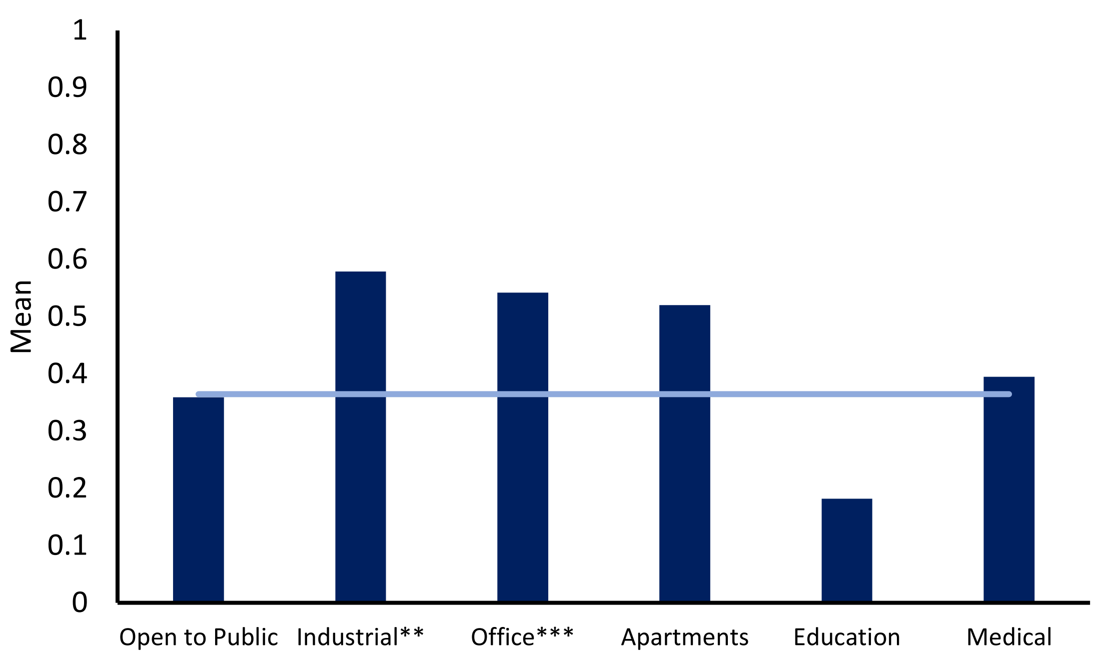
Figure 36: Response to "RCIs have made it easier for customers to reach my business" by business type



Strongly Disagree=1, Somewhat Disagree=2, Neither=3, Somewhat Agree=4, Strongly Agree=5
Statistical difference from the mean response is shown with asterisks, * indicates a 90% confidence level of a p-value of less than 0.10, ** indicates at 95% confidence level and a p-value of less than 0.05, and *** indicates a 99% confidence level and a p-value less than 0.01.
The horizontal blue line represents the mean response.

The more pessimistic view toward RCIs from industrial users may stem from three possible sources: a difference in the way additional time to turn left is valued by an industrial respondent, a larger cumulative effect on travel time form more numerous trips through the RCI, or increased difficulty navigating the U-turn procedure in a larger or heavier vehicle than passenger vehicles. Interestingly, industrial respondents did not differ from other respondents in their perceptions of traffic flow. That is, they were significantly more likely to state that they had a safety concern around their business, as shown in Figure 37 by the bar exceeding the sample average, shown by the horizontal line.

Figure 37: Response to "Do you have any traffic safety concerns in the area immediately surrounding your business?"



Yes = 1, No = 0

Statistical difference from the mean response is shown with asterisks, * indicates a 90% confidence level of a p-value of less than 0.10, ** indicates at 95% confidence level and a p-value of less than 0.05, and *** indicates a 99% confidence level and a p-value less than 0.01.

The horizontal blue line represents the mean response.

Safety concerns were further elaborated on in the follow-up comment request including many comments that referenced large volumes of traffic as a safety concern:

- *"Insufficient distance between pedestrians and vehicles…"*
- *"…easy to get in traffic jam"*
- *"…wish there was a turn lane so thru traffic could move on and turning not block it…"*
- *"Traffic jams are easy to cause traffic accidents"*
- *"Traffic accidents are easily caused by crowded local roads…"*

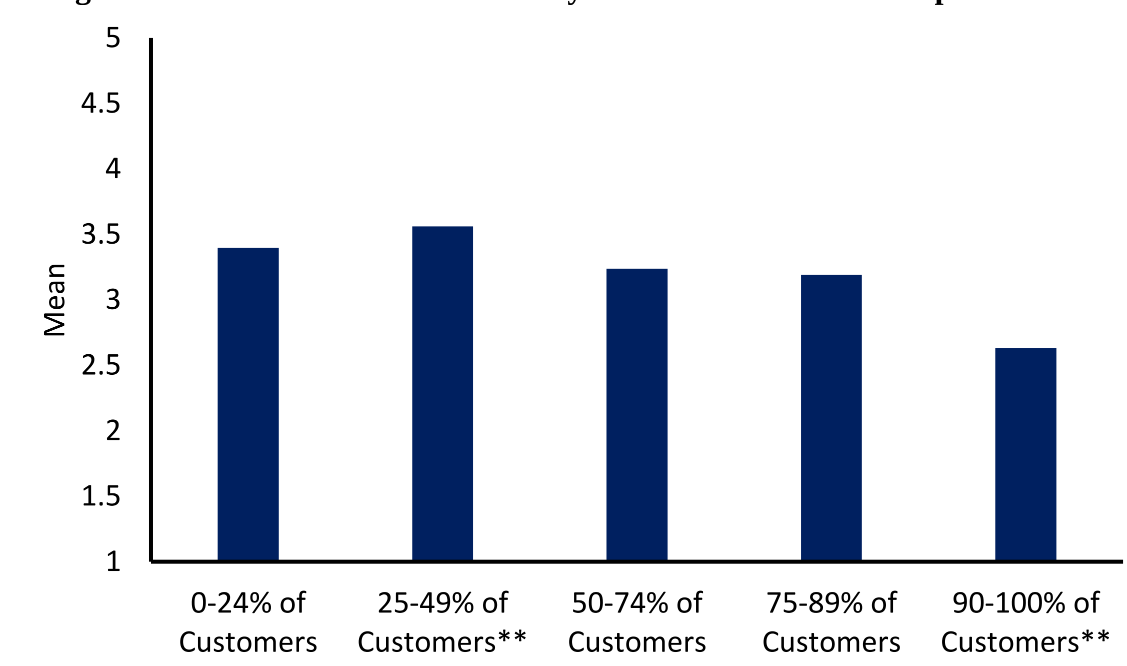
Examining comments from the full set of businesses regarding RCIs, a theme of "complication" emerges that is exemplified by the following comment:

> *"It's called a Michigan left isn't it? That should let you know that something like that would [take] a while to get used to driving on and learning which way you can go ..."*

Setting aside the more general comments about too many stop lights, too much traffic, too many accidents, etc., many respondents mentioned difficulty in customers learning how to navigate the intersections or where to turn. One respondent lamented that first time customers who miss their turn must make two U-turns to reach the respondent's business.

The additional costs of a U-turn are reflected by businesses whose customers visit on impulse rather than plan their visit are less likely to agree that RCIs make it easier to reach their business. Figure 38 presents responses to RCIs making a business easier to reach by the percentage of customers who visit on impulse (or do not plan their visit) and we see businesses with 90-100% of their customers visit on impulse are significantly less likely to respond favorably. Interestingly, businesses with somewhere between a quarter and half their customers stopping in without planning are significantly more likely to agree that RCIs make it easier.

Figure 38: RCIs Make Roads Easier by % of Customers Who Impulse Visit



Strongly Disagree=1, Somewhat Disagree=2, Neither=3, Somewhat Agree=4, Strongly Agree=5
Statistical difference from the mean response is shown with asterisks, * indicates a 90% confidence level of a p-value of less than 0.10, ** indicates at 95% confidence level and a p-value of less than 0.05, and *** indicates a 99% confidence level and a p-value less than 0.01.

Summary of Business Survey Results

We interpret these results as evidence that RCI's create tradeoffs of a macro-level positive effect from reduced congestion and improved traffic flow but a micro-level negative effect of increased costs from less direct routes. The radiance results above suggest that NCDOT has been judicious in their use of RCIs and the positive effect outweighed the negative for the commercial locations examined. In addition, the radiance analysis presented above is short-run and analyzes the installation of RCIs as improvements in existing roadways. The slightly positive effects, on net, identified above are expected to level off as the area of interest reaches its new equilibrium. Thus, we expect that RCI design of new roadways will maximize the positive effect of traffic flow while minimizing the micro-level negative effect as commercial development will optimize location and parcel layout around the RCI roadway design.

Residential Real Estate Effects

Another way RCIs' economic impacts may manifest themselves is through home values. A budding economic impact literature has focused primarily on taxable sales and business activity, but if consumption spending—especially on necessities—is a function of income and somewhat independent of travel time, it may be the case that changes in travel time—real or perceived—owing to the installation of RCIs will affect home values. Home buyers may be less willing to pay for homes which require residents to take additional steps to reach shopping destinations. Alternatively, reduced congestion and improved traffic flow may increase home values. For example, if a subdivision loses the ability to turn left onto an arterial road (i.e., residents are forced to go the opposite direction than they intend to find an RCI where they can U-turn) then home buyers may not be as willing to live in that neighborhood, reducing prices. In this section we consider this possibility by examining instances where RCIs were implemented around existing neighborhoods or streets. These RCI implementations give us examples of natural experiments where we can define treatment and control groups to tease out the causal effect of RCI implementation.

Real Estate Analysis Methodology

To examine the effect of RCI installations on home values, we pursue a difference-in-difference approach. The underlying idea behind this approach is much the same as randomized control trials in the medical field except the treatment and control groups are not randomized prior to administration of the treatment, in this case, the installation of an RCI. Social science researchers often confront an inability to randomize treatments and address statistical challenge by searching for a control group, similar to the treated group, and comparing outcomes, in this case home prices, following the treatment of a RCI installation.[4] This approach is substantially similar to the one used in the radiance section above.

Areas of Interest

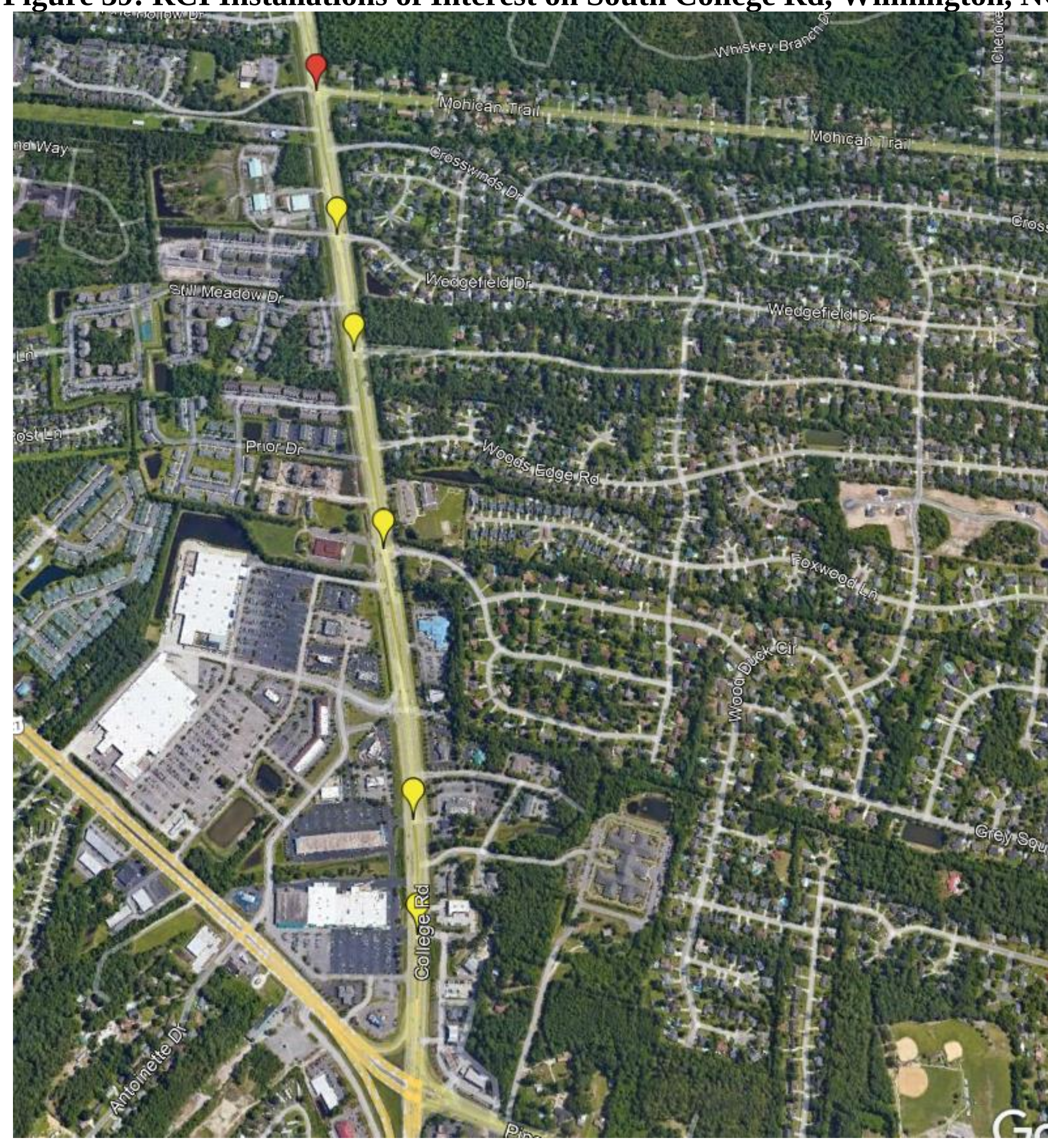
There are two levels at which RCI street design may affect home prices, at a macro level where neighborhood traffic funnels through RCIs on their way to shopping locations or work, or at a micro level as individual streets are affected by intersections with an RCI. We look at both by examining street level effects using four intersections located in Wilmington, NC along S. College Rd and by using two neighborhoods, one in Holly Springs, NC and one in Wilmington, NC to examine neighborhood effects.

Street Level Effects

[4] Medical researchers faced with an inability to conduct RCTs are starting to use some of these techniques as well.

To examine street level effects, we searched throughout North Carolina to identify suitable streets. We found four that had appropriate controls and exploit variation in these four intersections located in Wilmington, NC. We use home sales on nearby streets as control groups to investigate how the installation of RCIs affects home prices. When the RCIs were installed, residents of minor streets intersecting with an arterial, College Rd, lost the ability to turn left as median openings were rebuilt to eliminate conflict points of vehicle paths. We define these streets that lost the ability to turn left as our treatment group. Nearby minor streets without a median opening never had the ability to turn left and are defined as the control group. Figure 39 provides a visual of streets for analysis with the pins on College Rd marking the RCI installations. One can clearly see the minor streets east of the highlighted north-south arterial use College Rd as an arterial road; we use the minor east west neighborhood streets intersecting with the arterial at the marked intersections as our treated streets and the streets in between as controls.

Figure 39: RCI Installations of Interest on South College Rd, Wilmington, NC



The RCIs and residential streets along South College Rd provide an appropriate study location as treatment and control streets are located relatively close to each other minimizing variance in unobserved variables such as to amenities, school districts, and other variables not directly observed in the data. Difference-in-difference estimation compares post-installation value to pre-installation values for each group—treatment and control—to net out time-invariant factors and compares the pre-post differences across groups to control for time varying factors that affect both group (i.e., changes in tax rates, regional crime levels, etc.) We specify the following difference-in-difference model:

$$HomePrc_{i,t} = \beta_0 + \beta_1 iRCI\_Treated_{i,t} + \beta_2 iPost_t + \beta_3 iRCI\_Treated_{i,t} * iPost_t + \beta_4 Controls_{i,t} + \varepsilon_{i,t} \quad (1)$$

In equation 1, our dependent variable, *HomePrc*, is the real, detrended, price per square foot. *iRCI_Treated* is an indicator variable that takes the value of one if the street lost the ability to turn left due to installation of an RCI, and zero otherwise. *iPost* is an indicator variable that takes the value of one if the home sale was recorded after the installation of the RCI, and zero otherwise. In a diff-in-diff model, we are particularly interested in the interaction term, *iRCI_Treated***iPos*t, which provides the effect after the treatment relative to the control group. Finally, we include several controls for individual home prices including square footage (*LivingArea)*, year that the house was built (*YearBuilt*), exterior wall type, number of bedrooms, number of bathrooms, and number of fireplaces.

We collect home sale price data from the New Hanover Tax Assessors Office, which allows us to find home prices and estimate this model on four different RCIs. The four intersections of interest are listed in Table 7.

Table 7: Street Level Improvements in Wilmington, NC for Analysis

S. College Rd and Intersection of:	**Traffic Change**	**Approx. Date of Improvement**
Mohican Trail	Loss of left onto College Rd. (Signalized to Signalized RCI w/ unsignalized, U-turn with a loon)	April 2012
Wedgefield Dr.	Loss of left onto College Rd (Unsignalized to unsignalized RCI w/ a signalized, U-turn without a loon)	March 2011
Hidden Valley Dr	Loss of left onto College Rd (Unsignalized to Unsignalized RCI w/ unsignalized, U-turn without a loon)	March 2011
Greenbriar Rd	Loss of left onto College Rd (Unsignalized to unsignalized RCI w unsignalized, U-turn without a loon)	March 2011

Each analysis included over 100 home sales with the Mohican Trail intersection data included 148 home sales, Wedgefield Drive included 120 sales, Hidden Valley Road 133 sales, and Greenbriar Road 109 sales. Minimum sample sizes for such an analysis are on the order of 50 sales with each of the estimations containing more than a sufficient number of observations. These sample sizes and the home characteristics allow for estimation of a model that explain over 80% of the variation in home prices.

From Table 7, it is worth noting that the intersection of Wedgefield Drive is the only intersection to include a signalized U-turn. Three of the four intersections have relatively tight U-turn radiuses without a loon while Mohican Trail's U-turn incorporates a loon.

Mohican Trail

As shown in Figure 40, an RCI was installed where Mohican Trail Rd. intersects College Rd with Mohican Trail losing the ability to turn left. We use homes on Mohican trail as a treatment group and homes located on Crosswinds and its side streets as a control. We estimate a difference-in-difference model (as shown in Equation 1) with the results of estimation are found in Table 8.

Figure 40: Mohican Trail Rd. Wilmington, NC

Table 8: Mohican Trail Regression Results

Variables	Real PPSF	*Std.Error*
iPost	-1.756	3.94
iRCI_Treated	-35.95***	7.995
*iRCI_Treated*iPost*	*8.105*	*5.181*
Living_Area	-0.0762***	0.0073
Year_Built	0.448	0.307
iExtwall_BrickVener	0.747	5.654
iExtwall_VinylSiding	16.70	8.865
iExtwall_CementSiding	7.404	10.62
iExtwall_WoodShingle	4.562	7.685
iExtwall_Brick	9.784	6.269
Bedrooms	3.244	4.349
Full_bath	16.36***	4.229
Half_bath	15.73***	3.936
Fireplaces	8.437**	2.867
Constant	-703.8	607
Observations	148	
R-Squared	0.851	

This table presents the results of a diff-in-diff model where Mohican Trail in Wilmington, NC is the treatment group. The control streets are Crosswinds, Crosscurrent, Freeboard, Tropic Rushing, and Northeaster.
t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Our results for the *iRCI_treated* variable indicate homes on Mohican Trail are less expensive (~$36 per sqft) than those on Crosswinds.[5] Also noteworthy, is the lack of a statistically significant result on the variable *iPost*, which shows that home prices of the control group were not significantly changed by the installation of the RCI. However, the variable of interest here is the interaction term, *iRCI_Treated*iPost*, which is the interaction of *iRCI_Treated* and *iPost* and shows how home prices of the "treated" group change relative to the control group. The interaction term indicates whether there was a change in home prices on Mohican Trail after the installation of the RCI. Here, we fail to find a statistically significant relationship, indicating that home prices on Mohican Trail did not change after the implementation of the RCI.

Wedgefield Drive

Just south of Mohican Trail, we examine another RCI which was installed where Wedgefield Dr. intersects College Road as shown in Figure 41.

[5] Differences between treatment and control groups on average is not a problem as long as they follow similar trends, the variable of interest that measures the treatment effect is the difference between groups in the change in home prices, hence the model's name difference-in-differences.

Figure 41: Wedgefield Dr. Wilmington, NC

As before, we estimate a diff-in-diff model as shown in equation 1. The results of estimating this equation are found in Table 9. We find a positive and statistically significant relationship between *iRCI_Treated* and the price per square foot (*real_ppsf*), which suggests that homes on Wedgefield Dr. have higher prices than those on the control street of Crosswinds and its side streets. The *iPost* variable, which shows the differences in home prices before and after RCI installation for the control group shows there was no statistically significant difference in control group home prices post installation of the RCI. The interaction term, *iRCI_Treated*iPost* is the variable of interest and reveals a negative and statistically significant relationship, which suggests that home prices on Wedgefield Dr. decreased $12.44 after the implementation of the RCI. We note that this variable is significant at the 10% level.

Table 9: Wedgefield Dr. Regression Results

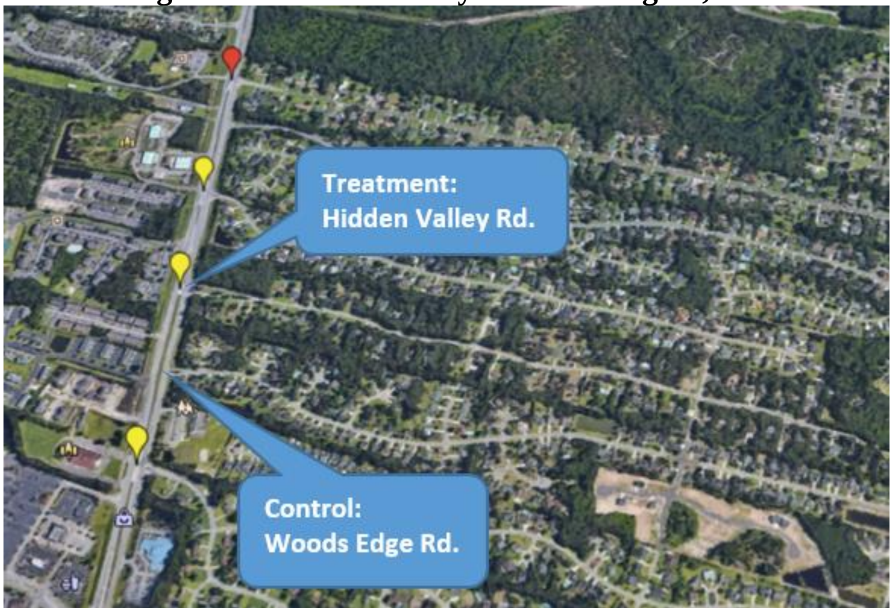
Variables	Real Price Per Square Foot	Std. Error
iPost	3.032	4.069
iRCI_Treated	37.46***	8.432
*iRCI_Treated*iPost*	*-12.44**	6.664
Living_Area	-0.0852***	0.0066
Year_Built	0.875	0.638
iExtwall_BrickVeneer	-0.269	6.645
iExtwall_VinylSiding	-2.429	10.33
iExtwall_CementSiding	-2.466	10.99
iExtwall_WoodShingle	-0.644	8.405
Bedrooms	7.416*	3.898
Full_Bath	18.02***	4.071
Half_Bath	7.672*	4.356
Fireplaces	12.73*	7.613
Constant	-1,560	1,271
Observations	120	
R-squared	0.837	

This table holds the diff-in-diff model where Wedgefield Dr in Wilmington, NC is the treated group and Crosswinds, Crosscurrent, Tropic, Rushing, and Northeaster Drives are controls.
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Hidden Valley Road

Next, we examine the RCI located at the intersection of Hidden Valley Rd and College Road as shown in Figure 42. Because an RCI was installed at Hidden Valley Road, we use the homes on this road as the treatment group, and the homes on Woods Edge, Blue Grass, Ranch Wood, Bren Wood, Lady Fern, Fox Wood and Bernhardt Drives as controls.

Figure 42: Hidden Valley Rd. Wilmington, NC



Again, we estimate the diff-in-diff model shown in equation 1. The results of estimation are shown in Table 10. The results indicate that the treated streets' home values are $31.47 less per square foot than the control pre-RCI installation. Control group home values are not significantly different after installation of the RCI as shown by the coefficient on the *iPost* variable. Our variable of interest in this model is the interaction between *iRCI_Treated* and the *iPost* variable, *iRCI_Treated*iPost*. For the Hidden Valley and College Road intersection, we fail to find a significant difference in the change of home prices following the installation of the RCI for the treatment group versus the control group.

Table 10: Hidden Valley Rd. Regression Results

Variables	Real Price Per Square Foot	Std. Error
iPost	4.885	3.234
iRCI_Treated	-31.47***	10.28
*iRCI_Treated*iPost*	*8.105*	*5.181*
Living_Area	-0.0951***	0.0119
Year_Built	-0.548	1.374
Iextwall_BrickVeneer	4.63	8.459
Iextwall_VinylSiding	8.585	11.18
Iextwall_CementSiding	18.33	12.19
Bedrooms	0.346	8.504
Full_Bath	26.56***	6.675
half_Bath	24.88***	9.257
Fireplaces	5.346	5.401
Constant	1,282	2,743
Observations	133	
R-squared	0.886	

This table holds the result of a diff-in-diff model where Hidden Valley is the treatment. Control streets are Woods Edge, Blue Grass, Ranch Wood, Bren Wood, Lady Fern, Fox Wood, and Bernhardt Drives.
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Greenbriar Road

Finally, we examine the RCI located at the intersection of Greenbriar Rd. and College Rd. in Wilmington, NC. Like before we define homes on Greenbriar Road and its side street, both use the Greenbriar and College intersection, where a median opening was redesigned as an RCI, as treated by the installation of an RCI. However, Woods Edge Rd. and its side streets' intersection with College Rd was unchanged and thus serve as a control. The intersections are shown in Figure 43.

Figure 43: Greenbriar Rd. Wilmington, NC

Again, we estimate a diff-in-diff model as shown in equation 1. The results of estimation are found in Table 11. The coefficient on the *iRCI_Treated* variable is negative and statistically significant, capturing the difference in home prices between the treatment and control groups before the RCI installation. The coefficient on the *iPost* variable home prices increased after the RCI was installed suggesting that home prices in the control group increased; however, the *iRCI_Treated*iPost* variable is significantly positive showing that home prices in the treated group increased even more than those in the control group. The finding indicates the RCI had a positive effect on homes on Greenbriar Road, Billmark, and Pine Forrest Roads adding nearly $18 per square foot to home values.

Table 11: Greenbriar Rd Regression Results

Variables	Real Price Per Square Foot	Std. Error
iPost	6.782**	2.848
iRCI_Treated	-66.39***	22.99
*iRCI_Treated*iPost*	17.54*	9.885
Living_Area	-0.0813***	0.0068
Year_Built	-0.55	1.26
Iextwall_BrickVeneer	6.96	9.749
Iextwall_VinylSiding	-17.06***	6.289
Iextwall_CementSiding	-7.955	7.309
Bedrooms	-3.499	7.836
Full_Bath	29.17***	8.059
Half_Bath	34.51***	5.148
Fireplaces	10.03*	5.229
Constant	1,290	2,513
Observations	109	
R-squared	0.931	

This table presents the results of a diff-in-diff model where Greenbriar, Billmark, and Pine Forrest roads in Wilmington, NC are the treatment group. The control streets are Woods Edge, Blue Grass, Ranch Wood, Bren Wood, and Lady Fern.
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Overall, the results are somewhat mixed for these four RCIs. In two of the specifications (Mohican Trail Rd and Hidden Valley Rd), we find insignificant results for the treatment effect. However, for Wedgefield Dr. we find that the RCI installation had a negative effect on home values, but the Greenbriar Rd. RCI installation had a positive effect on home prices. We surmise the difference in results may be due to the differing nature of the RCI designs and, importantly, the signalized U-turn for Wedgefield. The results suggest that the improvement in traffic flow on S. College Road (upward pressure on home prices) is more than offset by the extra time required (or perception of extra time) to make a U-turn at the signalized intersection.[6]

Neighborhood Effects

Our second approach to identifying the effect of RCIs on home prices is to examine RCIs where whole neighborhoods are affected by an RCI installation. The neighborhood level analysis is slightly different from street level analysis as the RCI installation may affect traffic patterns within neighborhoods. After searching RCIs in North Carolina, we identify two areas appropriate for the neighborhood level analysis. The first is an RCI that was installed on Carolina Beach Rd. in Wilmington, NC. The second is a series of RCIs installed on Highway 55 in Holly Springs, NC.

[6] We note that the U-turn radius is approximately the same for both treatment and control groups.

Wilmington, NC

The RCI that was installed on Carolina Beach Rd. is located at the intersection of St. Andrews Rd. and Carolina Beach Rd. as shown in Figure 44. Treatment group streets, such as Bexley, that access Carolina Beach Rd off St. Andrews lost their ability to turn left onto Carolina Beach Rd. While they can access Carolina Beach Rd through a signalized intersection with Silva Terra Rd., time costs have increased following the RCI installation. The neighborhoods in the control group have more convenient access Carolina Beach Rd via signalized intersections at Silva Terra Rd. or Shade Tree Ln. As above we use a diff-in-diff model to examine the effect.

Figure 44: RCI at Intersection of St. Andrews Rd and Carolina Beach Rd

The results of estimating our diff-in-diff model are shown in Table 12. The coefficient on the *iRCI_Treated* variable indicates that home prices are higher in the treated group compared to control pre RCI installation. However, as before, we are interested in the interaction term, *iRCI_Treated*iPost*, which reveals the change in home values for the treated group after the installation of the RCI. The results on the *iRCI_Treated*iPost* variable are statistically insignificant, indicating that we fail to find an effect on home values after the implementation of the RCI.

Table 12: Wilmington Neighborhood Regression Results

Variables	Real Price Per Square Foot	Std. Error
iPost	-3.145	3.825
iRCI_Treated	12.08**	6.109
*iRCI_Treated*iPost*	-2.772	6.4
Living_area	-0.0737***	0.00389
Year_built	0.897***	0.305
iExtwall_BrickVeneer	1.326	5.955
iExtwall_VinylSiding	-8.441**	3.794
iExtwall_CementSiding	-5.226	7.018
Bedrooms	14.42***	3.115
Full_Bath	26.95***	3.694
Half_Bath	31.88***	3.108
Fireplaces	6.117**	2.58
Constant	-1,675***	609.7
Observations	367	
R-squared	0.791	

This table holds the results of a diff-in-diff model where the Bexley Neighborhood in Wilmington, NC is the treatment. The controls are some of the surrounding neighborhoods that didn't lose the ability to turn left onto Carolina
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Holly Springs, NC

Finally, we examine a series of RCIs that were installed on NC 55-bypass in Holly Springs, NC as shown in Figure 45. For the Holly Springs neighborhood level analysis, series of neighborhoods (west of Highway 55, but east of Main St.) are subject to the treatment effect of RCIs restricting traffic movement at intersections along NC 55-bypass, unless using the signalized intersection of NC 55/Main St. and NC 55-bypass. However, the neighborhoods east of Main St. are not in close proximity to the RCIs and flow towards Main St. to access NC 55-bypass.

Figure 45: RCIs on NC 55-bypass in Holly Springs, NC

We use data from the Wake County Tax Assessors Office to conduct our analysis. The data differs in some respects to the New Hanover County data used in the previous analysis (e.g., see control variables in Table 12). As before, we use a diff-in-diff model to examine the effect. The results of model estimation are shown in Table 13.

Table 13: Holly Springs Neighborhood Regression Results

Variables	Real Price Per Square Foot	Std. Error
iPost	17.97***	1.699
iRCI_Treated	1.067	1.553
*iRCI_Treated*iPost*	-1.129	2.333
Heated_Area	-0.000796**	0.00035
Year_Built	-0.284**	0.123
iExtwall_Brick	-10.00*	5.766
iExtwall_CinderBlock	-54.71**	21.26
iExtwall_Brick&Frame	2.852	9.758
iExtwall_Brick&CinderBlock	-46.64***	13.21
iExtwall_CinderBlock&Frame	-36.55***	8.613
iExtwall_Stone	-1.642	15.3
iExtwall_Metal	-76.32***	18.95
iExtwall_Brick&Metal	-80.27***	10.09
iExtwall_PrecastConcrete	-11.2	28.11
iExtwall_CinderBlock&Metal	-97.71***	14.13
iExtwall_VinylSiding	-3.972***	1.364
iBath_1.5	-13.84	9.894
iBath_2	11.31	8.82
iBath_2.5	4.158	8.949
iBath_3	4.008	9.957
iBath_3.5	-8.682	9.214
iBath_NoPlbg	32.83	20.18
iBath_Adequate	61.95***	16.82
iBath_NoOfFixtures	-8.47	11.15
iBuiltIn_Elevator	-89.91**	45.22
iBuiltIn_MultipleFireplaces	-35.91	38.55
iBuiltIn_NA	-55.64	36.18
iBuiltIn_OneFireplaces	-58.05	36.45
iBuiltIn_SprinklerSystem	-30.06	41.71
Constant	700.8***	243
Observations	1,295	
R-squared	0.388	

This table holds the results of a diff-in-diff model where the homes located east of Highway 55, but west of Main St. in Holly Springs, NC are defined as the treatment group. Homes located east of Main St. are considered the control.
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In Table 13, the results of the *iPost* variable suggest that home prices have increased over the sample period. We find no evidence that the treatment homes differ in price compared to the control group as indicated by the insignificant coefficient on the *iRCI_Treated* variable. As before, we are mainly interested in the *iRCI_Treated*iPost* variable as our variable of interest. We fail to find statistical significance, suggesting that there is no discernable impact to the home values of the treated group from the installation of the RCIs.

Taken together, when we consider the neighborhood approach for defining treatment and control groups, we fail to find evidence that the installation of an RCI has an impact on home prices at the neighborhood level.

*Summary of Residential Real Estate Resul*ts

Real estate agents have long quipped "drive until you can afford it," a subtle reference to homebuyers factoring travel time into their home buying decisions, and prices. RCI developments on suburban arterial roads have two opposing effects, an improvement in traffic flow along the arterial and an increase in travel time for minor street traffic turning left or proceeding across the arterial road. A third effect is improved safety. These effects on traffic make the effect on home values an empirical question. We investigate two levels of effect, intersection effects and neighborhood effects and find no effect at the neighborhood level and mixed results at the intersection level. A summary of how RCI installations affect home values is presented in Table 14.

Table 14: RCI Installation Effect on Home Values

Intersection Level		
	S. College Rd and Intersection of:	**Effect**
	Mohican Trail	No effect
	Wedgefield Dr	Significantly negative*
	Hidden Valley Road	No effect
	Greenbriar Rd	Significantly positive
Neighborhood Level		
	Wilmington	No effect
	Holly Springs	No effect

*Intersection with signalized U-turn

Examining the intersection level effects of four RCI installations on S. College Rd in Wilmington, NC, we find a positive effect for one intersection (Greenbriar Dr), a negative effect for one (Wedgefield Dr), and fail to find a statistically significant effect for the other two (Mohican Trail and Hidden Valley Road). Both null effect intersections suggested a positive effect but not at the commonly accepted, statistically significant levels. Interestingly, the negative effect corresponds to a signalized U-turn for vehicles "turning left" onto the arterial road, potentially reflecting the additional time costs of a signalized U-turn outweighing the benefits of improved traffic flow and increased safety.[7] The explanation of increased travel time of a signalized U-turn leading to the negative effect on real estate values is consistent with Hummer's (2010) finding that survey respondents using signalized intersections are more likely to indicate (52% vs 32% of respondents) the RCI has affected their travel times. However, respondents were split as

[7] Experiential evidence for this intersection suggests the additional time required to complete the U-turn procedure is significantly longer than the one-minute rule of thumb for unsignalized intersections and highly variable depending on traffic conditions.

signalized respondents were both more likely to state that the RCI decreased their travel time and more likely to state the RCI increased their travel time than unsignalized respondents. The seemingly paradoxical responses are likely the result of those respondents "turning right" on the arterial road experiencing an improvement in travel times while those "turning left" experienced an increase in travel times.

Future research should investigate a third level of effect, regional effects. RCIs on arterial roads improve safety but also increase capacity, especially during peak times (Haley, et al., 2011), and thus, home prices on the urban periphery are likely to increase, relative to those closer to the core, following RCI installations on the connecting arterial.

Resident Perceptions of Reduced Conflict Intersections

To gather as many perspectives as possible, we also collected data from residents located in target locations in North Carolina. Our goal was to collect details about the respondents as well as their general attitudes toward RCIs.

Survey Development and Deployment

The resident survey was developed to include questions regarding perceptions of RCIs and a "choice experiment" asking respondents to choose a bundle of intersection attributes consisting of reduction in accidents, increased time to turn left, and change in total commute time, from a pair of attribute bundles. A choice experiment such as the one described below allows for the revelation of respondent preferences between the different attributes, in other words, how much time to turn left they are willing to give up for increased safety at an intersection. In addition, the survey asked about respondents' satisfaction with traffic flows and captured demographic data of respondents.

The survey and choice experiment were developed and piloted through an online system called Amazon Mechanical Turk, a centralized market for requestors to hire workers to do microtasks remotely, entering business card contact info for example; in our case we hired the workers to take a survey. Workers were paid $1.10 per survey, a relatively large payment by mTurk standards. The pilot survey was conducted using 100 workers located in Virginia, ensuring as much proximity to North Carolina as possible, in March 2022. Following confirmation of survey and item validity in the pilot sample, the survey was distributed though mTurk to 400 North Carolina respondents in April 2022 and mailed to approximately 6000 residents located near NC RCIs in April of 2022, with a second solicitation sent in May 2022. Residents near NC RCIs were mailed a postcard with a link to the survey, a note asking them to participate, and an announcement that they would be entered into an Amazon gift card raffle if they participate in the survey. A copy of the survey is available in Appendix E.

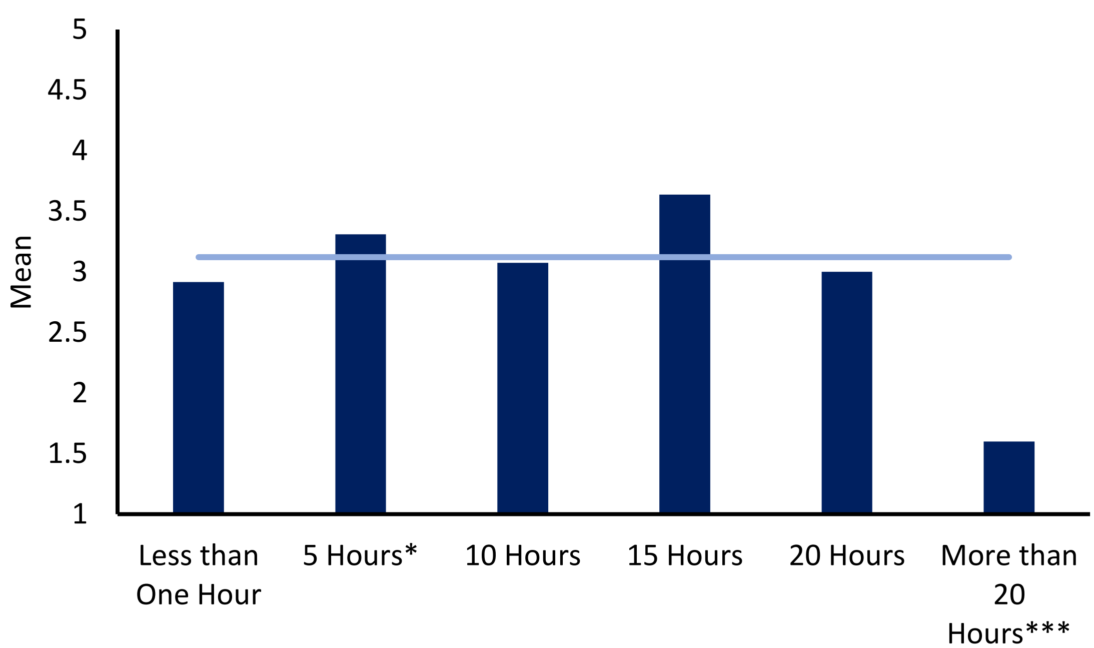
Response Descriptives

Survey responses included a range of respondents, especially when the mail survey was combined with the mTurk electronic distribution of the survey. Because of the more targeted nature of the mail survey to households located relatively close to RCIs, we will focus our descriptive data on mail survey respondents. Mail survey respondents are best described as being from “suburban” areas located in Wake County, New Hanover County, and Harnett County. The typical respondent was college educated, married with children and an upper middle-class income, living in a single-family home, and anticipating staying in that home for at least five more years. The mail responses reflect the targeted nature of the survey to those located near the RCIs which tend to be fitted on arterial roads serving to connect suburban subdivisions to commercial areas. The targeted nature of the survey and respondent demographics warrant caution before applying the results to more densely populated urban cores.

Survey Analysis and Results

Survey responses suggest that perceptions of RCIs differ by road use but not along demographic lines. For example, male and female respondents suggest that RCIs make the roads easier to use at the same rate; the same is true for responses by age range, vehicle type, number of children, etc. However, the way in which the roads are used, and time spent on the road influence how respondents view RCI design. For example, respondents who use the roads more than 20 hours per week are significantly less likely to respond that the RCIs make the roads easier to use, potentially reflecting a heightened level of annoyance with required U-turns after a long period of time on the road. However, the number of respondents in this category, only 10, means the result may not be generalizable.

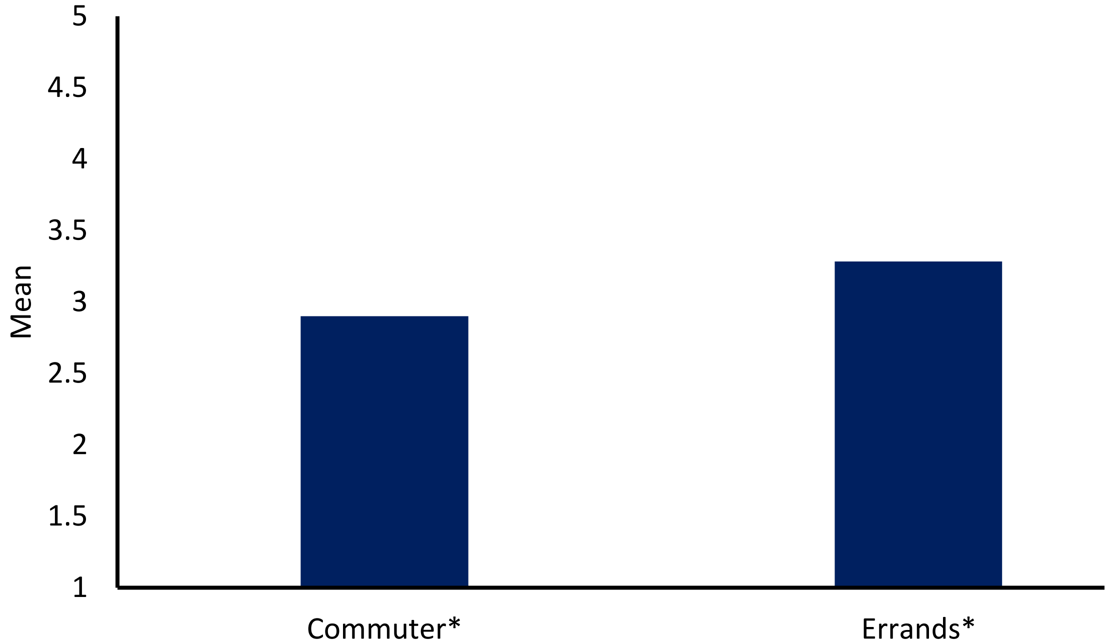
Figure 46: Response to “RCIs make using the roads near my house easier” by Weekly Hours on Roadways



Strongly Disagree=1, Somewhat Disagree=2, Neither=3, Somewhat Agree=4, Strongly Agree=5
Statistical difference from the mean response is shown with asterisks, * indicates a 90% confidence level of a p-value of less than 0.10, ** indicates at 95% confidence level and a p-value of less than 0.05, and *** indicates a 99% confidence level and a p-value less than 0.01.
The horizontal blue line represents the mean response.

Further, the idea that RCI design may be viewed less favorably by those who have been on the road for a longer period is supported by a difference in RCI favorability among those who use the road for commuting versus those who use the road for errands as shown in Figure 47.

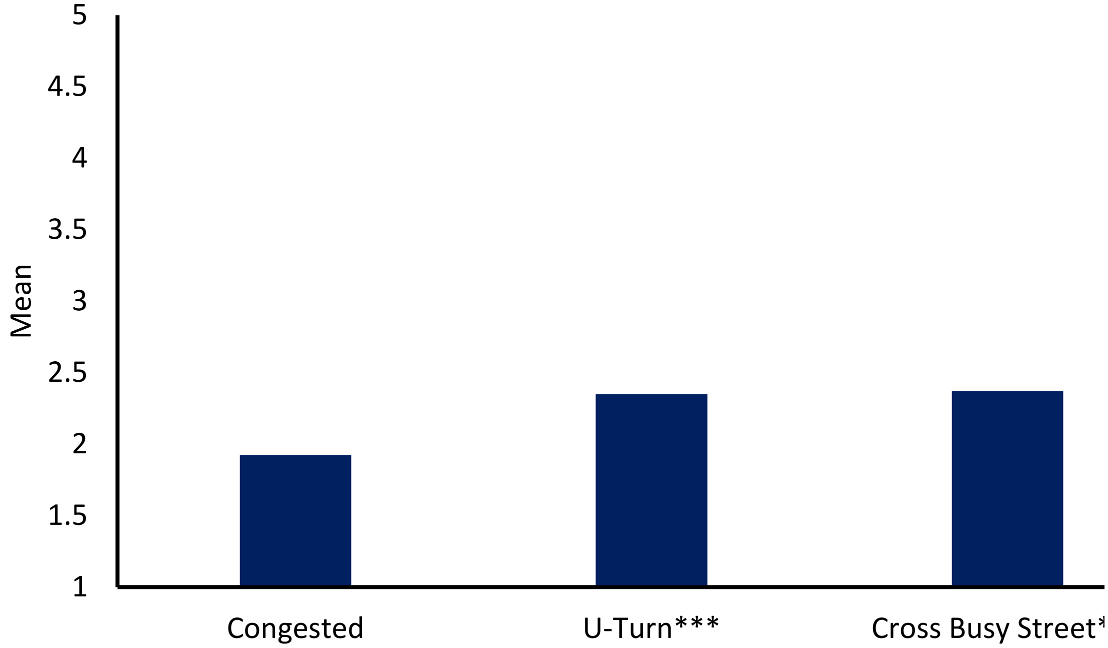
Figure 47: Response to "RCIs make using the roads near my house easier" by Primary Road Use Type



Strongly Disagree=1, Somewhat Disagree=2, Neither=3, Somewhat Agree=4, Strongly Agree=5
Statistical difference from the mean response is shown with asterisks, * indicates a 90% confidence level of a p-value of less than 0.10, ** indicates at 95% confidence level and a p-value of less than 0.05, and *** indicates a 99% confidence level and a p-value less than 0.01.

As one might expect, the length of a typical commute is considerably longer than a typical errand, approximately 20 minutes versus 12 minutes. However, respondents did indicate that making a U-turn is preferable to congested roads when deciding whether to make a trip for a single item, as shown in Figure 48.

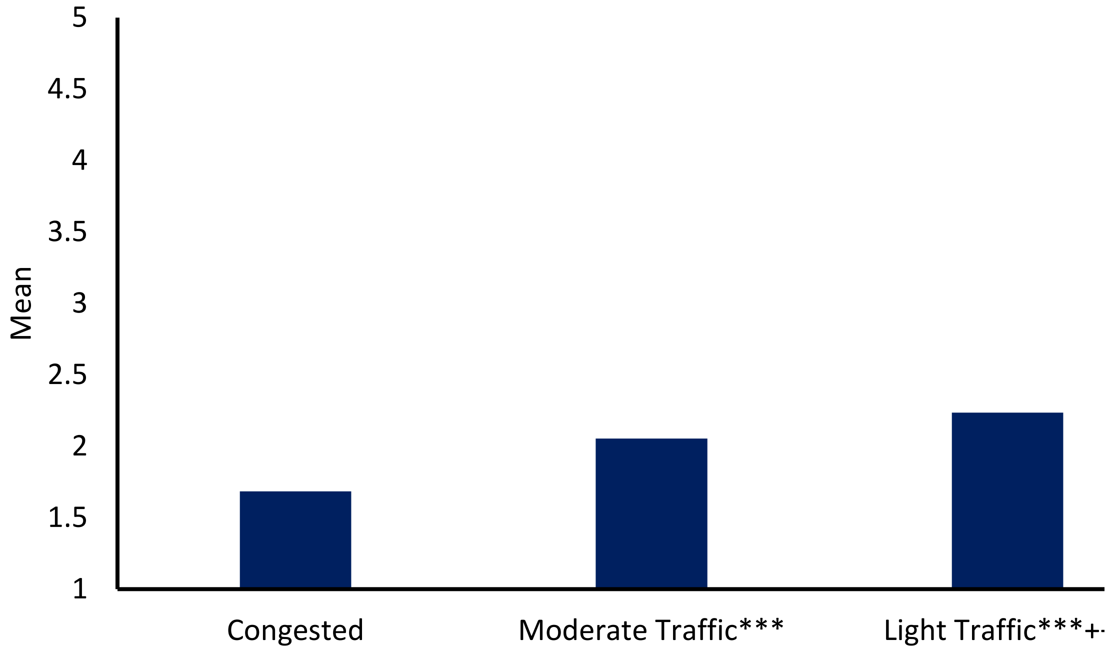
Figure 48: Likeliness to Make a Trip for a Single Item by Road Conditions



Strongly Disagree=1, Somewhat Disagree=2, Neither=3, Somewhat Agree=4, Strongly Agree=5
Statistical difference from the mean response is shown with asterisks, * indicates a 90% confidence level of a p-value of less than 0.10, ** indicates at 95% confidence level and a p-value of less than 0.05, and *** indicates a 99% confidence level and a p-value less than 0.01.

In addition, respondents also indicated that they are more likely to stop for coffee or a snack when the roads are less congested, as shown in Figure 49.

Figure 49: Likeliness to Stop for a Snack or Coffee by Road Congestion

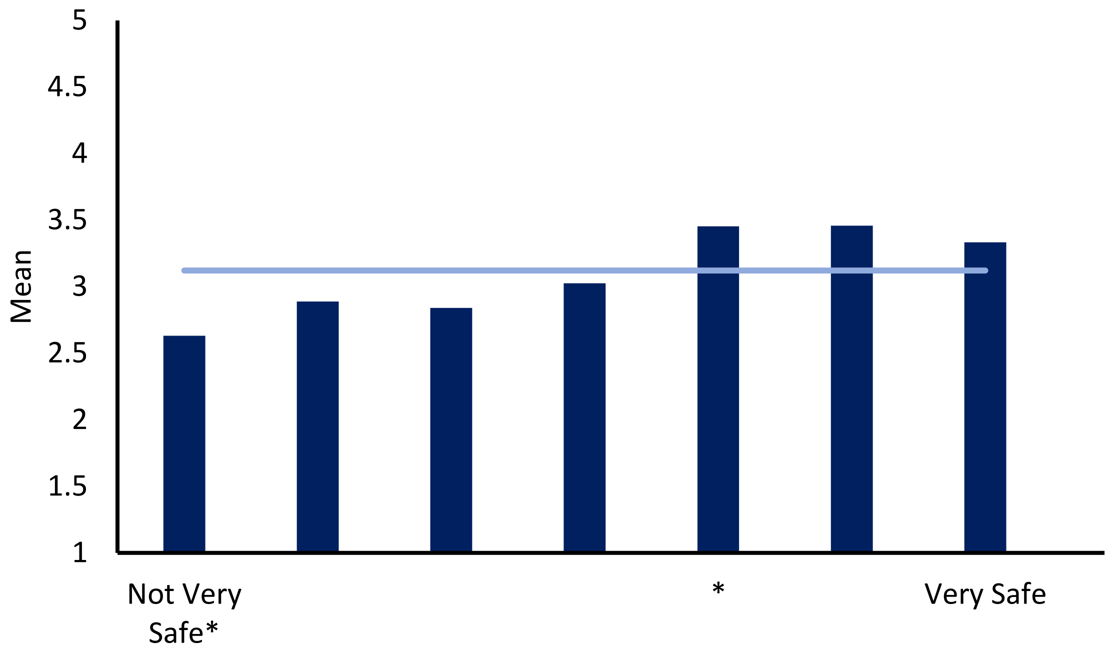


Strongly Disagree=1, Somewhat Disagree=2, Neither=3, Somewhat Agree=4, Strongly Agree=5
Statistical difference from the mean response is shown with asterisks, * indicates a 90% confidence level of a p-value of less than 0.10, ** indicates at 95% confidence level and a p-value of less than 0.05, and *** indicates a 99% confidence level and a p-value less than 0.01.

These results suggest that while businesses relying on customers to stop on impulse (as discussed above) are concerned that U-turns may hamper customer traffic, the alternative of congested roads may be even less attractive.

Finally, respondents' agreement that RCIs make the roads easier varied by perceptions of safety, with those respondents who feel the roads are unsafe being less likely to report agree that RCIs make the roads easier to use and those who believe the roads are relatively safe being more likely to agree that RCIs make the roads easier to use, as shown in Figure 50. The pattern is visible when considering mean responses from respondents who believe the roads are less safe, the left side of the figure, are below the sample mean, as shown by the horizontal blue line, while responses from those who believe the roads are more safe, the right side of the figure, exceed the sample mean. However, such responses may reflect general opinions about road conditions more so than RCI design specifically.

Figure 50: Response to "RCIs make using the roads near my house easier" by Perceptions of Road Safety



Strongly Disagree=1, Somewhat Disagree=2, Neither=3, Somewhat Agree=4, Strongly Agree=5
Statistical difference from the mean response is shown with asterisks, * indicates a 90% confidence level of a p-value of less than 0.10, ** indicates at 95% confidence level and a p-value of less than 0.05, and *** indicates a 99% confidence level and a p-value less than 0.01.
The horizontal blue line represents the mean response.

To untangle the tradeoffs around road use, time, and safety, an experimental design and a more in-depth analysis is warranted; we present the results of a choice experiment below.

Choice Experiment Background

Discrete Choice Experiments (DCEs) are a type of stated preference elicitation method used across a variety of disciplines to predict and understand human decision-making and choice behaviors. Stated preference methods, which include the Contingent Valuation Method and other choice-based elicitation techniques such as Conjoint Analysis and ranking exercises, rely on carefully crafted survey questions to understand the value of goods and services that may not be associated with direct use (e.g., conservation of biodiversity, pollution reduction) or for the ex-ante estimation of behaviors or values that may arise from proposed or hypothetical changes (e.g., whether a patients would adopt a new treatment, whether commuters would use a new rail line).

Grounded in Lancasterian microeconomic theory of preferences (Lancaster, 1966) DCEs are based on the idea that the satisfaction or "utility" from a given choice is a function of both observable and unobservable characteristics. Researchers interested in understanding preferences for specific goods or services first identify a set of attributes that comprise the good or service and specify various levels that those attributes can or might assume. Based on an experimental design, alternative versions of the good or service described in terms of different levels of the attributes are created and presented to survey respondents as a series of hypothetical choice scenarios between alternative versions of the good. Choices are presented to respondents with an opt-out alternative to simulate market decisions (i.e., in practice, buyers are not forced to purchase a good and may choose to not purchase). Statistical (regression) analysis of respondent choices allows for an understanding of preferences for the attributes and levels and respondents' willingness to trade between attribute levels. Additional details are provided in Appendix F.

Choice Experiments in the Transportation Literature

Choice experiments have a long history of policy applications in the disciplines of transportation, healthcare, and the natural environment. Given the importance of understanding consumer preferences prior to the implementation of new travel modes or routes, DCEs are commonly employed in transportation research and planning. Applications include research aimed at understanding preferences for attributes of public transportation (Alpizar & Carlsson, 2003; Henshar & Rose, 2007), tourist travel mode choices (Koo, Wu, & Dwyer, 2010), preferences for carpooling (Monchambert, 2020) and bicyclists' preferences for route and road characteristics (Stinson & Bhat, 2003; Vedel, Jacobsen, & Skov-Peterson, 2017; Poudel & Singleton, 2022). Several studies examine commuters' value of travel time savings (Hensher, 2001; Hess, Bierlaire, & Polak, 2005; Henshar & Greene, 2011; Rizzi, Limonado, & Steimetz, 2012; Mouter & Chorus, 2016) and the tradeoff that drivers are willing to make between travel time and travel safety (Mouter, Van Cranenburgh, & Van Wee, 2017; Mouter, Van Cranenburgh, & Van Wee, 2018). This latter topic includes numerous studies employing DCEs to infer the value of a statistical life (see Bahamonde-Birke et al. (2015) for a review).

The use of DCEs to assess preferences for travel/commuter safety presents an interesting issue related to survey design. Several studies reveal that survey respondents assuming the role of "citizen" assign more value to safety relative to travel time than they do in their role as "consumer" (Mouter, Van Cranenburgh, & Van Wee, 2017). This difference in preferences is caused by a range of factors, including individual perceptions that their personal risk is both controllable and lower than average, and the influence of social norms on choices when adopting a citizen perspective (Mouter, Van Cranenburgh, & Van Wee, 2018). Regardless of the reason, the DCE must be framed to target one of these two perspectives from survey respondents.

A DCE to understand preferences for RCI attributes

To improve our understanding of the costs and benefits of reduced conflict intersections (RCIs), a DCE was designed to assess drivers' preferences for three characteristics of roadway travel that are commonly influenced by the introduction of RCIs: road safety (reduction in accidents), time required to make left-hand turns, and overall travel time. That is, our DCE was designed to have three attributes. To understand preferences on a granular level, we included five levels for each attribute, based on conversations with NC DOT personnel, a review of the relevant literature and personal judgement. A list of attributes and levels is shown in Table 15.

Table 15: RCI DCE Design: Attributes and levels

Attributes	Levels
Reduction in accidents (RIA)	**No change** -10% -15% -30% -50%
Change in time to turn left (CTTL)	**No change** +15 seconds +30 seconds +1 minute +2 minutes
Change in total commute time (CTCT)	-1 minute -3 minutes **No change** +1 minute +3 minutes

Bold font indicates baseline level

Because RCIs are expected to result in fewer accidents and longer time to turn left, levels of these two attributes appear on only one side of the baseline level of no change (i.e., accidents are expected to decrease and time to turn left is expected to increase following the introduction of an RCI). Because RCIs may make some commutes shorter via improved traffic flow and may make some commutes longer via additional time at stoplights, levels of the change in total commute time attribute appear on both sides of the "no change" baseline. We note that because our attribute levels are quantitative in nature, in addition to conventional dummy coding and effects coding of attribute levels, continuous coding is also feasible. Our DCE is therefore designed to estimate the following models describing the utility associated with RCI attributes:

$$U_i = \beta_1(\text{RIA -10\%}) + \beta_2(\text{RIA -15\%}) + \beta_3(\text{RIA -30\%}) + \beta_4(\text{RIA -50\%}) + \beta_5(\text{CTTL +15 sec}) + \beta_6(\text{CTTL +30 sec}) + \beta_7(\text{CTTL +1 min}) + \beta_8(\text{CTTL +2 min}) + \beta_9(\text{CTCT -1 min}) + \beta_{10}(\text{CTCT -3 min}) + \beta_{11}(\text{CTCT +1 min}) + \beta_{12}(\text{CTCT +3 min}) \quad (2)$$

$$U_i = \beta_1(\text{RIA}) + \beta_2(\text{CTTL}) + \beta_3(\text{CTCT}) \quad (3)$$

$$U_i = \beta_1(\text{RIA -10\%}) + \beta_2(\text{RIA -15\%}) + \beta_3(\text{RIA -30\%}) + \beta_4(\text{RIA -50\%}) + \beta_5(\text{CTTL}) + \beta_6(\text{CTCT}) \quad (4)$$

Equation 2 specifies utility as a fully discrete version of the attribute levels, where the marginal utility of each attribute level relative to the "no change" baseline is estimated separately. Equation 3 specifies utility as continuous in the attribute levels and imposes the assumption that the marginal utility of each attribute is constant. Equation 4 is a hybrid specification, whereby the two-time attributes are treated in a continuous fashion and the safety attribute is treated as discrete. This specification is analogous to those used in non-market valuation whereby a monetary (price, cost) attribute is coded in a continuous fashion to produce a single coefficient and non-price attributes are coded as discrete. In essence, equations 3 and 4 allow travel time to be treated as a cost, facilitating the exploration of respondents' willingness to pay that cost in exchange for the benefit of improved traffic safety. In short, the parameters in equations 3 and 4 can be used to estimate drivers' willingness to substitute two aspects of travel time (time to turn left and total commute time) for reductions in accidents.

The DCE was included in a larger survey that solicited a range of information on respondents' driving history, driving characteristics, and driving preferences, in addition to several questions related to demographic and household characteristics. Prior to the DCE aspect of the survey, respondents were provided a detailed explanation of the differences between RCIs and conventional intersections, a list of the pros and cons of RCIs and an artistic rendering of a conventional intersection and an RCI. Figure 51 below shows the script that preceded the DCE.

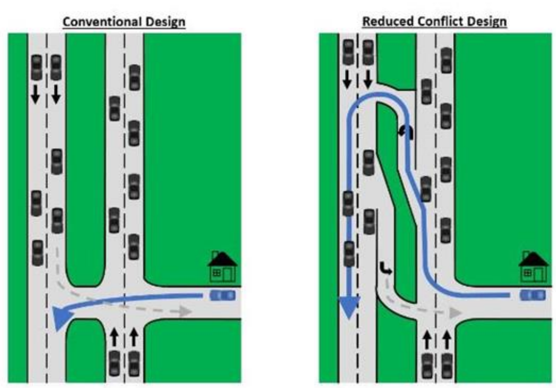
Figure 51: Explanation of RCIs provided to survey respondents prior to DCE

Intersection design and Reduced Conflict Intersections

As traffic volume increases on the main road, transportation planners must improve the road design to handle additional traffic, such improvements often include additional lights, medians, lanes, intersection redesigns, etc.

Corridors with growing traffic volumes and high crash rates are good candidates for replacing conventional intersections with a "reduced-conflict intersection".

A conventional intersection has many potential conflict points because drivers can go in many directions and vehicle paths cross, a conflict point. An alternative design, called a reduced conflict intersection, eliminates left turns from side roads onto busy main roads. Raised medians direct traffic from the side road to turn right. Traffic that needs to "turn left" onto the main road, or cross the highway, will pull into a dedicated lane – and make a U-turn.



Such designs improve traffic flow by reducing the need for traffic lights as well as reducing the number of times vehicle paths cross.

Reduced conflict intersections may have other benefits as well, including:

- Improved safety for drivers entering the main road
- Reduced delays for traffic on the main road
- Requires less right of way and costs than adding additional lanes to a road
- Improved safety for pedestrians and bicyclists

The DCE was implicitly framed using the "citizen perspective" and asked respondents to consider a scenario of exiting from their neighborhood onto a main road via a conventional intersection which is being considered for redesign to improve safety and road congestion. Figure 52 shows the full script of this introduction.

Figure 52: Script Used to Introduce the DCE

Please imagine that you live in a residential neighborhood with the primary entrance being located on the main road, a four-lane road with medians in the middle. From your neighborhood, you can turn right onto the main road, or you can move forward, pause in the median-break in the middle of the road, and then turn left. Imagine that for your commute and errands, **about half the time you leave your subdivision you are turning left**.

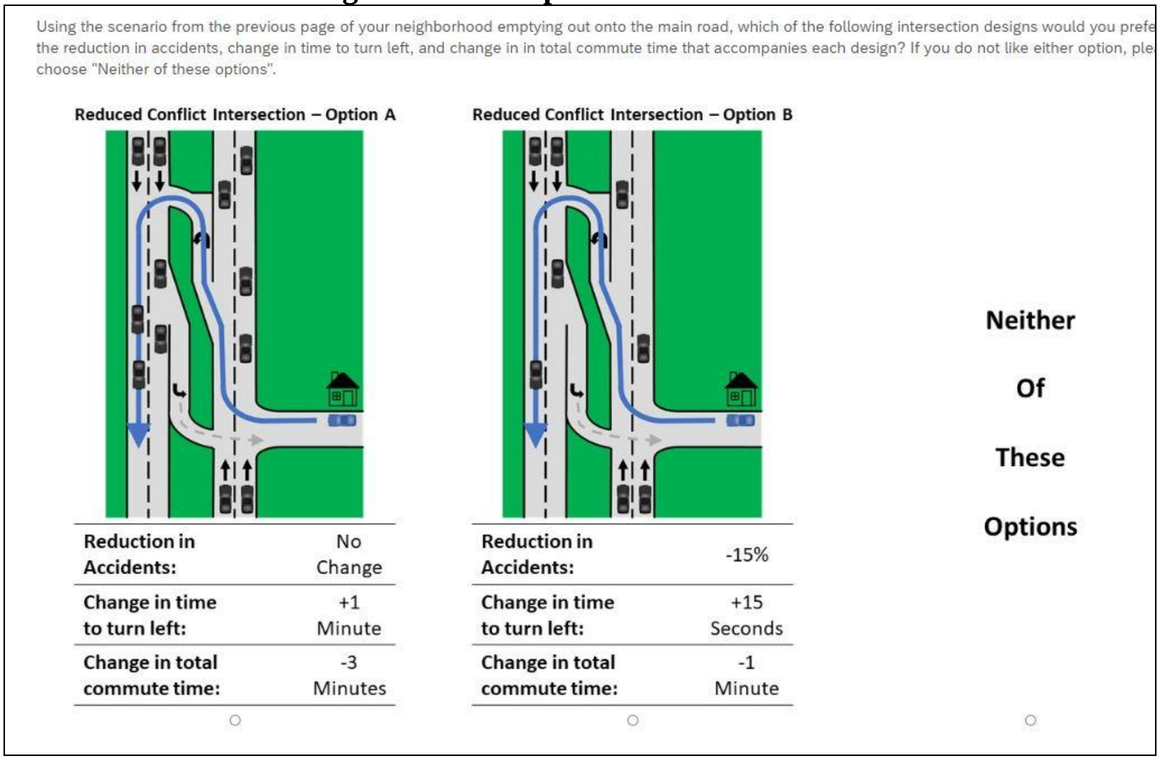
Over time, the road has become busier, more congested and accidents have become relatively frequent. In response, the department of transportation is considering new designs for the intersection. A traffic light or signal is not feasible because of the large volume of traffic the main road is required to carry. Thus, a reduced conflict intersection design is being considered.

On the following pages, you will be asked to choose between intersection designs based on reduction in accidents, time spent turning left, and effect on total commute times.

Respondents were then presented with four choice panels, each consisting of a choice between two alternative RCIs and a “neither” option. Given the framing provided by the introductory script, the opt-out alternative can be considered a conventional non-RCI intersection.[8] An example choice panel is shown in Figure 53.

[8] A D-efficient design was created using the %choiceff and %mktblock macros in SAS (Kuhfeld, 2002). The full design included 20 pairwise choice panels blocked into five sets of four panels. Survey respondents were randomly assigned one of the five blocks.

Figure 53: Example DCE Choice Panel



Following the four DCE choice panels, respondents were asked to rank the three attributes in terms of their importance when making the DCE decisions.

DCE Survey Data

After internal vetting for clarity and flow, the survey and DCE were pretested using a sample of 100 respondents from Virginia gathered using mTurk. Responses to the DCE were examined for consistency, coherence, and completion. Basic MNL regression models produced logical signs and statistical significance for the DCE attributes and levels using both dummy coding and continuous coding. The survey was then administered to two samples in North Carolina using mTurk and distribution of a pen/paper version of the survey via mail. After removing incomplete and untrustworthy surveys, the mTurk solicitation produced a sample of 324 completed responses from a total of 406. The mail survey was sent as a postcard with web address for an electronic survey to approximately 6,000 households using addresses from the Wake County and New Hanover County GIS databases and supplemented with addresses from Google Maps. Approximately 200 postcard recipients responded via the electronic survey. Of these, 169 completed surveys were retained for analysis. For estimation of main effects, the minimum sample size for choice experiments is 500c/(t x a) (Orme, 1998) where c = largest number of levels for any attribute (5 in our case) t = number of choice tasks per respondent (4 in our case) a = number of alternatives in each choice set (this is 3 in our case: A, B, neither) The minimum sample size for estimation of main effects is therefore 500(4)/(4x3) = 166. Even the smallest sub-sample, that of mail respondents, exceeds the minimum threshold.

DCE Results

Multinomial logit results for equations 2, 3 and 4 are shown in Appendix F, Table 35. In the continuous versions of the model, equations 3 and 4, the two time-related variables are converted to seconds. Table 35 includes results from the standard conditional logit model estimated using dummy-coded discrete levels of each attribute relative to the omitted (baseline) level and using continuous coding. Despite the slightly larger mTurk sample size, the mail sample produces stronger overall model fit across specifications.

For both the mTurk and mail samples, the coefficients on reduction in accidents are of the expected sign (positive) and highly statistically significant, indicating that respondents have preferences for reductions in accidents and higher reductions are preferred.[9] Respondents illustrate relatively moderate aversion to additional time to turn left and additional commute time. It seems clear that reduction in accidents is the most important of the three attributes included in the DCE.[10] In the fully discrete version of the model, equation 2, only the highest levels of additional commute time appear to significantly detract from utility. In the continuous and hybrid specifications, all coefficients are of the expected sign and are highly significant. The signs and magnitude of the two-time coefficients in equations 3 and 4 suggest that drivers are averse to additional travel time. Drivers in the mTurk sample are roughly three times more averse to time associated with turning left, while drivers in the mail sample experience only marginally more disutility from additional time to turn left. Because additional time to turn left creates more disutility than additional travel time, we can infer those drivers have preferences for traffic flow.

Using the ratio of coefficients from the fully continuous specification, we can conclude that on average, respondents in the mTurk sample are willing to trade 5.33 seconds of additional time to turn left for each one-percent reduction in accidents, or approximately one minute of additional time to turn left for each 10 percent reduction in accidents. mTurk respondents are willing to trade 18 seconds of additional commute time for each one-percent reduction in accidents, or roughly 3 minutes for each 10 percent reduction in accidents. Mail survey respondents are willing to trade roughly 12 seconds of additional time to turn left each one-percent reduction in accidents, or approximately 2 minutes of additional time to turn left for each 10 percent reduction in accidents. Mail respondents are willing to trade approximately 15 seconds of additional total commute time for each one-percent reduction in accidents or approximately 2.5 minutes of total commute time for each 10 percent reduction in accidents.[11]

We can conclude that preferences are very similar between the two samples – both sets of respondents have strong preferences for safety, are averse to additional travel

---

[9] Note that in the fully continuous versions of the model, equation 2, the coefficient on RIA is negative, as RIA is coded using negative values (fewer accidents), indicating that a larger reduction in accidents is preferred.

[10] This result is confirmed by the post-experiment ranking of attribute importance, with 61 and 63 percent of the mTurk and mail samples indicating that safety was the most important attribute of the three included in the DCE.

[11] Mixed logit specifications produce qualitatively similar but slightly different values for these marginal rates of substitution, with respondents to the mTurk survey willing to give up roughly one minute and 6 minutes of time to turn left and total commute time for each 10 percent reduction in accidents and mail survey respondents willing to give up approximately one minute and 5 minutes, respectively.

time and are more averse to additional time to turn left than to additional total commute time. Mail survey respondents appear slightly more willing to give up time to turn left than mTurk respondents and slightly less willing to give up additional commute time. Table 16 below shows the average number of minutes that survey respondents are willing to give up in exchange for a 10 percent reduction in traffic accidents, as well as the 95 percent confidence intervals around the means.

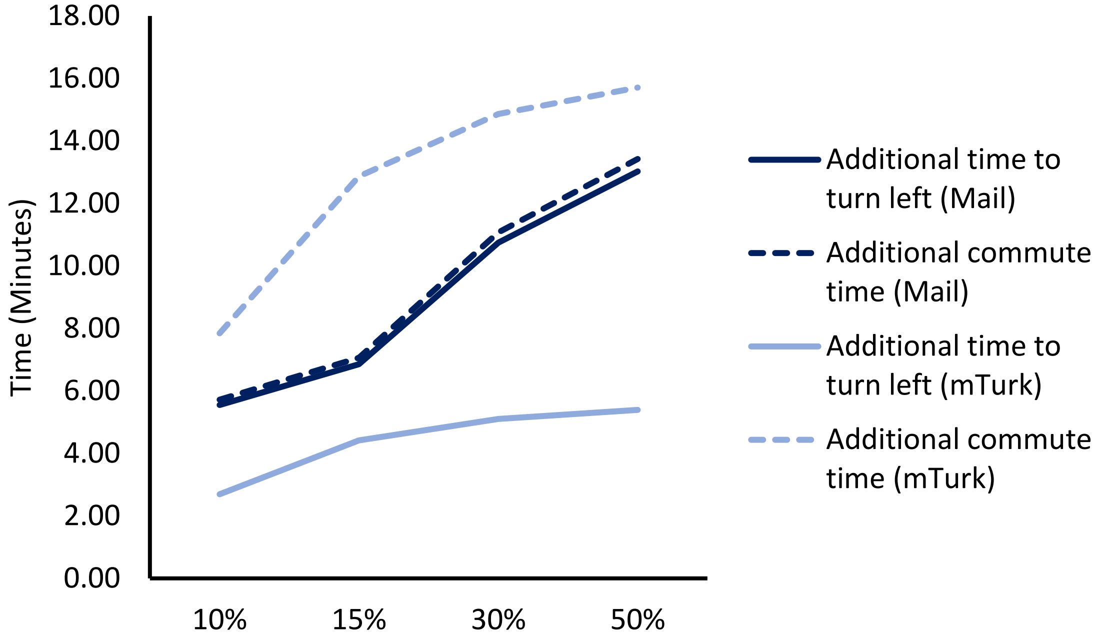
Table 16: Survey respondents' average willingness to trade travel time (minutes)

	mTurk sample	**Mail sample**
Additional time to turn left (minutes)	0.96 (0.33, 1.59)	1.93 (0.299, 3.55)
Additional total commute time (minutes)	3.01 (0.99, 5.03)	2.57 (1.51, 3.63)

95% confidence intervals in parentheses for a 10% reduction in accidents (continuous conditional logit specification)

The hybrid specification, equation 4, allows for estimation of these tradeoffs for each level of the accident reduction attribute, and illustrates that drivers' willingness to trade travel time for reduction in accidents is nonlinear. In the case of the mTurk sample, willingness to give up travel time is diminishing in accident reduction, while for the mail sample willingness to give up travel time increases at first and then diminishes. Figure 54 shows respondents' willingness to substitute travel time (in minutes) for reductions in accidents for both samples. This illustration clearly shows that mTurk respondents are significantly more averse to total commute time than mail respondents (yellow line compared to orange line), but mail respondents are more accepting of time to turn left (blue line compared to grey line).

Figure 54: Survey respondents' willingness to substitute travel time (minutes) for reductions in accidents (hybrid discrete/continuous specification)



Implications

Results from the DCE administered to two samples of NC residents suggest that NC drivers have strong preferences for the traffic safety attribute (reduction in accidents) associated with reduced conflict intersections and are willing to sacrifice additional travel time for increased safety. From a marketing perspective, this suggests that promoting the safety features of RCIs can help mitigate opposition to their implementation. DCE results also strongly suggest that while drivers are averse to both forms of increased travel time, they are decidedly more averse to additional time to turn left than additional total commute time. This finding highlights the importance of traffic flow – additional total commute time may be more palatable to drivers than additional time to turn left because the latter involves waiting in a fixed position, such as at a stoplight. Therefore, highlighting the benefits of RCIs in terms of improved overall traffic flow would appear to be an important strategy to mitigate opposition to the implementation of RCIs.

Summary of Residential Survey Results

Residential survey results complement our findings from the radiance analysis suggesting that RCIs have a positive effect on commercial development. Respondents indicated that they are more likely to stop for a snack or coffee when congestion is light and that they are more likely to make a trip for a single item when making a U-turn than in congested conditions. The survey responses suggest that the traffic flow improvements of the RCI outweigh the costs of additional time to make a U-turn. In addition, residents suggested they are willing to trade off some additional time in an intersection for improved safety. These results suggest RCIs will be most popular in areas where congestion is highest, and improvements in safety are needed. Transportation engineers would be well served to highlight the congestion improvements and accident reduction features of RCI design when presenting improvements to residents and commuters. However, business drivers are less willing to pay for safety and may be more responsive to the through traffic improvements and are more sensitive to the time required to make a U-turn when "turning left" onto an arterial street.

Findings and Conclusions

This project examined the economic impact of reduced conflict intersections (RCIs) through a multifaceted approach including analysis of economic activity surrounding the RCIs using radiance data, residential real estate effects using home prices, a business survey, and a resident survey.

Remote Sensing Analysis

Remote sensing analysis examined two intersections and one corridor of RCI improvements and found evidence that RCI installation had no effect to a small positive effect on economic activity of commercial developments. If one assumes that business activity is driven largely by demand, RCIs are unlikely to have a large effect unless they disrupt access such that customers find travel costs to an alternative business more attractive or improve access through traffic flow improvements such that customers find the affected business more attractive.

The RCI improvement on NC 55-Bypass and Avent Ferry in Holly Springs showed strong evidence of a positive effect, on the order of 20%. However, the finding of a positive effect is likely not generalizable to other commercial locations as each intersection is unique. The Holly Springs intersection connecting residents on the east side of the road and commercial development on the west side likely had a near universally positive impact on residents' ability to reach the development as the reverse RCI design shortens light cycles while allowing cross street traffic to enter the development via the arterial road entrance. Few, if any, commercial development travelers would be negatively affected as U-turns were not required for travelers coming from any direction to enter the development. However, through traffic on Avent Ferry Rd or left-turning traffic on the arterial are required to make a U-turn. The results suggest thoughtful intersection design, including consideration of upstream and downstream improvements and access points, has the potential to improve traffic flows and increase activity on adjacent developments.

In the majority of RCI installations examined, no significant effect was found. One comparison showed evidence of a significantly negative effect versus one of eight comparison controls sites, but seven other control sites failed to show a significant effect. Further, the one control site yielding the negative effect was an outlier with increasing activity while the other controls all saw declining activity, likely driven by a macroeconomic trend. In general, we believe RCIs to have a slightly positive effect if any effect at all. These results reflect NCDOT's judicious use of RCIs in appropriate situations to improve traffic flow without detrimental effects to nearby commercial businesses.

RCI road design appears to have a negative effect on industrial development with activity decreasing in two of the three business parks located near RCI improvements while increasing in control locations. These results suggest that industrial development is affected differently by RCIs than commercial businesses, potentially because of more difficulty navigating the U-turn process in larger vehicles or because the business is bearing the costs of the U-turn rather than diffusing the costs across customers. A deeper investigation into the causes of the differing effects between commercial and industrial development should be the subject of future research.

Business Survey Data

Business responses to the statement that "RCIs make their business easier to reach" are difficult to interpret in isolation as we lack a baseline for comparison. However, the responses can be compared across respondents revealing some interesting patterns. For example, we note the following three findings. First, businesses with more customers are more likely to agree that RCIs make their business easier to reach. Second, businesses serving customers during more congested periods of the day are more likely to agree than those serving customers earlier in the less congested part of the day that RCIs are helpful for customers reaching their business. Third, industrial businesses are significantly less likely to agree that RCIs make their business easier to reach and are also more likely than other respondents to indicate a concern about traffic safety near their business. Comments from these respondents indicated that traffic congestion and jams causing accidents are a concern for them.

Real Estate Analysis

Residential real estate prices show mixed effects following RCI installations. While coefficients are generally positive, they are statistically insignificant except for one intersection studied where we find a positive and statistically significant result. However, the case study of home prices for streets utilizing an RCI with a signalized U-turn are negatively affected by the RCI installation. Thus, we conclude that home prices near RCIs using an unsignalized U-turn are either positively affected or unaffected in a statistically significant way. These results may be indicative of residents valuing the improvement in traffic flow from RCIs, but the benefits may be offset by long wait times at signalized U-turns.

Resident Survey Data

Residents indicated that traffic congestion is a major impediment to commercial activity. Residents indicated they are significantly less likely to make a trip for a single item if the roads are congested than if they must do a U-turn. In addition, respondents indicated they are more likely to stop for a cup of coffee or a snack when traffic is light.

A discrete choice experiment included in the resident survey indicates that respondents are willing to trade 12 seconds of additional time to turn left for a 1% reduction in accidents. The choice experiment results indicate a strong preference for safety on the part of North Carolina respondents and a willingness to "pay" for safety with time. The results also indicate that drivers are decidedly more averse to waiting at a U-turn than to longer commute times. This finding emphasizes the importance of traffic flow, for vehicles turning as well as those continuing straight through an intersection on an arterial road.

Recommendations

NCDOT should continue to use RCI street design near commercial developments in a judicious manner. While RCIs should not be considered a direct means of increasing business activity, in addition to improving traffic safety and flow, their use can remove impediments to customers accessing businesses if engineered and used appropriately. A review of RCIs around North Carolina shows a diversity of intersection circumstances and RCI implementation. Each intersection must be considered on an individual basis utilizing the appropriate version of an RCI style intersection.

RCIs should be used to support large commercial development with larger customer bases as both the customer and business value the improved traffic flow of a well-designed intersection. Businesses with large numbers of customers believe that RCIs are beneficial in helping customers reach their business and residents indicate that they are more likely to make shopping trips when roads are not congested. Both responses suggest that good traffic design is conducive to economic activity and economic growth.

RCIs should be considered as part of a comprehensive approach to improvements near industrial developments. Appropriate use of RCIs can be useful in reducing traffic congestion and safety risks for industrial traffic, but care should be given to allow for industrial traffic to access arterial roads without the need for U-turns, potentially through improvements to alternative routes or by modeling and designing minor industrial streets in a manner that is consistent with the design characteristics of major streets, thereby reducing the use of U-turns in industrial areas.

Residents appreciate safer roads and improved traffic flow and are willing to pay for these benefits through both marginally longer commute times and marginal increases in the time to turn left. However, residents appear to dislike waiting to make U-turns. Thus, RCI installations should look to minimize wait times for U-turns and avoid using signalized four-legged intersections as the U-turn component of RCI designs when possible.

Future research should extend the analysis presented above to include an examination of regional effects in addition to local or intersection level effects. For example, RCIs increasing capacity on arterial roads may have farther reaching affects as travel times for through traffic are the arterial road are reduced, potentially increasing home prices for development on an urban periphery and providing easier connection between industrial development and their customers or to limited access highways. Such effects are beyond the scope of this report. In addition, future research should investigate the differing effects on commercial and industrial development to minimize any negative effects and maximize the positive effects. Such an inquiry would likely require focus groups of location decision makers as well as operational personnel. A similar inquiry should be pursued to validate the differing effects on residential real estate and focus on differences in resident experiences with signalized vs. unsignalized U-turns.

References

Alpizar, F., & Carlsson, F. (2003). Policy implications and analysis of the determinants of travel mode choice: An application of choice experiments to metropolitan Costa Rica. *Environment and Development, 8*(4), 603-619.

Bagby, D. G. (1980). The effects of traffic flow on residential property values. *Journal of the American Planning Association, 46*(1), 88-94.

Bahamonde-Birke, F., Kunert, U., & Link, H. (2015). The value of a statistical life in a road safety context-A review of the current literature. *Transport Reviews, 35*(4), 488-511.

Ban-Akiva, M., & Lerman, S. R. (1985). *Discrete Choice Analysis: Theory and Application to Travel Demand.* New York: MIT Press.

Chen, X., & Nordhaus, W. D. (2011). Using luminosity data as a proxy for economic statistics. *Proceedings of the National Academy of Sciences*, *108*, pp. 8589-8594.

Cooper, B., Rose, J., & Crase, L. (2012). Does anybody like water restrictions? Some observations in Austalian urban communities. *Australian Journa of Agricultural and Resource Economics, 56,* 61-81.

Cunningham, C. M., Katz, D., Smith, S., Carter, D., Miller, M., Findley, D. J., . . . Foyle, R. S. (2015). Business Perceptions of Access Management Techniques. *Public Works Management & Policy, 20*(1), 60-79.

Eisele, W. L., & Frawley, W. E. (1999). *A methodology for deteriming economic impacts of raised medians: Data analysis on additional case studies.* Austin, TX: Texas Department of Transportation.

Ghosh, T., Powell, R. L., Elvidge, C. D., Baugh, K. E., Sutton, P. C., & Anderson, S. (2010). Shedding light on the global distribution of economic activity. *The Open Geography Journal, 3*, 147-160.

Greene, W. H., & Hensher, D. A. (2003). A latent class model for discrete choice analysis: contrasts with mixed logit. *Transporation Research Part B Methodology, 37*, 681-698.

Haley, R. L., Ott, S. E., Hummer, J. E., Foyle, R. S., Cunningham, C. M., & Schroeder, B. J. (2011). Operational Effects of Signalized Superstreets in North Carolina. *Transportation Research Record: Journal of the Tranportation Research Board, 2223*, 72-79.

Henderson, J. V., Squires, T., Storeygard, A., & Weil, D. (2018). The global distribution of economic activity: Nature, history, and the role of trade. *The Quarterly Journal of Economics,* 357-406.

Henderson, J. V., Storeygard, A., & Weil, D. (2012). Measuring economic growth from outer space. *American Economic Review, 102*(2), 994-1028.

Henshar, D. A., & Greene, W. H. (2011). Valuation of travel time savings in WTP and prefernce space in the presence of taste and scale heterogeneity. *Journal of Transport Economics and Policy, 45*(3), 505-525.

Henshar, D. A., & Rose, J. M. (2007). Development of commuter and on-commuter mode choice models for the assessment of new public transport infrastructure projects: A case study. *Transportation Research Part A: Policy and Practice, 41*(5), 428-443.

Hensher, D. A. (2001). The valuation of commuter travel time savings for car drivers: evaluating alternative model specifications. *Transportation, 28*(2), 101-118.

Hess, S., Bierlaire, M., & Polak, J. W. (2005). Estimation of value of trave-time savings using mixed logit models. *Transportation and Research Park A: Policy and Practice, 39*(2-3), 221-236.

Hummer, J. E., Haley, R. L., Ott, S. E., Foyle, R. S., & Cunningham, C. M. (2010). *Superstreet Benefits and Capacities.* North Carolina Department of Transportation.

Hummer, J., Ray, B., Daeleiden, A., Jenior, P., & Knudsen, J. (2014). *RestrictedCrossing U-turn Informational Guide.* Washington, DC: Federal Highway Administration.

Huybers, T. (2004). Destination choice modeling: To label or not to label? Paphos, Cyprus: Paper presented at the conference "Tourism Modelling and Competitiveness: Implications for Policy and Strategic Planning".

Inman, V. W., & Haas, R. P. (2012). *Field evaluation of a restricted corssing U-turn Intersection.* McLean, VA: Federal Highway Administration.

Kawamura, K., & Mahajan, S. (2005). Hedonic analysis of impacts of traffic volumes on property values. *Transportation Research Record: Journal of the Transportation Research Board, 1924*, 69-75.

Koo, T. T., Wu, C. L., & Dwyer, L. (2010). Ground travel mode choices of air arrivals at regional destinations: The significance of tourism attributes and destination contexts. *Research in Transportation Economics, 26*(1), 44-53.

Lancaster, K. J. (1966). A new approach to consumer theory. *Journal of Political Economy, 74*, 132-157.

Levin, N., & Zhang, Q. (2017). A global analysis of factors controling VIIRS nighttime light levels from densely populated areas. *Remote Sensing of Environment*, *190*, 366-382.

Li, J., He, S., Wang, J., Ma, W., & Ye, H. (2022). Investingating the spatiotemporal changes and drivng factors of nighttime light patterns in RCEP countries based on remote sensed satellite images. *Journal of Cleaner Production*.

McFadden, D. (1973). Conditional choice analysis of qualitative choice behavior. In P. Zarembka, *Frontiers of Econometrics* (pp. 105-142). New York: Academic Press.

Miller, J. (2019). *Economic impacts of innovative intersections on adjacent parcels.* Virginia Department of Transportation.

Monchambert, G. (2020). Why do (or don't) people carpool for long distance trips? A discrete choice experiment in France. *Transporation Research Part A: Policy and Practice*, *132*, 911-931.

Moreland, M. (2021). *Traffic Safety Evaluation at Reduced Conflict Intersections in Minnesota.* Minnesota Department of Transportation.

Mouter, N., & Chorus, C. (2016). Value of time-A citizen perspective. *Transportation Research Park A: Policy and Practice, 91*, 317-3029.

Mouter, N., Van Cranenburgh, S., & Van Wee, B. (2017). Do individuals have different preferences as consumers and citizen? The trade-off between travel time and safety. *Transportation Research Part A: Policy and Practice, 106*, 333-349.

Mouter, N., Van Cranenburgh, S., & Van Wee, B. (2018). The consumer-citizen duality: Ten reasons why citizens prefer safety and drivers desire speed. *Accident Analysis & Prevention, 121*, 53-63.

Poudel, N., & Singleton, P. A. (2022). Preferences for roundabout attributes among US bicyclists: A discrete choice experiment. *Transportation research part A: Policy and Practice, 155*, 316-329.

Proville, J., Zavala-Araiza, D., & Wagner, G. (2017). Night-time lights: A global, long term look at links to socio-economic trends. *PLoS ONE, 12*(3).

Riffkin, M., Allen, C., Baker, M., Richman, C., & Dorwart, J. (2013). *Raised Median Economic Impact Study.* Salt Lake City, UT: Utah Department of Transportation.

Rizzi, L. I., Limonado, J. P., & Steimetz, S. S. (2012). The impact of traffic images on travel time valuation in stated-preference choice experiments. *Transportmetrica, 8*(6), 427-442.

SAS Institute. (2008). *SAS ETS 9.2 Users Guide.* Cary, North Carolina, USA: SAS Publishing, SAS Institute Inc.

Schneider, H., Barnes, S., Pfetzer, E., & Hutchinson, C. (2019). *Economic Effect of Restricted Crossing U-Turn Intersections in Lousiana.* Louisiana State University, Louisiana Transportation Research Center.

Stinson, M. A., & Bhat, C. R. (2003). Commuter bicyclist route choice: Analysis using a stated preference survey. *Transportation Research Record, 1828*(1), 107-115.

Train, K. E. (1999). Halton Sequences for Mixed Logit. *Working Paper*. University of California at Berkeley.

Vedel, S. E., Jacobsen, J. B., & Skov-Peterson, H. (2017). Bicyclists' preferences for route characteristics and crowding in Copenhagen-A choice experiment study of commuters. *Transportation Research Part A: Policy and Practice, 100*, 53-64.

Villa, J. M. (2014). Social transfers and growth: The missing evidence from luminosity data. *World Institute for Development Economics Research Working Paper Series*.

Vu, P., Shankar, V. N., & Ulfarsson, G. F. (2006). Is access management good for business? Business perceptions of the effects of traffic access managment on accessibiity and patronage. *Transportation Planning and Technology, 29*(4), 273-293.

Appendix A – RCI Locations and Installation Dates

Table 17: RCI location and Imagery dates from Google Earth

RCI Latitude	RCI Longitude	Latest Imagery Without RCI	Earliest Imagery with RCI	Midpoint of Dates
35.2843602	-81.558238			Pre 1993
35.3083992	-77.829718			Pre 1993
35.2732084	-81.5139064	Feb 2003	Mar 1998	
35.2733266	-81.504001	Feb 2003	Mar 1998	
36.05395	-80.2594426			Pre 1998
35.127646	-80.701715			Pre 1998
35.1245266	-80.6908706			Pre 1998
35.1164112	-80.695277	Jan 1993	Mar 1998	Aug 1995
35.5234806	-83.0287403			Pre 1998
34.7793461	-77.3898813	Mar 1993	Jan 1999	Jan 1996
34.8931099	-76.9246951	Jan 1998	Aug 2002	Apr 2000
35.907333	-80.074779	Mar 2002	Dec 2002	Jul 2002
34.2683434	-77.8688997	Jan 1998	Dec 2002	Jun 2000
34.1440544	-77.8926802	Dec 2002	Oct 2003	May 2003
35.7602669	-81.3799985	Mar 1998	Mar 2004	Mar 2001
35.328558	-80.7833558	Mar 1998	Mar 2004	Mar 2001
34.2576354	-77.8705895	Dec 2002	Nov 2004	Nov 2003
34.2593214	-77.8703119	Dec 2002	Nov 2004	Nov 2003
34.173669	-77.8912801	Feb 2004	Nov 2004	Jun 2004
35.3719377	-80.6644347	Mar 1998	Feb 2005	Aug 2001
35.333048	-80.789574	Mar 2004	Feb 2005	Aug 2004
35.779702	-78.606596	Jun 2002	Feb 2005	Oct 2003
35.7797902	-78.6046404	Jun 2002	Feb 2005	Oct 2003
35.80673	-78.452551	Feb 1999	Feb 2005	Feb 2002
35.889842	-78.562596	Jun 2002	Feb 2005	Oct 2003
35.9573636	-78.5416031	Dec 2004	Feb 2005	Jan 2005
35.335847	-83.254214	Dec 2002	May 2005	Feb 2004
35.876001	-81.507625	Mar 1998	Oct 2005	Dec 2001
35.8799447	-81.5126243	Mar 1998	Oct 2005	Dec 2001
35.8950582	-81.5214005	Mar 1998	Oct 2005	Dec 2001
35.8665857	-81.4941788	Mar 1998	Oct 2005	Dec 2001
35.8639066	-81.4915529	Mar 1998	Oct 2005	Dec 2001
35.8534092	-81.4813578	Mar 1998	Oct 2005	Dec 2001
35.8429549	-81.4696942	Mar 1998	Oct 2005	Dec 2001
35.8399913	-81.4658104	Mar 1998	Oct 2005	Dec 2001
35.8325667	-81.4568853	Mar 1998	Oct 2005	Dec 2001
35.8284197	-81.4521056	Mar 1998	Oct 2005	Dec 2001
35.8194052	-81.4416692	Mar 1998	Oct 2005	Dec 2001

RCI Latitude	RCI Longitude	Latest Imagery Without RCI	Earliest Imagery with RCI	Midpoint of Dates
35.8028785	-81.4263055	Mar 2004	Oct 2005	Dec 2004
35.7942897	-81.4174247	Mar 2004	Oct 2005	Dec 2004
35.7676135	-81.3866624	Mar 2004	Oct 2005	Dec 2004
35.804969	-81.427668	Mar 2004	Oct 2005	Dec 2004
35.273393	-81.52448	Mar 1998	Oct 2005	Dec 2001
35.2731602	-81.5195712	Mar 1998	Oct 2005	Dec 2001
35.4545548	-83.0526321	Apr 1998	Oct 2005	Dec 2001
35.6298187	-77.3297355	Feb 2008	Oct 2005	Dec 2006
35.35736	-79.232689	Oct 2005	Feb 2006	Dec 2005
35.359794	-79.232588	Oct 2005	Feb 2006	Dec 2005
35.354213	-79.232828	Oct 2005	Feb 2006	Dec 2005
35.384569	-79.231254	Oct 2005	Feb 2006	Dec 2005
35.380982	-79.231367	Oct 2005	Feb 2006	Dec 2005
34.6166851	-78.643983	Oct 2005	Jul 2006	Feb 2006
34.208479	-78.032292	Oct 2005	Jul 2006	Feb 2006
34.212374	-78.025419	Oct 2005	Jul 2006	Feb 2006
34.213862	-78.022814	Oct 2005	Jul 2006	Feb 2006
34.21247	-78.025195	Oct 2005	Jul 2006	Feb 2006
34.215033	-78.020807	Oct 2005	Jul 2006	Feb 2006
34.216052	-78.018955	Oct 2005	Jul 2006	Feb 2006
34.215089	-78.020597	Oct 2005	Jul 2006	Feb 2006
34.217118	-78.01726	Oct 2005	Jul 2006	Feb 2006
34.7498079	-76.8389891	Oct 2005	Jul 2006	Feb 2006
35.23826	-79.30496	Oct 2005	Jul 2006	Feb 2006
35.239453	-79.301362	Oct 2005	Jul 2006	Feb 2006
35.236832	-79.308464	Oct 2005	Jul 2006	Feb 2006
35.287524	-79.261879	Oct 2005	Jul 2006	Feb 2006
35.29164	-79.260563	Oct 2005	Jul 2006	Feb 2006
35.284449	-79.262822	Oct 2005	Jul 2006	Feb 2006
35.0211886	-80.5789876	Mar 1998	Jul 2006	May 2002
35.0153214	-80.5710107	Mar 1998	Jul 2006	May 2002
35.006432	-80.561429	Mar 1998	Jul 2006	May 2002
35.911062	-78.783411	Feb 2005	Jul 2006	Oct 2005
34.3124101	-77.7757332	Jul 2006	Dec 2006	Sep 2006
34.3143331	-77.7735928	Jul 2006	Dec 2006	Sep 2006
34.3196698	-77.767885	Jul 2006	Dec 2006	Sep 2006
34.3213578	-77.7658385	Jul 2006	Dec 2006	Sep 2006
34.3241866	-77.7621987	Jul 2006	Dec 2006	Sep 2006
34.3273409	-77.758272	Jul 2006	Dec 2006	Sep 2006
34.31045	-77.778042	Jul 2006	Dec 2006	Sep 2006
34.31227	-77.77596	Jul 2006	Dec 2006	Sep 2006

RCI Latitude	RCI Longitude	Latest Imagery Without RCI	Earliest Imagery with RCI	Midpoint of Dates
34.8022832	-76.8784753	Jul 2006	Jan 2007	Oct 2006
34.811795	-76.8796903	Jul 2006	Jan 2007	Oct 2006
34.9024769	-76.9316447	Jul 2006	Jan 2007	Oct 2006
34.9054026	-76.9336805	Jul 2006	Jan 2007	Oct 2006
34.9082665	-76.9356626	Jul 2006	Jan 2007	Oct 2006
34.21068	-78.02834	Jul 2006	Mar 2007	Oct 2006
35.955123	-78.5408333	Jul 2006	Mar 2007	Oct 2006
35.3176508	-77.8514332	Jul 2006	May 2007	Nov 2006
35.784892	-78.809933	Feb 2005	Jun 2007	Apr 2006
34.3297176	-78.3984107	Jul 2006	Oct 2007	Feb 2007
34.3292635	-78.3956453	Jul 2006	Oct 2007	Feb 2007
34.3301716	-78.4011599	Jul 2006	Oct 2007	Feb 2007
34.1216751	-77.900075	Jul 2006	Oct 2007	Feb 2007
35.941997	-79.018428	Jun 2007	Feb 2008	Oct 2007
35.943144	-79.016111	Jun 2007	Feb 2008	Oct 2007
35.940904	-79.020451	Jun 2007	Feb 2008	Oct 2007
35.7765076	-81.394178	Jul 2006	Mar 2008	May 2007
34.9965042	-80.2316898	Jul 2006	Oct 2008	Aug 2007
34.9970623	-80.2295065	Jul 2006	Oct 2008	Aug 2007
34.9787597	-80.1172346	Jul 2006	Oct 2008	Aug 2007
34.9789135	-80.1048669	Jul 2006	Oct 2008	Aug 2007
36.404241	-81.480383	Jul 2006	Oct 2008	Aug 2007
34.6151267	-78.6426204	Jul 2006	Oct 2008	Aug 2007
34.20116	-78.051735	Oct 2007	Oct 2008	Apr 2008
34.202061	-78.049256	Oct 2007	Oct 2008	Apr 2008
34.200242	-78.054379	Oct 2007	Oct 2008	Apr 2008
34.0071195	-78.3017707	Oct 2007	Oct 2008	Apr 2008
35.3685542	-80.6665081	Jul 2006	Oct 2008	Aug 2007
34.7932593	-76.8772602	Feb 2007	Oct 2008	Dec 2007
34.8051023	-76.8788642	Feb 2007	Oct 2008	Dec 2007
34.7846883	-76.8745136	Jul 2006	Oct 2008	Aug 2007
34.8254539	-76.8760854	Feb 2007	Oct 2008	Dec 2007
34.7582338	-76.8499044		Oct 2008	
35.0648974	-77.0224804	Mar 2007	Oct 2008	Dec 2007
34.8572431	-76.8961416	Mar 2007	Oct 2008	Dec 2007
35.0773795	-77.167553	Mar 2007	Oct 2008	Dec 2007
35.0753797	-77.1721423	Mar 2007	Oct 2008	Dec 2007
34.860569	-76.897359	Mar 2007	Oct 2008	Dec 2007
35.0430152	-78.9877832	Jul 2006	Oct 2008	Aug 2007
35.4523764	-83.0583116	Jul 2006	Oct 2008	Aug 2007
35.4496124	-83.06274	Jul 2006	Oct 2008	Aug 2007

RCI Latitude	RCI Longitude	Latest Imagery Without RCI	Earliest Imagery with RCI	Midpoint of Dates
35.4470254	-83.0656958	Jul 2006	Oct 2008	Aug 2007
35.4480217	-83.0645679	Jul 2006	Oct 2008	Aug 2007
35.014313	-79.158783	Jul 2006	Oct 2008	Aug 2007
35.0101699	-79.1628	Jul 2006	Oct 2008	Aug 2007
35.3849215	-83.2909584	Jul 2006	Oct 2008	Aug 2007
35.3925529	-83.2967895	Jul 2006	Oct 2008	Aug 2007
35.3819431	-83.2882333	Jul 2006	Oct 2008	Aug 2007
35.3884814	-83.2937264	Jul 2006	Oct 2008	Aug 2007
35.3886258	-83.2937425	Jul 2006	Oct 2008	Aug 2007
35.3974025	-83.2965535	Jul 2006	Oct 2008	Aug 2007
35.391777	-83.187403	Jul 2006	Oct 2008	Aug 2007
35.034655	-80.847557	Mar 2007	Oct 2008	Dec 2007
34.9211573	-77.6313043	Jul 2006	Oct 2008	Aug 2007
34.9221778	-77.6372641	Jul 2006	Oct 2008	Aug 2007
34.9206867	-77.6282412	Jul 2006	Oct 2008	Aug 2007
34.7929818	-79.511801	Jul 2006	Oct 2008	Aug 2007
34.7915368	-79.5095748	Jul 2006	Oct 2008	Aug 2007
34.7945633	-79.5142204	Jul 2006	Oct 2008	Aug 2007
34.810685	-79.5541236	Jul 2006	Oct 2008	Aug 2007
35.8850364	-78.5681596	Jun 2007	Oct 2008	Jan 2008
35.91455	-78.780467	Jun 2007	Oct 2008	Jan 2008
33.9551212	-78.4453332	Oct 2008	Sep 2009	Mar 2009
34.6058859	-78.6300194	Oct 2008	Oct 2009	Apr 2009
34.6053252	-78.6026609	Oct 2008	Oct 2009	Apr 2009
34.9000638	-78.8526106	Oct 2008	Oct 2009	Apr 2009
34.8881971	-78.8488126	Oct 2008	Oct 2009	Apr 2009
34.8848396	-78.8482225	Oct 2008	Oct 2009	Apr 2009
34.895015	-78.8500679	Oct 2008	Oct 2009	Apr 2009
34.895103	-78.8500813	Oct 2008	Oct 2009	Apr 2009
34.9048449	-78.8549133	Oct 2008	Oct 2009	Apr 2009
34.134761	-77.894853	Oct 2008	Oct 2009	Apr 2009
34.131471	-77.896312	Oct 2008	Oct 2009	Apr 2009
34.137134	-77.89434	Oct 2008	Oct 2009	Apr 2009
35.2540259	-80.4597366	Oct 2008	Oct 2009	Apr 2009
35.2536141	-80.4621828	Oct 2008	Oct 2009	Apr 2009
34.836477	-80.429127	Oct 2008	Oct 2009	Apr 2009
34.840941	-80.431753	Oct 2008	Oct 2009	Apr 2009
35.47767	-81.012845		Apr 2010	
35.475063	-81.011935		Apr 2010	
35.481382	-81.013869		Apr 2010	
35.515753	-81.023906		Apr 2010	

RCI Latitude	RCI Longitude	Latest Imagery Without RCI	Earliest Imagery with RCI	Midpoint of Dates
35.517127	-81.026822		Apr 2010	
35.513879	-81.020003		Apr 2010	
34.876299	-80.451456	Oct 2008	Apr 2010	Jul 2009
34.87923	-80.453175	Oct 2008	Apr 2010	Jul 2009
34.89466	-80.461906	Oct 2009	Apr 2010	Dec 2009
34.892486	-80.460651	Oct 2008	Apr 2010	Jul 2009
34.896924	-80.463257	Oct 2008	Apr 2010	Jul 2009
34.911257	-80.471362	Oct 2008	Apr 2010	Jul 2009
34.908901	-80.469962	Oct 2008	Apr 2010	Jul 2009
34.913617	-80.472764	Oct 2008	Apr 2010	Jul 2009
34.9242956	-80.4789707	Oct 2008	Apr 2010	Jul 2009
34.9242076	-80.4790699	Oct 2008	Apr 2010	Jul 2009
34.9336173	-80.4850566	Oct 2008	Apr 2010	Jul 2009
34.9337449	-80.4848877	Oct 2008	Apr 2010	Jul 2009
34.944321	-80.4914054	Oct 2008	Apr 2010	Jul 2009
34.9459963	-80.4923576	Oct 2008	Apr 2010	Jul 2009
34.946126	-80.4923576	Oct 2008	Apr 2010	Jul 2009
34.953968	-80.4973224	Oct 2008	Apr 2010	Jul 2009
34.9559861	-80.498524	Oct 2008	Apr 2010	Jul 2009
34.6049962	-78.6268839	Apr 2010	May 2010	Apr 2010
34.604707	-78.6054933	Oct 2009	May 2010	Jan 2010
33.9546784	-78.4482327	Oct 2008	Oct 2010	Oct 2009
34.434703	-77.631479	Oct 2009	May 2011	Jul 2010
34.4322197	-77.6339811	Oct 2009	May 2011	Jul 2010
34.8288028	-76.8776411	Oct 2008	Jun 2011	Jan 2010
35.0854239	-77.148913	Oct 2010	Jun 2011	Jan 2011
35.0842277	-77.1516502	Oct 2010	Jun 2011	Jan 2011
35.0867781	-77.1457493	Oct 2010	Jun 2011	Jan 2011
35.262081	-79.048632	Oct 2009	Jun 2011	Aug 2010
34.838734	-80.430476	Oct 2009	Jun 2011	Aug 2010
34.873632	-80.450063	Apr 2010	Jun 2011	Oct 2010
35.4452347	-83.0677463	Oct 2009	Aug 2011	Aug 2010
35.526531	-83.028896	Oct 2008	Aug 2011	Mar 2010
35.5309908	-83.0289106	Oct 2009	Aug 2011	Aug 2010
35.5222886	-83.0282588	Oct 2009	Aug 2011	Aug 2010
35.359255	-79.791642	Oct 2009	Aug 2011	Aug 2010
34.1594589	-77.8918406	Oct 2010	Aug 2011	Mar 2011
34.1540987	-77.892074	Oct 2010	Aug 2011	Mar 2011
34.1519434	-77.8921679	Oct 2010	Aug 2011	Mar 2011
34.1484763	-77.892302	Oct 2010	Aug 2011	Mar 2011
34.1673221	-77.8915107	Oct 2010	Aug 2011	Mar 2011

RCI Latitude	RCI Longitude	Latest Imagery Without RCI	Earliest Imagery with RCI	Midpoint of Dates
34.142296	-77.892984	Oct 2010	Aug 2011	Mar 2011
34.031585	-78.257247	Feb 2011	Sep 2011	May 2011
34.033668	-78.2556689	Feb 2011	Sep 2011	May 2011
34.0291245	-78.2590377	Feb 2011	Sep 2011	May 2011
35.254503	-79.032884	Jun 2011	Oct 2011	Aug 2011
35.253309	-79.030341	Jun 2011	Oct 2011	Aug 2011
35.259874	-79.043751	Jun 2011	Oct 2011	Aug 2011
35.648872	-78.84615	Jul 2010	Oct 2011	Feb 2011
35.8997666	-78.4970891	Jul 2010	Oct 2011	Feb 2011
35.9016394	-78.4848261	Jul 2010	Oct 2011	Feb 2011
35.8976026	-78.502593	Jul 2010	Oct 2011	Feb 2011
35.8927245	-78.5149017	Jul 2010	Oct 2011	Feb 2011
34.8671611	-76.8997264	Jun 2011	Dec 2011	Aug 2011
34.8658561	-76.8991041	Jun 2011	Dec 2011	Aug 2011
34.692151	-77.478491	Jun 2010	Dec 2011	Mar 2011
36.04975	-80.25964	Jul 2010	Feb 2012	Apr 2011
34.6233511	-78.6492321	Dec 2011	Aug 2012	Apr 2012
34.6257062	-78.6512035	Dec 2011	Aug 2012	Apr 2012
34.6284077	-78.6534405	Dec 2011	Aug 2012	Apr 2012
35.377449	-80.656839	Apr 2010	Aug 2012	Jun 2011
35.749241	-80.765169	Oct 2009	Oct 2012	Apr 2011
36.475047	-80.584338	Oct 2009	Oct 2012	Apr 2011
34.193181	-78.071672	Aug 2011	Jan 2013	Apr 2012
34.0107103	-78.2915515	Sep 2011	Jan 2013	May 2012
34.0383846	-78.2489848	Sep 2011	Jan 2013	May 2012
34.0393514	-78.2467586	Sep 2011	Jan 2013	May 2012
34.1568665	-77.8919452	Aug 2011	Jan 2013	Apr 2012
34.0734818	-77.895534	Aug 2011	Jan 2013	Apr 2012
34.0695559	-77.8967437	Aug 2011	Jan 2013	Apr 2012
34.1838429	-77.8908187	Aug 2011	Jan 2013	Apr 2012
34.179292	-77.8910387	Aug 2011	Jan 2013	Apr 2012
34.1905679	-77.8899765	Aug 2011	Jan 2013	Apr 2012
35.202386	-78.078227	Apr 2010	Feb 2013	Sep 2011
34.7450221	-76.8299447	Dec 2011	Mar 2013	Jul 2012
35.454408	-80.809543	Apr 2010	Apr 2013	Oct 2011
35.254757	-80.454475	Feb 2013	Apr 2013	Mar 2013
35.254606	-80.457385	Feb 2013	Apr 2013	Mar 2013
35.009477	-80.563022	Apr 2010	Apr 2013	Oct 2011
35.651489	-78.84742	Oct 2011	Apr 2013	Jul 2012
35.653518	-78.84789	Oct 2011	Apr 2013	Jul 2012
35.657624	-78.848567	Oct 2011	Apr 2013	Jul 2012

RCI Latitude	RCI Longitude	Latest Imagery Without RCI	Earliest Imagery with RCI	Midpoint of Dates
35.653731	-78.84792	Oct 2011	Apr 2013	Jul 2012
35.660522	-78.847971	Oct 2011	Apr 2013	Jul 2012
35.662867	-78.846062	Oct 2011	Apr 2013	Jul 2012
35.660665	-78.847791	Oct 2011	Apr 2013	Jul 2012
35.7441895	-78.8240021	Oct 2011	Apr 2013	Jul 2012
35.135244	-78.876222	Oct 2011	May 2013	Jul 2012
35.141633	-78.873465	Oct 2011	May 2013	Jul 2012
35.142486	-78.873087	Oct 2011	May 2013	Jul 2012
35.144694	-78.872236	Oct 2011	May 2013	Jul 2012
35.150303	-78.870767	Oct 2011	May 2013	Jul 2012
35.151962	-78.870353	Oct 2011	May 2013	Jul 2012
35.261006	-79.046226	Oct 2011	May 2013	Jul 2012
35.439108	-79.217619	Oct 2009	May 2013	Jul 2011
34.6404486	-78.6724117	Aug 2012	Oct 2013	Mar 2013
34.6419094	-78.6757913	Aug 2012	Oct 2013	Mar 2013
34.6431452	-78.6788329	Aug 2012	Oct 2013	Mar 2013
35.577528	-81.074925		Nov 2013	
35.572479	-81.074126		Nov 2013	
35.578971	-81.075894		Nov 2013	
35.282775	-81.5553412	Apr 2011	Nov 2013	Jul 2012
35.2641685	-81.4732736	Apr 2011	Nov 2013	Jul 2012
35.2629202	-81.4688426	Apr 2011	Nov 2013	Jul 2012
35.2638488	-81.4722383	Apr 2011	Nov 2013	Jul 2012
35.0123931	-79.1603807	Sep 2011	Nov 2013	Oct 2012
35.0192556	-79.154622	Jul 2006	Nov 2013	Mar 2010
35.0217575	-79.1513819	Oct 2009	Nov 2013	Oct 2011
35.0234137	-79.1493031	Oct 2009	Nov 2013	Oct 2011
35.0022081	-80.2103019	Mar 2012	Dec 2013	Jan 2013
35.0023399	-80.2073622	Mar 2012	Dec 2013	Jan 2013
35.0023882	-80.2059245	Mar 2012	Dec 2013	Jan 2013
35.0024893	-80.2028561	Mar 2012	Dec 2013	Jan 2013
35.002709	-80.198999	Mar 2012	Dec 2013	Jan 2013
35.0027178	-80.1968265	Mar 2012	Dec 2013	Jan 2013
35.0027178	-80.194509	Mar 2012	Dec 2013	Jan 2013
34.7476789	-76.8356511	Mar 2013	Apr 2014	Sep 2013
34.194458	-78.069254	Jan 2013	Oct 2014	Nov 2013
34.196069	-78.066229	Jan 2013	Oct 2014	Nov 2013
35.4027109	-80.701189	Nov 2013	Oct 2014	Apr 2014
35.4037702	-80.7043152	Aug 2012	Oct 2014	Aug 2013
35.4020878	-80.6939323	Nov 2013	Oct 2014	Apr 2014
35.403134	-80.6919689	Nov 2013	Oct 2014	Apr 2014

RCI Latitude	RCI Longitude	Latest Imagery Without RCI	Earliest Imagery with RCI	Midpoint of Dates
35.4087907	-80.7165554	Apr 2013	Oct 2014	Dec 2013
35.4056208	-80.7087985	Nov 2013	Oct 2014	Apr 2014
35.4048294	-80.7067949	Nov 2013	Oct 2014	Apr 2014
35.4031941	-80.6917208	Nov 2013	Oct 2014	Apr 2014
34.4368499	-77.6296976	Mar 2013	Oct 2014	Dec 2013
35.0390777	-79.0004285	Jun 2013	Nov 2014	Feb 2014
35.913475	-78.450046	Jun 2014	May 2015	Nov 2014
35.915158	-78.448199	Jun 2014	May 2015	Nov 2014
35.911838	-78.451823	Jun 2014	May 2015	Nov 2014
35.9001403	-78.4787375	Jun 2014	May 2015	Nov 2014
35.9022087	-78.4874922	Jun 2014	May 2015	Nov 2014
35.900753	-78.4813607	Jun 2014	May 2015	Nov 2014
35.8995667	-78.4761196	Jun 2014	May 2015	Nov 2014
35.9287496	-78.4364015	Jun 2014	May 2015	Nov 2014
35.9268513	-78.4378499	Jun 2014	May 2015	Nov 2014
35.9306738	-78.434996	Jun 2014	May 2015	Nov 2014
35.9376018	-78.4282798	Jun 2014	May 2015	Nov 2014
35.9357515	-78.4298033	Jun 2014	May 2015	Nov 2014
35.4358305	-80.6606206	Nov 2013	Jun 2015	Aug 2014
35.4358764	-80.6648853	Nov 2013	Jun 2015	Aug 2014
35.3998359	-78.8157544	May 2013	Oct 2015	Jul 2014
35.4024158	-78.8148692	May 2013	Oct 2015	Jul 2014
35.404068	-78.814429	May 2013	Oct 2015	Jul 2014
35.3026325	-81.9181737	Nov 2013	Oct 2015	Oct 2014
35.2996225	-81.9153465	Nov 2013	Oct 2015	Oct 2014
35.2966239	-81.9125523	Nov 2013	Oct 2015	Oct 2014
35.2945419	-81.9105888	Nov 2013	Oct 2015	Oct 2014
35.7459963	-78.8302758	May 2015	Apr 2016	Oct 2015
35.863717	-78.710783	May 2015	Apr 2016	Oct 2015
35.4074244	-80.7133555	Nov 2013	Oct 2016	Apr 2015
35.6441624	-78.8409966	Apr 2016	Oct 2016	Jul 2016
35.6412198	-78.8368607	Apr 2016	Oct 2016	Jul 2016
36.4512512	-76.8624651	Oct 2014	Apr 2017	Dec 2015
36.4495899	-76.864568	Oct 2014	Apr 2017	Dec 2015
36.448058	-76.8666494	Oct 2014	Apr 2017	Dec 2015
36.44625	-76.869404	Oct 2014	Apr 2017	Dec 2015
36.4440923	-76.8719333	Oct 2014	Apr 2017	Dec 2015
36.4422713	-76.8743473	Oct 2014	Apr 2017	Dec 2015
36.4401869	-76.8770564	Oct 2014	Apr 2017	Dec 2015
36.4391425	-76.8811601	Oct 2014	Apr 2017	Dec 2015
36.4346369	-76.8905935	Oct 2014	Apr 2017	Dec 2015

RCI Latitude	RCI Longitude	Latest Imagery Without RCI	Earliest Imagery with RCI	Midpoint of Dates
36.4294663	-76.8990934	Oct 2014	Apr 2017	Dec 2015
36.4277204	-76.9006303	Oct 2014	Apr 2017	Dec 2015
36.4242652	-76.9045383	Oct 2014	Apr 2017	Dec 2015
36.4199227	-76.9103506	Oct 2014	Apr 2017	Dec 2015
36.4181572	-76.9126627	Oct 2014	Apr 2017	Dec 2015
36.4171254	-76.9141406	Oct 2014	Apr 2017	Dec 2015
36.4123509	-76.920476	Oct 2014	Apr 2017	Dec 2015
36.4110212	-76.9223589	Oct 2014	Apr 2017	Dec 2015
36.4089705	-76.9249982	Oct 2014	Apr 2017	Dec 2015
36.3997007	-76.9553125	Oct 2014	Apr 2017	Dec 2015
36.3998821	-76.9586867	Oct 2014	Apr 2017	Dec 2015
36.400452	-76.9631606	Oct 2014	Apr 2017	Dec 2015
36.4023043	-76.9721889	Oct 2014	Apr 2017	Dec 2015
36.4028052	-76.975413	Oct 2014	Apr 2017	Dec 2015
36.4047697	-76.9816679	Oct 2014	Apr 2017	Dec 2015
36.4059699	-76.9969779	Oct 2014	Apr 2017	Dec 2015
36.4072954	-77.0090103	Oct 2014	Apr 2017	Dec 2015
36.4080941	-77.0115101	Oct 2014	Apr 2017	Dec 2015
36.4086726	-77.0138597	Oct 2014	Apr 2017	Dec 2015
36.4091043	-77.0165741	Oct 2014	Apr 2017	Dec 2015
36.415675	-77.0244277	Oct 2014	Apr 2017	Dec 2015
36.4176478	-77.026611	Oct 2014	Apr 2017	Dec 2015
36.4240968	-77.0329463	Oct 2014	Apr 2017	Dec 2015
36.4260176	-77.0348722	Oct 2014	Apr 2017	Dec 2015
36.4270881	-77.0397216	Oct 2014	Apr 2017	Dec 2015
36.4267514	-77.048589	Oct 2014	Apr 2017	Dec 2015
36.4262852	-77.0523119	Oct 2014	Apr 2017	Dec 2015
36.4263543	-77.0593607	Oct 2014	Apr 2017	Dec 2015
36.4268679	-77.0694083	Oct 2014	Apr 2017	Dec 2015
36.4266823	-77.0742846	Oct 2014	Apr 2017	Dec 2015
35.6426977	-78.8389474	Oct 2016	May 2017	Jan 2017
35.3466201	-80.6087529	Oct 2016	Sep 2017	Mar 2017
35.3443667	-80.6103825	Oct 2016	Sep 2017	Mar 2017
35.3596932	-80.5937581	Sep 2017	Mar 2018	Nov 2017
34.1194701	-77.9003137	Oct 2016	Apr 2018	Jul 2017
35.3588882	-80.596738	Sep 2018	Aug 2019	Feb 2019
35.0591276	-79.0073667	Sep 2018	Dec 2019	Apr 2019
35.0589915	-79.0065406	Sep 2018	Dec 2019	Apr 2019
35.4143903	-80.613151	Aug 2019		
34.1611744	-77.9140454	Jun 2015	Oct 2016	Jan 2016
34.1582159	-77.9111553	Jun 2015	Oct 2016	Jan 2016

RCI Latitude	RCI Longitude	Latest Imagery Without RCI	Earliest Imagery with RCI	Midpoint of Dates
34.1541409	-77.9072006	Oct 2016	Apr 2018	Jul 2017
34.1519841	-77.9051134	Oct 2016	Oct 2018	Oct 2017
34.1491088	-77.9023195	Oct 2016	Apr 2018	Jul 2017
34.1459078	-77.8992108	Oct 2016	Apr 2018	Jul 2017
34.1647239	-77.9174862	Oct 2010	Aug 2011	Mar 2011
34.1298148	-77.8972659	Jun 2015	Apr 2018	Oct 2016
34.1156264	-77.9007043	Oct 2016	Apr 2018	Jul 2017
34.1179222	-77.9004619	Oct 2016	Apr 2018	Jul 2017
34.1008671	-77.899211	Oct 2016	Apr 2018	Jul 2017
34.0972427	-77.898547	Oct 2016	Apr 2018	Jul 2017
34.091441	-77.8969334	Jun 2015	Oct 2016	Jan 2016
34.0856303	-77.8957798	Jun 2015	Oct 2016	Jan 2016
34.0807344	-77.8947899	Jun 2015	Oct 2016	Jan 2016
34.0765489	-77.89457	Jun 2015	Oct 2016	Jan 2016
35.1575502	-80.7340297			Pre 1993
35.1543774	-80.7306971			Pre 1993
35.151248	-80.7279264			Pre 1998
35.1478289	-80.7248606			Pre 1998
35.1436947	-80.7212718			Pre 1998
35.1399068	-80.7179351	Jan 1993	Mar 1998	Aug 1995
35.1388715	-80.7170285	Jan 1993	Mar 1998	Aug 1995
35.0764387	-80.6527007	Sep 2018	Aug 2019	Feb 2019
35.0738096	-80.6498719	Mar 2018	Sep 2018	Jun 2018
35.0781034	-80.654436	Oct 2005	Jul 2006	Feb 2006
35.0802903	-80.6567731			Pre 1998
35.0817346	-80.6583328	Jan 1993	Mar 1998	Aug 1995
35.0838483	-80.6605791	Aug 2019	Jan 2021	Apr 2020
35.0706481	-80.6464577			Pre 1998
35.0701783	-80.6459025	Mar 2018	Sep 2018	Jun 2018
35.0681279	-80.6431801	Sep 2018	Sep 2018	Sep 2018
35.0660774	-80.6402967	Mar 2018	Sep 2018	Jun 2018
35.0647624	-80.6385372	Sep 2017	Mar 2018	Nov 2017
35.0640774	-80.6376145	Sep 2017	Mar 2018	Nov 2017
35.062251	-80.6351122	Mar 2018	Sep 2018	Jun 2018
35.0603651	-80.632489	Mar 2018	Sep 2018	Jun 2018
35.0571025	-80.6280741	Apr 2002	Oct 2005	Dec 2003
35.0547554	-80.6248581	Feb 2007	Oct 2008	Dec 2007
35.0378529	-80.6017503	Aug 2019	Jan 2021	Apr 2020
35.0393813	-80.6038317	Aug 2019	Jan 2021	Apr 2020
35.0355513	-80.5986175	Sep 2018	Aug 2019	Feb 2019
35.0313021	-80.5928115			Pre 1998

RCI Latitude	RCI Longitude	Latest Imagery Without RCI	Earliest Imagery with RCI	Midpoint of Dates
35.0249478	-80.5841431	Jun 2015	Oct 2016	Jan 2016
35.0140811	-80.5692944	Jun 2015	Oct 2016	Jan 2016
34.9965316	-80.5450311	Oct 2016	Sep 2017	Mar 2017
34.9913756	-80.5352075	Oct 2016	Sep 2017	Mar 2017
34.9729401	-80.5146548	Mar 1998	Oct 2005	Dec 2001
34.9736759	-80.5118704	Mar 1998	Oct 2005	Dec 2001
34.9750672	-80.5067554	Mar 1998	Oct 2005	Dec 2001
34.9768386	-80.500229	Mar 1998	Oct 2005	Dec 2001
34.977555	-80.4975414	Sep 2017	Mar 2018	Nov 2017
34.9783242	-80.4947948	Sep 2017	Mar 2018	Nov 2017
34.9790143	-80.4922253	Sep 2017	Mar 2018	Nov 2017
34.9793088	-80.4906911	Sep 2017	Mar 2018	Nov 2017
34.9796824	-80.4882395	Sep 2017	Mar 2018	Nov 2017
34.9800736	-80.4855251	Sep 2017	Mar 2018	Nov 2017
34.9804296	-80.4831809	Sep 2017	Mar 2018	Nov 2017
34.984671	-80.3953543	Nov 2014	Sep 2018	Oct 2016
35.346627	-80.6087589	Oct 2016	Sep 2017	Mar 2017
35.3443618	-80.6104061	Oct 2016	Sep 2017	Mar 2017

Appendix B – Remote Sensing Analysis Materials

Table 18: Holly Springs, NC: Hwy 55-Bypass and Avent Ferry Rd

	Multitenant	Big Box
Control Pre-Install Trend	0.121	-0.0430**
	(1.00)	(-2.04)
Control Post-Install Trend	-0.101	0.0565*
	(-0.59)	(1.93)
Impacted Pre-Install Trend	-0.127	-0.441**
	(-0.75)	(-2.30)
Impacted Post-Install Trend	0.951***	1.031***
	(3.22)	(4.57)
Initial Effect on Control	-1.829	0.526*
	(-0.70)	(1.67)
Initial Effect on Impacted	-1.764	3.137
	(-0.43)	(1.15)
Intercept for Control	-0.558	-0.289
	(-0.32)	(-1.35)
Treated Intercept Difference	1.108	-4.916**
	(0.46)	(-2.24)
N	98	98
R^2	0.455	0.403

t statistics in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Figure 55: RCI Grocery v. Control Grocery 1

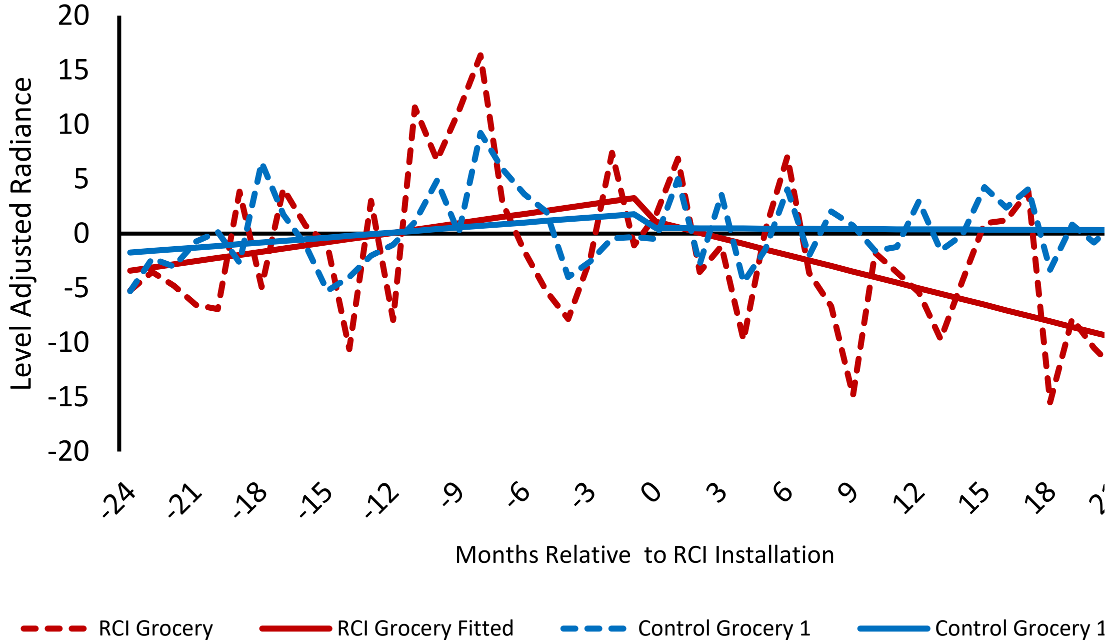


Figure 56: RCI Grocery v. Control Grocery 2

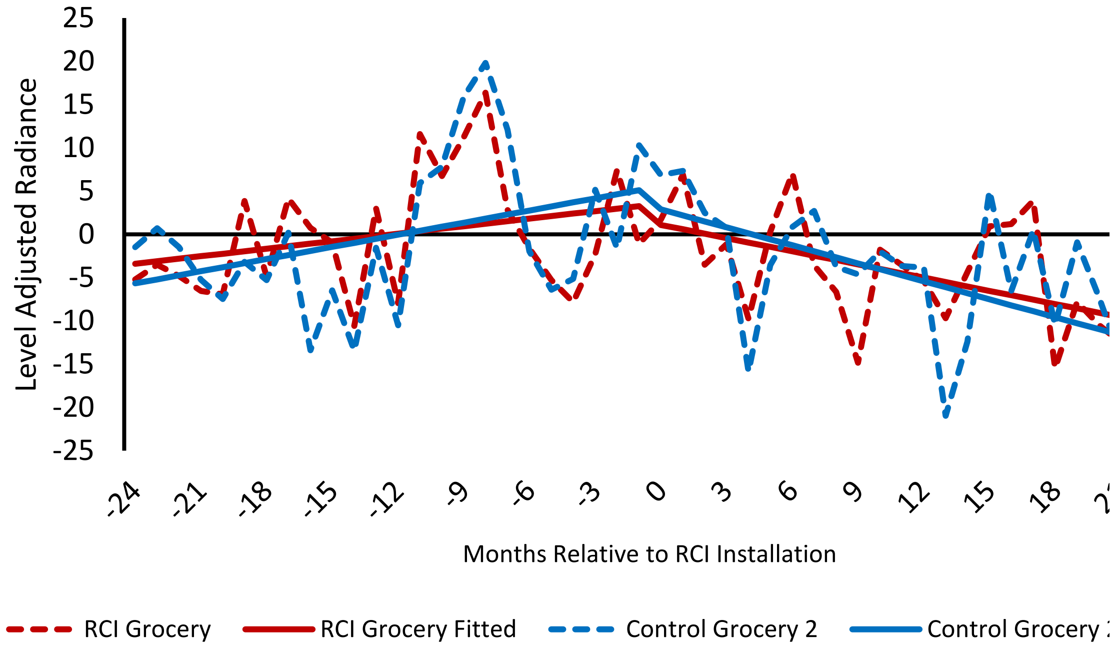


Table 19: Indian Trail, NC: Highway 74 and Faith Church Rd - Grocery Store

	Same Company	Competitor
Control Pre-Install Trend	0.153	0.468**
	(1.58)	(2.50)
Control Post-Install Trend	-0.162	-1.161***
	(-1.29)	(-4.39)
Impacted Pre-Install Trend	0.136	-0.179
	(0.74)	(-0.73)
Impacted Post-Install Trend	-0.635**	0.363
	(-2.51)	(1.06)
Initial Effect on Control	-1.421	-1.994
	(-0.69)	(-0.46)
Initial Effect on Impacted	-0.531	0.0428
	(-0.13)	(0.01)
Intercept for Control	1.933	5.568
	(1.23)	(1.62)
Treated Intercept Difference	1.615	-2.020
	(0.48)	(-0.45)
N	96	96
R^2	0.275	0.288

t statistics in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Table 20: Indian Trail, NC: Highway 74 and Faith Church Rd - Grocery Store

	Same Company and Competitor
Contr. Not Aff. by Entrant Pre-Install Trend	0.153
	(1.58)
Control Not Aff. by entrant Post-Install Trend	-0.162
	(-1.29)
Contr. Aff. by Entrant Pre Trend	0.315
	(1.50)
Contr. Aff. by Entrant Post Trend	-0.999***
	(-3.41)
Impacted Pre-Install Trend	0.136
	(0.74)
Impacted Post-Install Trend	-0.635**
	(-2.51)
Init. Eff. on Contr. Not Aff. by Entrant	-1.421
	(-0.69)
Initial Effect on Contr. Aff. by Entrant	-0.574
	(-0.12)
Initial Effect on Impacted	-0.531
	(-0.13)
Contr. Intercept Not Aff. by New Entrant	1.933
	(1.23)
Contr. Intercept Aff. by New Entrant	3.635
	(0.96)
Treated Intercept Difference	1.615
	(0.48)
N	144
R^2	0.297

t statistics in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Figure 57a: RCI Big Box General Store v. Big Box General Store Control 1

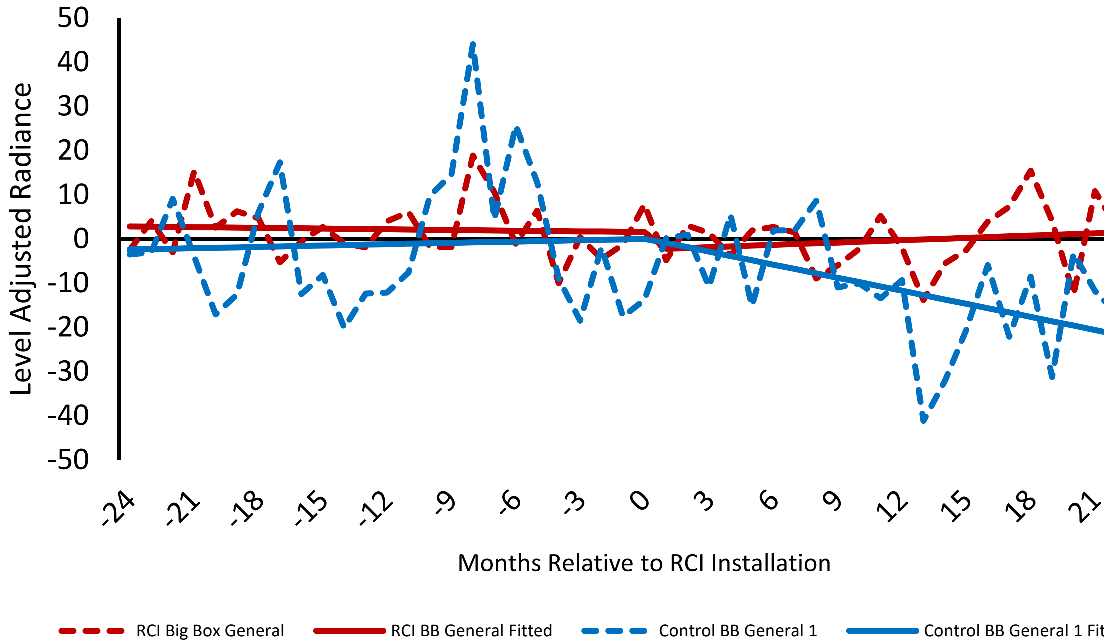


Figure 57b: RCI Big Box General Store v. Big Box General Store Control 2

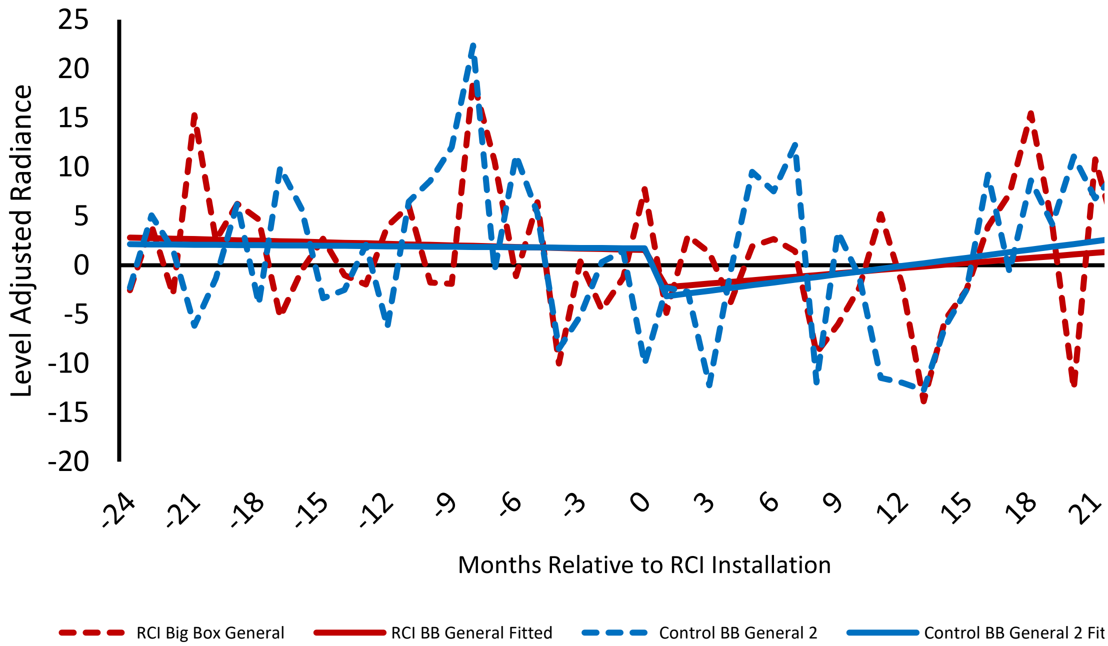


Figure 57c: RCI Big Box General Store v. Big Box General Store Control 3

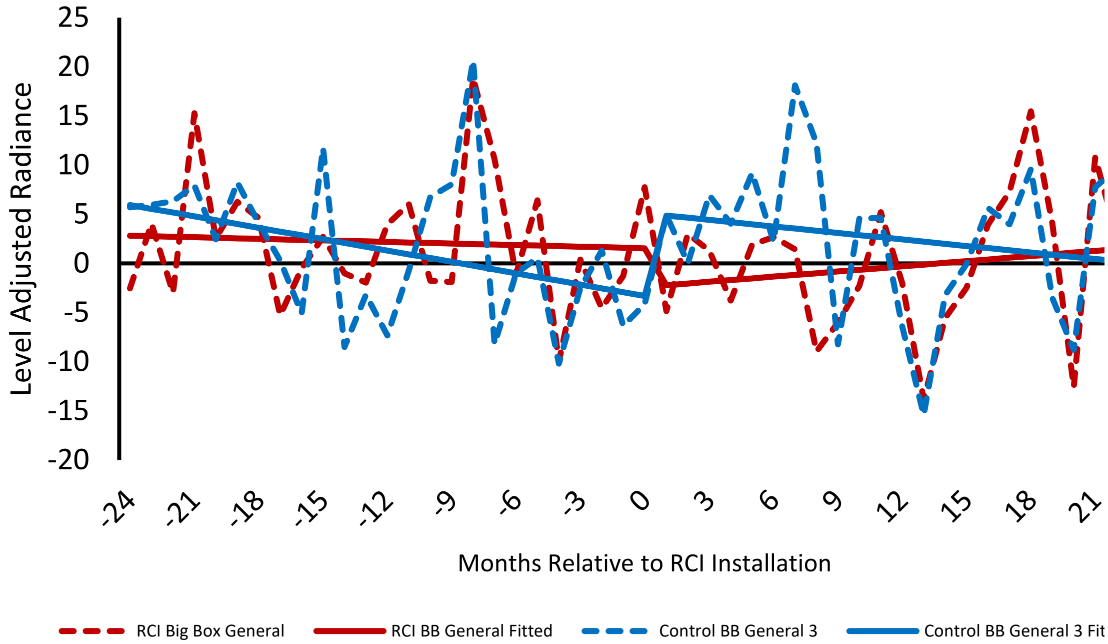


Figure 57d: RCI Big Box General Store v. Big Box General Store Control 4

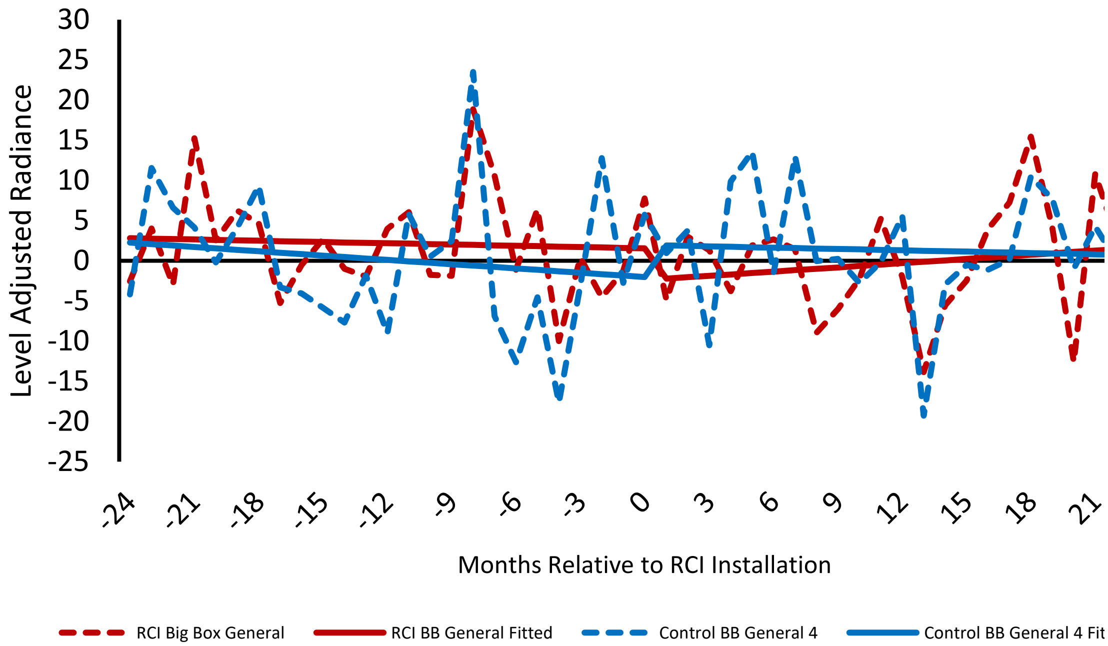


Table 21: Indian Trail, NC: Highway 74 and Wesley Chapel Stouts Rd - Home Improvement Store

	Same Company Closer In	Competitor Closer In	Same Company Further Out
Control Pre-Install Trend	0.0546	-0.0392	-0.0386
	(0.16)	(-0.13)	(-0.17)
Control Post-Install Trend	-0.316	-0.139	0.410
	(-0.77)	(-0.38)	(1.32)
Impacted Pre-Install Trend	0.324	0.418	0.417
	(0.80)	(1.16)	(1.33)
Impacted Post-Install Trend	-0.431	-0.608	-1.157***
	(-0.86)	(-1.32)	(-2.75)
Initial Effect on Control	0.798	-4.642	-4.311
	(0.14)	(-1.02)	(-1.10)
Initial Effect on Impacted	-1.898	3.542	3.211
	(-0.27)	(0.57)	(0.56)
Intercept for Control	2.056	1.127	0.827
	(0.44)	(0.28)	(0.27)
Treated Intercept Difference	1.087	2.016	2.316
	(0.20)	(0.41)	(0.55)
N	98	98	98
R^2	0.102	0.181	0.150

t statistics in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Table 22: Indian Trail, NC: Highway 74 and Wesley Chapel Stouts Rd - Home Improvement Store

	Competitor 1	Competitor 2	Competitor 3	Same Company 1	Same Company 2
Control Pre-Install Trend	0.484**	0.0386	-0.0986	0.0213	-0.113
	(1.99)	(0.14)	(-0.46)	(0.11)	(-0.82)
Control Post-Install Trend	-0.863**	-0.199	-0.278	-0.188	-0.207
	(-2.58)	(-0.56)	(-0.97)	(-0.81)	(-0.85)
Impacted Pre-Install Trend	-0.105	0.340	0.477	0.357	0.492*
	(-0.33)	(0.98)	(1.59)	(1.26)	(1.96)
Impacted Post-Install Trend	0.116	-0.548	-0.469	-0.559	-0.540
	(0.26)	(-1.21)	(-1.17)	(-1.52)	(-1.44)
Initial Effect on Control	-9.541**	-1.388	3.557	-2.761	0.581
	(-2.12)	(-0.28)	(0.85)	(-0.76)	(0.18)
Initial Effect on Impacted	8.440	0.287	-4.657	1.660	-1.682
	(1.37)	(0.04)	(-0.78)	(0.30)	(-0.32)
Intercept for Control	6.218*	1.677	-0.195	2.186	0.525
	(1.72)	(0.40)	(-0.06)	(0.76)	(0.28)
Treated Intercept Difference	-3.075	1.466	3.339	0.957	2.618
	(-0.67)	(0.29)	(0.79)	(0.24)	(0.76)
N	98	98	98	98	98
R^2	0.279	0.116	0.140	0.173	0.193

t statistics in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Table 23: Concord, NC: Highway 49 and Stough Rd - Industrial - Single Series

	Single Series
Pre-Install Trend	-0.262***
	(-2.87)
Post-Install Trend	0.178
	(1.07)
Shift at Installation	2.767
	(1.02)
Intercept	-0.305
	(-0.21)
N	49
R^2	0.119

t statistics in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Table 24: Concord, NC: Highway 49 and Stough Rd - Industrial - Multi Series

	Control 1
Control Pre-Install Trend	0.00568
	(0.04)
Control Post-Install Trend	0.100
	(0.56)
Impacted Pre-Install Trend	-0.268*
	(-1.70)
Impacted Post-Install Trend	0.0773
	(0.32)
Initial Effect on Control	-6.422***
	(-2.89)
Initial Effect on Impacted	9.189**
	(2.62)
Intercept for Control	1.758
	(1.08)
Treated Intercept Difference	-2.063
	(-0.94)
N	98
R^2	0.245

t statistics in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Appendix C – Business Survey

Business Survey

This survey is part of a research collaboration between the University of North Carolina Wilmington and the North Carolina Department of Transportation to better understand local business' attitudes and opinions about traffic flow and reduced conflict intersections.

Your participation in this study is completely voluntary. You may refuse to participate or refuse to answer any questions you wish not to answer. You may also stop participating at any time without penalty. Your responses are anonymous and you will only be asked for contact information if you wish to participate in the **drawing for a $49 Amazon gift card (in total there will be 10 gift cards given out as prizes)**. Your information for the drawing will not be linked to your survey response. This study has been approved by UNCW's Institutional Review Board 22-0086.

The survey (rrcis) will take approximately 5-7 minutes to complete. There are no right or wrong answers - only honest answers. Data will be aggregated across all respondents. Should you have any questions as you complete the survey, please email jonesat@uncw.edu

To take this survey you must be 18 years of age.

1. Are you 18 years of age?

○ Yes

○ No

2. Have you worked at this business for at least one month?

○ Yes

○ No

Unfortunately you do not qualify for this survey because of your age or how long you have been at your current job. Have a good day.

3. What type of business is your company in?

- ☐ Retail
- ☐ Hospitality (hotels, restaurants, bar, etc.)
- ☐ Apartment Rentals or Real Estate Leasing
- ☐ Medical (hospitals, nursing, clinics, therapy, etc.)
- ☐ Administrative (secretarial, support staff, etc.)
- ☐ Banking / finance
- ☐ Online customer service
- ☐ Logistics
- ☐ Engineering / architecture
- ☐ Software / technology
- ☐ Education
- ☐ Automotive or other mechanical repair
- ☐ Community service

- [ ] Government
- [ ] Manufacturing
- [ ] Gas station
- [ ] Law Practice / Consulting / Accounting
- [ ] Other ____

4. How would you classify your business?

- ○ Local with one location
- ○ Local with multiple locations
- ○ Regional or national chain
- ○ Unsure
- ○ Other ____

5. How long has the business been operating at this location?

◯ less than 2 years

◯ 2 - 5 years

◯ 6 - 10 years

◯ More than 10 years

◯ Not sure ____

6. How many employees currently work at this location? (estimation is fine)

____

7. What is the general location of the business on the street?

◯ Street intersection

◯ Mid-block (between intersections)

To the best of your ability please estimate the following:

8. How many customers does your business serve per day?

◯ 0-20 customers

◯ 21-50 customers

◯ 51-100 customers

◯ 101-200 customers

◯ Over 200 customers

9. What % of your customers do you believe **plan to visit** (rather than visiting on impulse.)

- ◯ 0 - 10%
- ◯ 11% - 25%
- ◯ 26% - 50%
- ◯ 51% - 75%
- ◯ 76% - 100%

10. What time(s) of the day tend to be the busiest for customers coming into your business? (select all that apply)

- ☐ Early morning (before 9:00 AM)
- ☐ Morning (9:00-11:00 AM)
- ☐ Lunchtime (11:00 AM - 1:00 PM)
- ☐ Afternoon (1:00 - 4:00 PM)
- ☐ Late Afternoon (4:00 - 6:00 PM)
- ☐ Evening (After 6:00 PM)
- ☐ Not sure

11. How important do you think the following factors are to customers when choosing to come to your business?

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Distance to travel					
Hours of operation					
Customer service					
Quality of products/services					
Pricing of products/services					
Accessibility of location / ease of access					

The next set of questions will be about your parking.

12. What type of parking lot does your business have?

◯ We have our own parking lot

◯ Shared parking lot

◯ We do not have a parking lot

◯ Other ____

13. Do you consider your parking lot:

- ◯ Non-existent - we do not have a parking lot
- ◯ Very Small (1-5 cars)
- ◯ Small (6-15 cars)
- ◯ Moderate (16-30 cars)
- ◯ Large (over 30 cars)

14. How would you describe your business' parking situation?

- ◯ We always have enough spaces for our employees and customers
- ◯ We usually have enough spaces for our employees and customers
- ◯ We rarely have enough places for our employees and customers

15. How do customers access your parking lot?

- ◯ Customers enter our parking lot from a major street
- ◯ Customers enter from a minor street or frontage road
- ◯ Customers enter the parking lot through neighboring business' parking lot
- ◯ Customers enter shared driveway to enter parking lot
- ◯ Our business does not have designated parking or a parking lot
- ◯ Other ____

The next set of questions will ask about traffic around your business.

16. How often do **CUSTOMERS** complain about difficulty accessing your business because of:

	Never	Rarely	Occasionally	Frequently	Always
Traffic congestion					
Street design					
Parking					

17. How often do **YOU** experience difficulty accessing your business because of:

	Never	Rarely	Occasionally	Frequently	Always
Traffic congestion					
Street design					
Parking					

Please provide any explanations of access issues you feel are appropriate.

____

____

____

____

____

18. On a typical **<u>weekday</u>** how would you classify traffic in the area surrounding your business?

	Not congested / free flowing traffic	Mild Congestion	Heavily Congested
Early Morning (before 9:00 AM)			
Morning (9:00-11:00 AM)			
Lunchtime (11:00 AM - 1:00 PM)			
Afternoon (1:00 - 4:00 PM)			
Late Afternoon (4:00 - 6:00 PM)			
Evening (After 6:00 PM)			

19. On a typical **<u>weekend</u>** how would you classify traffic in the area surrounding your business?

	Not congested / free flowing traffic	Mild Congestion	Heavily Congested
Early Morning (before 9:00 AM)			
Morning (9:00-11:00 AM)			
Lunchtime (11:00 AM - 1:00 PM)			
Afternoon (1:00 - 4:00 PM)			
Late Afternoon (4:00 - 6:00 PM)			
Evening (After 6:00 PM)			

20. Do you have any traffic safety concerns in the area immediately surrounding your business?

○ Yes

○ No

If yes, please explain:

____

____

____

____

____

The following questions will be asking about your general attitudes about traffic flow around your business.

21. To what extent would you say you are **DELIGHTED** with the current traffic flow surrounding your business?

○ Never

○ Sometimes

○ About half the time

○ Most of the time

○ Always

22. To what extent would you say you are **SATISFIED** with the current traffic flow surrounding your business?

- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

23. To what extent do you think your **customers** agree with the following statements:

	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
Customers can get to your location quickly					
Customers can get to your location conveniently					
Customers feel safe entering and exiting my business					

Somewhere near your business is a "Reduced Conflict Intersection" where traffic patterns are limited by medians to increase traffic flow and improve safety. For example, vehicles wanting to turn left, may need to turn right and then do a u-turn. With this RCI in mind please respond to the following statement:

24. Reduced conflict intersections (RCIs) have made it easier for customers to reach my business.

- ◯ Strongly disagree
- ◯ Somewhat disagree
- ◯ Neither agree nor disagree
- ◯ Somewhat agree
- ◯ Strongly agree

With the intersection mentioned above in mind, please share your experiences and/or customer feedback about the intersection.

____

____

____

____

____

The following questions will ask general details about the people taking our survey. The only reason we collect this data is to report summaries of our sample. We will not be able to identify any individual respondent based on these questions.

25. What is your current position?

- ◯ Sales
- ◯ Assistant Manager
- ◯ Manager
- ◯ Owner
- ◯ Other ____

26. How long have you worked in your current position?

- ◯ 0-6 months
- ◯ 7 - 12 months
- ◯ 1-2 years
- ◯ 2-5 years
- ◯ 5+ years

27. How many days per week did you typically work at your business location (pre-covid)?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7

28. Which category best describes your age?

- ◯ 18-25
- ◯ 26-35
- ◯ 36-45
- ◯ 46-55
- ◯ 55-65
- ◯ 65+
- ◯ Prefer not to disclose

29. What is your gender?

- ◯ Male
- ◯ Female
- ◯ Prefer not to disclose
- ◯ Other ____

What is your business's zipcode? (Optional but appreciated)

____

30. What is your ethnicity?

- ◯ White
- ◯ Black or African American
- ◯ American Indian or Alaska Native
- ◯ Asian
- ◯ Native Hawaiian or Pacific Islander
- ◯ Hispanic
- ◯ Prefer not to disclose
- ◯ Other ____

While this survey is anonymous, we'd like to know your business name and address if you are willing to share it with us - but this is OPTIONAL

____

Appendix D – Business Survey Additional Descriptives and Analysis Materials

Table 25: Industry Responses

Industry	Number	%
Retail	86	24
Medical (hospitals, nursing, clinics, therapy, etc.)	40	11
Banking / finance	32	9
Hospitality (hotels, restaurants, bar, etc.)	31	9
Apartment rentals / real estate leasing	25	7
Engineering / architecture	23	6
Software / technology	22	6
Administrative (secretarial, support staff, etc.)	17	5
Online customer service	17	5
Automotive / mechanical repair	12	3
Logistics	11	3
Education	11	3
Manufacturing	10	3
Other	27	7
	364	100

Table 26: Respondent Characteristics

Current Position	**#**	**%**
Manager	99	39
Owner	61	24
Assistant Manager	45	18
Sales	35	14
Other	14	6
	254	100
Length at Current Position		
0-6 months	9	4
7 - 12 months	34	13
1-2 years	63	25
2-5 years	69	27
5+ years	79	31
	254	100
Age		
18-25	20	8
26-35	106	42
36-45	75	30
46-55	31	12
55-65	15	6
65+	6	2
Prefer not to disclose	1	0
	254	100
Gender		
Male	148	59
Female	96	38
Prefer not to disclose	6	2
	250	100
Ethnicity		
White	198	80
African American	26	11
Asian	7	3
American Indian or Alaska Native	6	2
Hispanic	5	2
Prefer not to say	4	2
	246	100

Business Characteristics

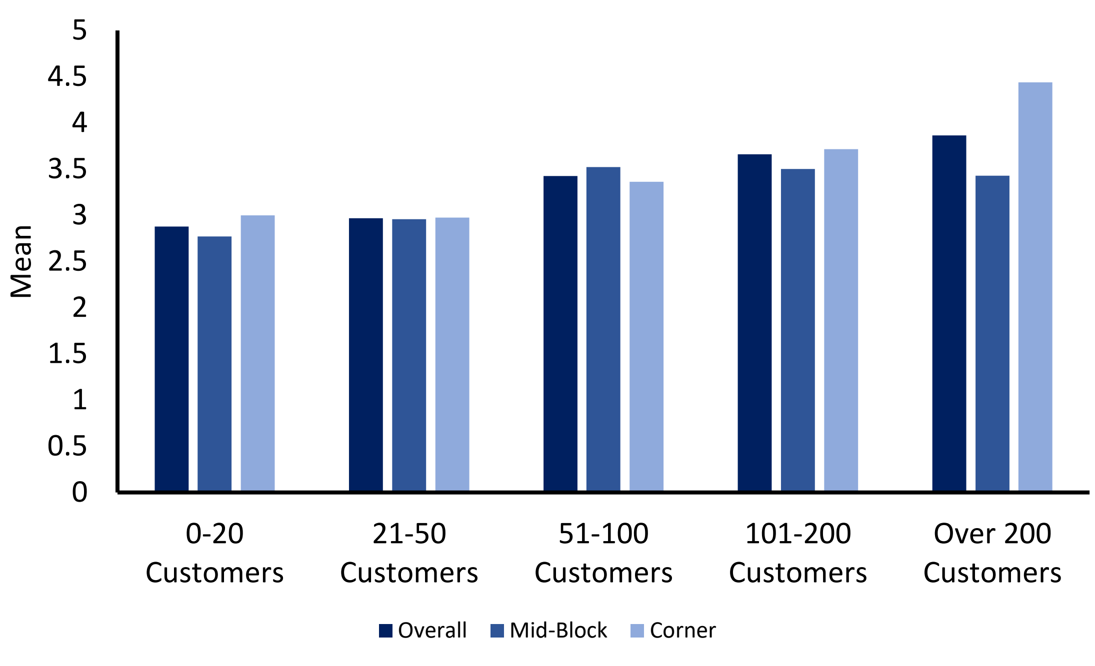
Table 26(con't): Business Characteristics

Business Classification	#	%
Local with one location	118	42
Local with multiple locations	112	40
Regional or national chain	52	18
	282	100
Length at Location		
Less than 2 years	24	9
2 - 5 years	95	34
6 - 10 years	82	29
More than 10 years	79	28
	280	100
Location		
Mid-block (between intersections)	160	57
Street intersection	122	43
	282	100
Customers Per Day		
21-50 customers	67	25
51-100 customers	60	22
101-200 customers	50	19
Over 200 customers	39	14
	269	100
Busiest Time of the Day		
Early morning (before 9:00 AM)	7	6
Morning (9:00-11:00 AM)	39	35
Lunchtime (11:00 AM - 1:00 PM)	20	18
Afternoon (1:00 - 4:00 PM)	32	29
Late Afternoon (4:00 - 6:00 PM)	5	5
Evening (After 6:00 PM)	7	6
	110	100
% Customers Who Plan to Visit (vs. impulse visit)		
0 - 10%	20	7
11% - 25%	44	16
26% - 50%	67	25
51% - 75%	74	28
76% - 100%	64	24
	269	100
# of Employees		
Average	99	
Range	0-5000	
Median	30	
Mode	50	
Standard Deviation	364.32	

Table 27: Traffic Congestion

Traffic safety concerns in the area immediately surrounding their business	#	%
Yes	113	43
No	148	57
	261	100
Traffic congestion on a typical weekday (1=not congested, 2 is mild, 3 is heavily)		
Early Morning (before 9:00 AM)	2.37	
Morning (9:00-11:00 AM)	1.76	
Lunchtime (11:00 AM - 1:00 PM)	1.98	
Afternoon (1:00 - 4:00 PM)	1.84	
Late Afternoon (4:00 - 6:00 PM)	2.14	
Evening (After 6:00 PM)	1.96	
Traffic congestion on a typical weekend (1=not congested, 2 is mild, 3 is heavily)		
Early Morning (before 9:00 AM)	1.67	
Morning (9:00-11:00 AM)	1.80	
Lunchtime (11:00 AM - 1:00 PM)	1.88	
Afternoon (1:00 - 4:00 PM)	1.82	
Late Afternoon (4:00 - 6:00 PM)	1.89	
Evening (After 6:00 PM)	1.83	
How often customers complain about difficulty accessing your business because of (1=never, 5= always):		
Traffic congestion	2.71	
Street design	2.75	
Parking	2.48	

Figure 58: Response to "RCIs have made it easier for customers to reach my business" by number of customers: Overall, Mid-Block, Corner



Strongly Disagree=1, Somewhat Disagree=2, Neither=3, Somewhat Agree=4, Strongly Agree=5

*P<0.10 **P<0.05 ***P<0.01

Appendix E – Residential Survey

Resident Survey

This survey is part of a research collaboration between the University of North Carolina Wilmington and the North Carolina Department of Transportation to better understand attitudes and experiences with traffic flow and reduced conflict intersections.

Your participation in this study is completely voluntary. You may refuse to participate or refuse to answer any questions you wish not to answer. You may also stop participating at any time without penalty. Only completed surveys are eligible for payment. (At the end of the survey you will be given a code to enter for your payment.)

The data you provide will be kept secure once it is in the researcher's possession. However, the researcher cannot guarantee security during transmission of data due to keylogging or other spyware that may exist on the computer you are using. This study has been approved by UNCW's Institutional Review Board XX-XXXX.

The survey (SSN) will take approximately 10-15 minutes to complete. There are no right or wrong answers - only honest answers. Data will be aggregated across all respondents. Should you have any questions as you complete the survey, please email jonesat@uncw.edu.

To take this survey you must be 18 years of age.

1. Are you 18 years of age?

○ Yes

○ No

2. Have you lived at your current residence for at least 3 months?

○ Yes

○ No

3. Please tell us the county where you currently live:

____

4. Please provide the postal (zip) code for the country where you are currently live:

____

5. What is your favorite place to visit in North Carolina?

____

____

____

____

____

6. Please tell us how you typically use the main roads near your home?

- ◯ I use them to commute to and from work or job sites
- ◯ I use them to transport family members, run errands, etc.
- ◯ I use them to to deliver products for my business and for commercial purposes
- ◯ Other. Please explain:

____

7. How many accidents have you had in the past 3 years?

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4 or more

8. Approximately, how many miles per year do you drive? (choose the closest answer)

- ○ Less than 1000 miles
- ○ 3000 miles
- ○ 5000 miles
- ○ 7500 miles
- ○ 10,000 miles
- ○ 15,000 miles
- ○ 20,000 miles
- ○ 25,000 miles
- ○ 30,000 or more miles

9. Which of the following do you do on a regular basis? (Check all that apply)

- ☐ Drive a car
- ☐ Ride a bike or electric bicycle
- ☐ Ride a motorcycle
- ☐ Ride a moped
- ☐ Go for walks

10. Which of the following is your primary mode of transportation?

- ◯ Car
- ◯ Bicycle or Electric Bicycle
- ◯ Motorcycle
- ◯ Moped
- ◯ Walking
- ◯ Public Transit (bus, train, etc.)
- ◯ Other

11. Which of the following do you drive on a regular basis? (check all that apply)

- ☐ Motorcycle
- ☐ Sportscar or convertible
- ☐ 2 Door Sedan or Coupe
- ☐ 4 Door Sedan
- ☐ Small or Mid-size SUV (Rav-4, CRV, etc.)
- ☐ Full Size SUV (Suburban or similar)
- ☐ Small or Mid-size Pickup Truck (Tacoma, Ranger, etc.)
- ☐ Full Size Pickup Truck

- [ ] Work Truck, Dual Rear Axle Truck, etc.
- [ ] Pull a trailer
- [ ] Box Truck or Larger Delivery or Transport Truck

12. In which of the following time ranges do you typically leave for work?

- ○ Before 7:00 AM
- ○ Between 7:00 AM and 7:29 AM
- ○ Between 7:30 AM and 7:59 AM
- ○ Between 8:00 AM and 8:29 AM
- ○ Between 8:30 AM and 8:59 AM
- ○ Between 9:00 AM and 9:29 AM
- ○ Between 9:30 AM and 9:59 AM
- ○ Between 10:00 AM and noon
- ○ Other. Please explain: ________________________________

13. How long is your commute to work? (please choose the closest answer)

- ○ Less than 10 minutes
- ○ 10 minutes
- ○ 15 minutes
- ○ 20 minutes
- ○ 30 minutes
- ○ 45 minutes
- ○ More than 45 minutes

14. How long is the drive from your home, one way, for a typical errand like going to the grocery store? (please choose the closest answer)

- ○ Less than 10 minutes
- ○ 10 minutes
- ○ 15 minutes
- ○ 20 minutes
- ○ 30 minutes
- ○ 45 minutes
- ○ More than 45 minutes

15. Please evaluate your driving characteristics:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

I am a good driver	
I am an impatient driver	
I am a courteous driver	
I am sometimes a distracted driver	

16. While driving and waiting at a light, I _____ play with my phone:

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Usually
- ◯ Always

17. How likely are you to make an unplanned stop, on impulse, for coffee or a snack when:

	Extremely unlikely	Somewhat unlikely	Neither likely nor unlikely	Somewhat likely	Extremely likely
The road you are on is congested and traffic isn't moving?					
The road you are on has moderate traffic and is moving along?					
The road you are on has only light traffic and traffic is moving along at a high rate of speed?					

18. Suppose you are at home and realize you could really use a single item from the grocery store, how likely are you to make the trip if:

	Extremely unlikely	Somewhat unlikely	Neither likely nor unlikely	Somewhat likely	Extremely likely
The roads are congested and you may have to wait through a couple cycles of a light?					
You know traffic on the road is moving but you'll have to make a u-turn around a median to get to the store?					
Traffic is moving but you have to cross a busy four lane highway?					

19. During which time of the day do you most frequently use the major roads near your home?

- ○ Early morning (before 7:00 AM)
- ○ Morning (7:00 AM - 8:59 AM)
- ○ Late morning (9:00-10:59 AM)
- ○ Lunchtime (11:00 AM - 1:59 PM)
- ○ Afternoon (2:00 PM - 3:59 PM)
- ○ Later afternoon (4:00 PM - 5:59 PM)
- ○ Evening (after 6:00 PM)

20. How long is the drive from your home, one way, for a typical errand like going to the grocery store? (please choose the closest answer)

- ○ Less than 10 minutes
- ○ 10 minutes
- ○ 15 minutes
- ○ 20 minutes
- ○ 30 minutes
- ○ 45 minutes
- ○ More than 45 minutes

21. Please evaluate your driving characteristics:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I am a good driver					
I am an impatient driver					
I am a courteous driver					
I am sometimes a distracted driver					

22. While driving and waiting at a light, I _____ play with my phone:

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Usually
- ◯ Always

23. How likely are you to make an unplanned stop, on impulse, for coffee or a snack when:

	Extremely unlikely	Somewhat unlikely	Neither likely nor unlikely	Somewhat likely	Extremely likely
The road you are on is congested and traffic isn't moving?					
The road you are on has moderate traffic and is moving along?					
The road you are on has only light traffic and traffic is moving along at a high rate of speed?					

24. Suppose you are at home and realize you could really use a single item from the grocery store, how likely are you to make the trip if:

	Extremely unlikely	Somewhat unlikely	Neither likely nor unlikely	Somewhat likely	Extremely likely
The roads are congested and you may have to wait through a couple cycles of a light?					
You know traffic on the road is moving but you'll have to make a u-turn around a median to get to the store?					
Traffic is moving but you have to cross a busy four lane highway?					

25. During which time of the day do you most frequently use the major roads near your home?

- ◯ Early morning (before 7:00 AM)
- ◯ Morning (7:00 AM - 8:59 AM)
- ◯ Late morning (9:00-10:59 AM)
- ◯ Lunchtime (11:00 AM - 1:59 PM)
- ◯ Afternoon (2:00 PM - 3:59 PM)
- ◯ Later afternoon (4:00 PM - 5:59 PM)
- ◯ Evening (after 6:00 PM)

26. If you commute to work, how long is your commute to work? (please choose the closest answer)

- ◯ Less than 10 minutes
- ◯ 10 minutes
- ◯ 15 minutes
- ◯ 20 minutes
- ◯ 30 minutes
- ◯ 45 minutes
- ◯ More than 45 minutes

27. How long is the drive from your home, one way, for a typical errand like going to the grocery store? (please choose the closest answer)

- ◯ Less than 10 minutes
- ◯ 10 minutes
- ◯ 15 minutes
- ◯ 20 minutes
- ◯ 30 minutes
- ◯ 45 minutes
- ◯ More than 45 minutes

28. Please evaluate your driving characteristics:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I am a good driver					
I am an impatient driver					
I am a courteous driver					
I am sometimes a distracted driver					

29. While driving and waiting at a light, I _____ play with my phone:

- Never
- Rarely
- Sometimes
- Usually
- Always

30. How likely are you to make an unplanned stop, on impulse, for coffee or a snack when:

	Extremely unlikely	Somewhat unlikely	Neither likely nor unlikely	Somewhat likely	Extremely likely
The road you are on is congested and traffic isn't moving?					
The road you are on has moderate traffic and is moving along?					
The road you are on has only light traffic and traffic is moving along at a high rate of speed?					

31. Suppose you are at home and realize you could really use a single item from the grocery store, how likely are you to make the trip if:

	Extremely unlikely	Somewhat unlikely	Neither likely nor unlikely	Somewhat likely	Extremely likely
The roads are congested and you may have to wait through a couple cycles of a light?					
You know traffic on the road is moving but you'll have to make a u-turn around a median to get to the store?					
Traffic is moving but you have to cross a busy four lane highway?					

32. To what extent would you say you are **SATISFIED** with the current traffic flow on the main roads nearest your home?

- Never
- Sometimes
- About half the time
- Most of the time
- Always

33. To what extent would you say you are **DELIGHTED** with the current traffic flow on the main roads nearest your home?

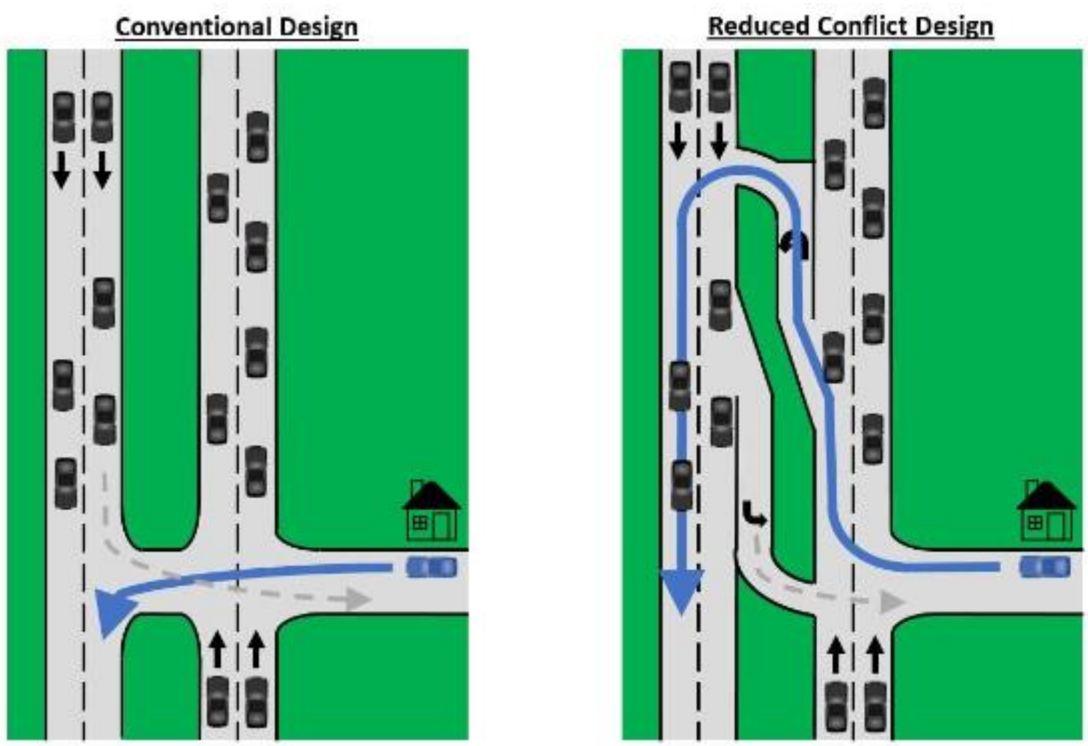
- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

Intersection design and Reduced Conflict Intersections

As traffic volume increases on the main road, transportation planners must improve the road design to handle additional traffic, such improvements often include additional lights, medians, lanes, intersection redesigns, etc.

Corridors with growing traffic volumes and high crash rates are good candidates for replacing conventional intersections with a "reduced-conflict intersection".

A conventional intersection has many potential conflict points because drivers can go in many directions and vehicle paths cross, a conflict point. An alternative design, called a reduced conflict intersection, eliminates left turns from side roads onto busy main roads. Raised medians direct traffic from the side road to turn right. Traffic that needs to "turn left" onto the main road, or cross the highway, will pull into a dedicated lane – and make a U-turn.



Such designs improve traffic flow by reducing the need for traffic lights as well as reducing the number of times vehicle paths cross.

Reduced conflict intersections may have other benefits as well, including: Improved safety for drivers entering the main road, Reduced delays for traffic on the main road, Requires less right of way and costs than adding additional lanes to a road, Improved safety for pedestrians and bicyclists

The following page will provide a scenario for you to consider and then you will be asked to choose between different intersection designs. No technical expertise is needed, just a thoughtful decision.

Below you will find a short scenario and then on the following pages you will be asked to choose between two intersection designs based on characteristics including reduction in likelihood of an accident, time it takes to turn left onto an arterial road, and total commute times.

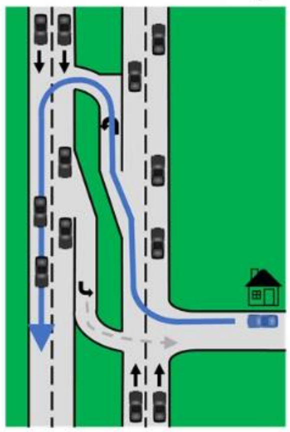
Please imagine that you live in a residential neighborhood with the primary entrance being located on the main road, a four lane road with medians in the middle. From your neighborhood, you can turn right onto the main road, or you can move forward, pause in the median-break in the middle of the road, and then turn left. Imagine that for your commute and errands, **about half the time you leave your subdivision you are turning left**.

Over time, the road has become busier, more congested and accidents have become relatively frequent. In response, the department of transportation is considering new designs for the intersection. A traffic light or signal is not feasible because of the large volume of traffic the main road is required to carry. Thus, a reduced conflict intersection design is being considered.

On the following pages, you will be asked to choose between intersection designs based on reduction in accidents, time spent to turn left, and effect on total commute times.

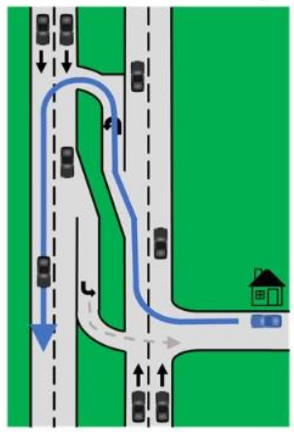
34. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A



Reduction in Accidents:	No Change
Change in time to turn left:	+1 Minute
Change in total commute time:	-3 Minutes

Reduced Conflict Intersection – Option B

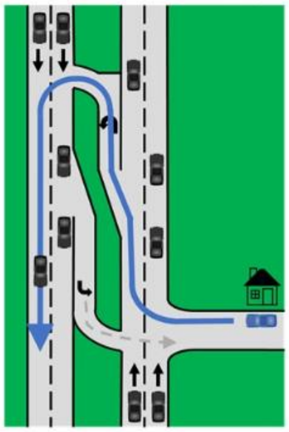


Reduction in Accidents:	-15%
Change in time to turn left:	+15 Seconds
Change in total commute time:	-1 Minute

Neither Of These Options

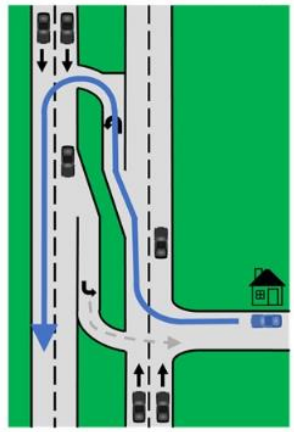
35. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A



Reduction in Accidents:	-15%
Change in time to turn left:	+30 Seconds
Change in total commute time:	+1 Minute

Reduced Conflict Intersection – Option B

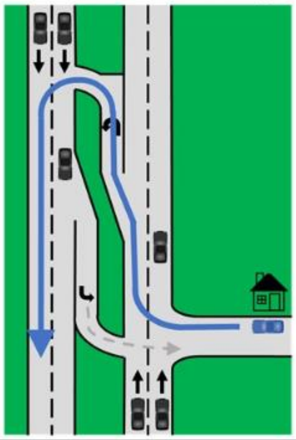


Reduction in Accidents:	-10%
Change in time to turn left:	No Change
Change in total commute time:	-3 Minutes

Neither Of These Options

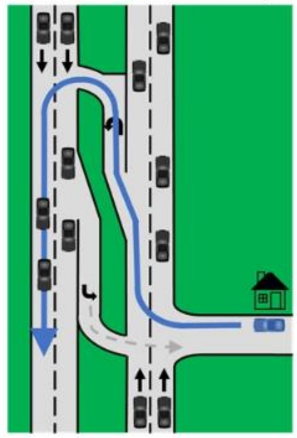
36. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A



Reduction in Accidents:	-50%
Change in time to turn left:	No Change
Change in total commute time:	+1 Minute

Reduced Conflict Intersection – Option B

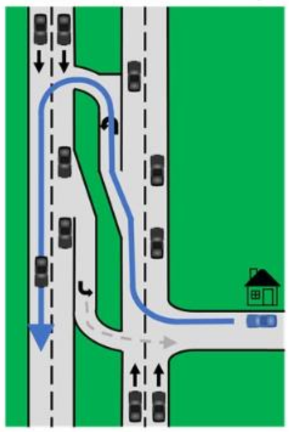


Reduction in Accidents:	-30%
Change in time to turn left:	+1 Minute
Change in total commute time:	No Change

Neither Of These Options

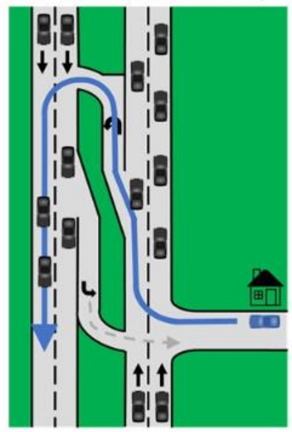
37. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A



Reduction in Accidents:	-30%
Change in time to turn left:	+30 Seconds
Change in total commute time:	+3 Minutes

Reduced Conflict Intersection – Option B

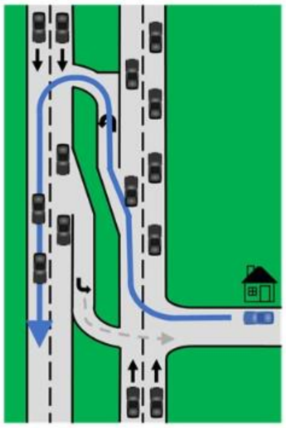


Reduction in Accidents:	No Change
Change in time to turn left:	+2 Minutes
Change in total commute time:	+1 Minutes

Neither Of These Options

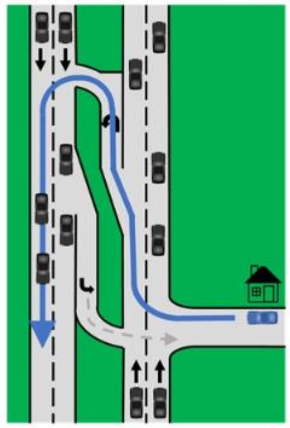
38. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A



Reduction in Accidents:	-30%
Change in time to turn left:	+2 Minutes
Change in total commute time:	No Change

Reduced Conflict Intersection – Option B

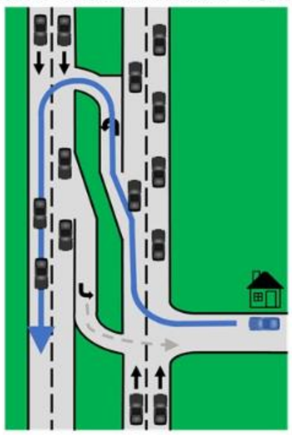


Reduction in Accidents:	-15%
Change in time to turn left:	+1 Minute
Change in total commute time:	+3 Minutes

Neither Of These Options

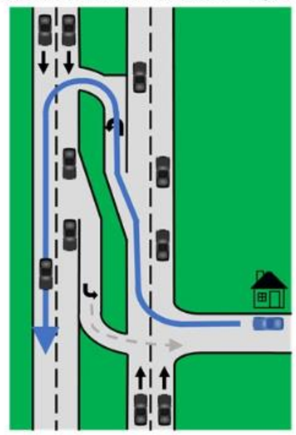
39. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A



Reduction in Accidents:	-10%
Change in time to turn left:	+2 Minutes
Change in total commute time:	-3 Minutes

Reduced Conflict Intersection – Option B

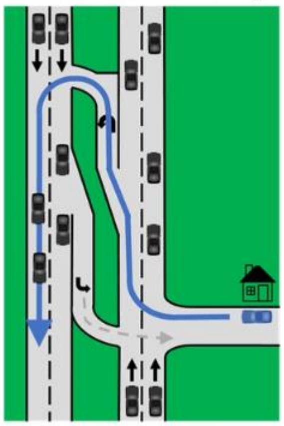


Reduction in Accidents:	-50
Change in time to turn left:	+30 Seconds
Change in total commute time:	-1 Minute

Neither Of These Options

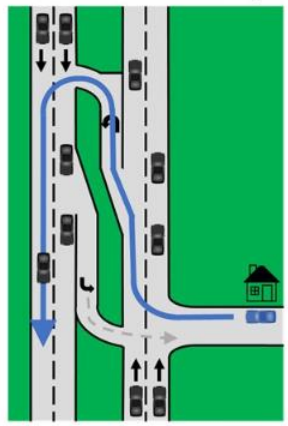
40. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A



Reduction in Accidents:	-50%
Change in time to turn left:	+1 Minute
Change in total commute time:	-1 Minute

Reduced Conflict Intersection – Option B

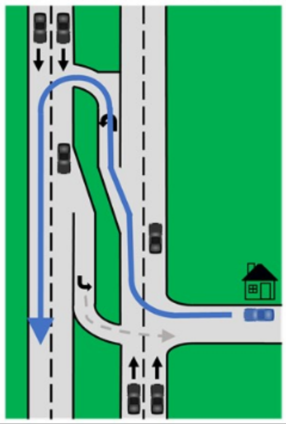


Reduction in Accidents:	No Change
Change in time to turn left:	+30 Seconds
Change in total commute time:	+1 Minute

Neither Of These Options

41. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

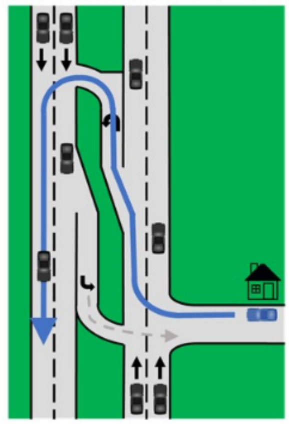
Reduced Conflict Intersection – Option A



Reduction in Accidents:	-30%
Change in time to turn left:	No Change
Change in total commute time:	+3 Minutes

○

Reduced Conflict Intersection – Option B



Reduction in Accidents:	-50%
Change in time to turn left:	+15 Seconds
Change in total commute time:	-3 Minutes

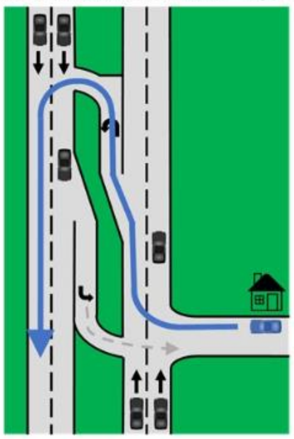
○

Neither Of These Options

○

42. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

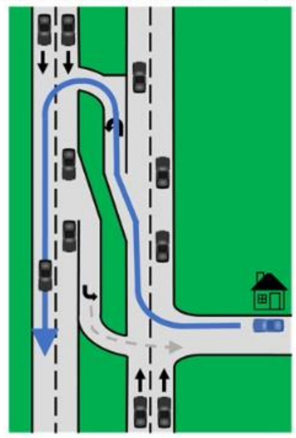
Reduced Conflict Intersection – Option A



Reduction in Accidents:	No Change
Change in time to turn left:	No Change
Change in total commute time:	+3 Minutes

○

Reduced Conflict Intersection – Option B



Reduction in Accidents:	-10%
Change in time to turn left:	+30 Seconds
Change in total commute time:	+1 Minute

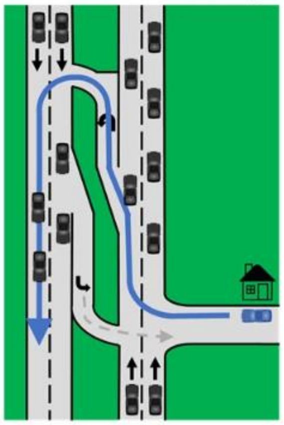
○

Neither Of These Options

○

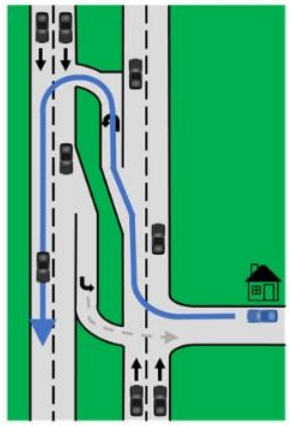
43. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A



Reduction in Accidents:	-50%
Change in time to turn left:	+2 Minutes
Change in total commute time:	-1 Minute

Reduced Conflict Intersection – Option B

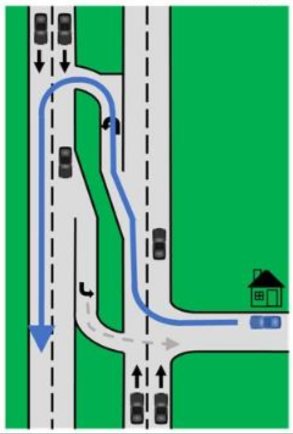


Reduction in Accidents:	-15%
Change in time to turn left:	+15 Seconds
Change in total commute time:	-3 Minutes

Neither Of These Options

44. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

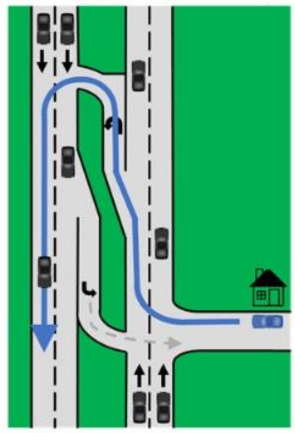
Reduced Conflict Intersection – Option A



Reduction in Accidents:	-15%
Change in time to turn left:	No Change
Change in total commute time:	No Change

○

Reduced Conflict Intersection – Option B



Reduction in Accidents:	-30%
Change in time to turn left:	+15 Seconds
Change in total commute time:	-1 Minutes

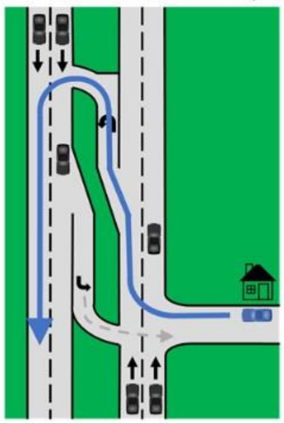
○

Neither Of These Options

○

45. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A



Reduction in Accidents:	-10%
Change in time to turn left:	No Change
Change in total commute time:	-1 Minute

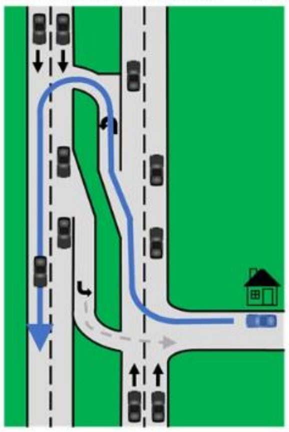
Reduced Conflict Intersection – Option B

Reduction in Accidents:	-50%
Change in time to turn left:	+2 Minutes
Change in total commute time:	+3 Minutes

Neither Of These Options

46. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

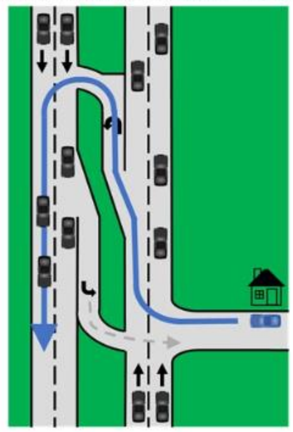
Reduced Conflict Intersection – Option A



Reduction in Accidents:	-10%
Change in time to turn left:	+30 Seconds
Change in total commute time:	+3 Minutes

○

Reduced Conflict Intersection – Option B



Reduction in Accidents:	-15%
Change in time to turn left:	+1 Minute
Change in total commute time:	No Change

○

Neither Of These Options

○

47. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A

Reduction in Accidents:	-30%
Change in time to turn left:	No Change
Change in total commute time:	+1 Minute

○

Reduced Conflict Intersection – Option B

Reduction in Accidents:	-10%
Change in time to turn left:	+30 Seconds
Change in total commute time:	No Change

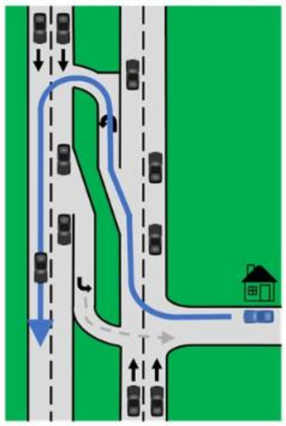
○

Neither Of These Options

○

48. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

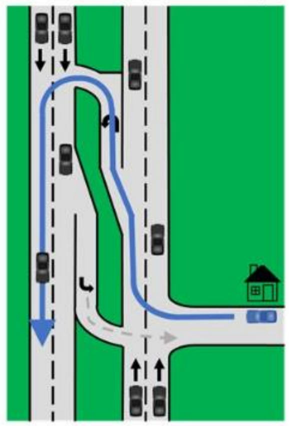
Reduced Conflict Intersection – Option A



Reduction in Accidents:	No Change
Change in time to turn left:	+30 Seconds
Change in total commute time:	-1 Minute

○

Reduced Conflict Intersection – Option B



Reduction in Accidents:	-30%
Change in time to turn left:	+15 Seconds
Change in total commute time:	+1 Minute

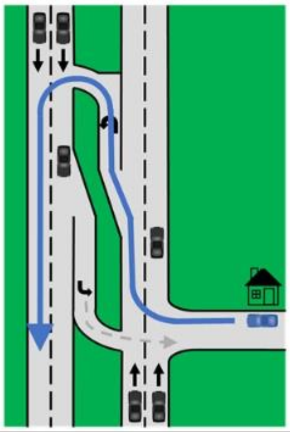
○

Neither Of These Options

○

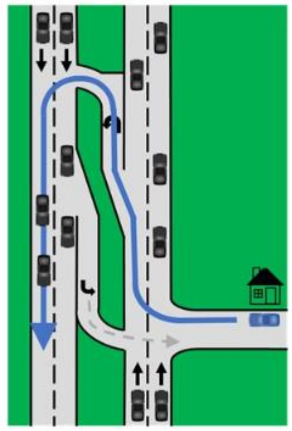
49. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A



Reduction in Accidents:	-50%
Change in time to turn left:	No Change
Change in total commute time:	No Change

Reduced Conflict Intersection – Option B

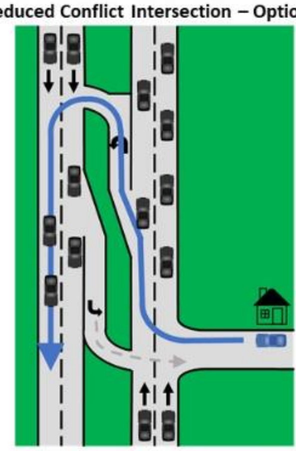


Reduction in Accidents:	No Change
Change in time to turn left:	+1 Minute
Change in total commute time:	-1 Minute

Neither Of These Options

50. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A



Reduction in Accidents:	-15%
Change in time to turn left:	+2 Minutes
Change in total commute time:	-1 Minute

○

Reduced Conflict Intersection – Option B

Reduction in Accidents:	-50%
Change in time to turn left:	+1 Minute
Change in total commute time:	+1 Minute

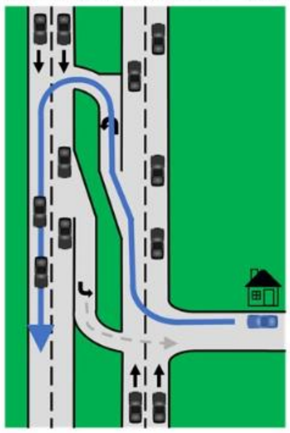
○

Neither Of These Options

○

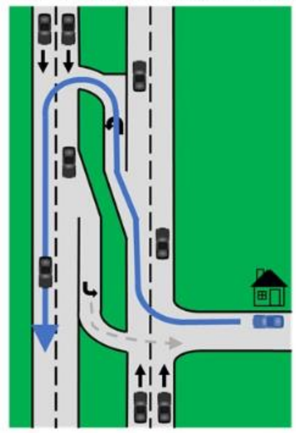
51. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A



Reduction in Accidents:	-10%
Change in time to turn left:	+1 Minute
Change in total commute time:	+1 Minute

Reduced Conflict Intersection – Option B

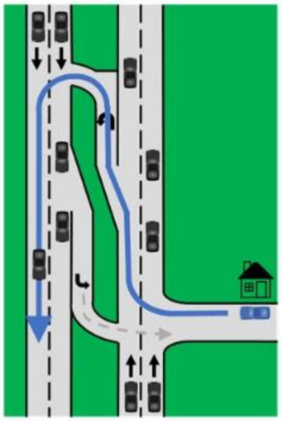


Reduction in Accidents:	No Change
Change in time to turn left:	+15 Seconds
Change in total commute time:	-3 Minutes

Neither Of These Options

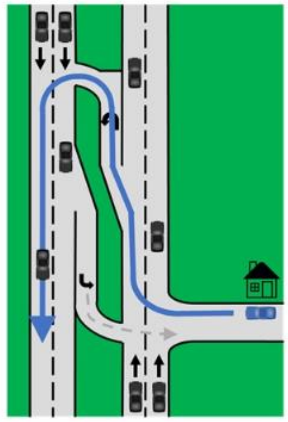
52. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A



Reduction in Accidents:	-30%
Change in time to turn left:	+30 Seconds
Change in total commute time:	-3 Minutes

Reduced Conflict Intersection – Option B

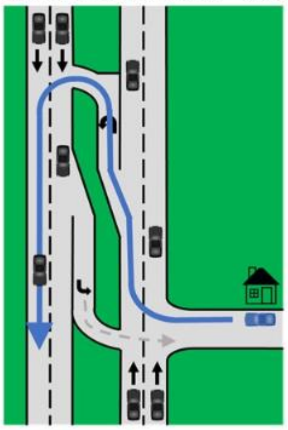


Reduction in Accidents:	-10%
Change in time to turn left:	+15 Seconds
Change in total commute time:	+3 Minutes

Neither Of These Options

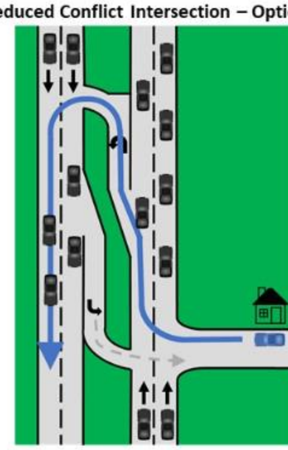
53. Using the scenario from the previous page of your neighborhood emptying out onto the main road, which of the following intersection designs would you prefer given the reduction in accidents, change in time to turn left, and change in in total commute time that accompanies each design? If you do not like either option, please choose "Neither of these options".

Reduced Conflict Intersection – Option A



Reduction in Accidents:	No Change
Change in time to turn left:	+15 Seconds
Change in total commute time:	No Change

Reduced Conflict Intersection – Option B



Reduction in Accidents:	-15%
Change in time to turn left:	+2 Minutes
Change in total commute time:	-3 Minutes

Neither Of These Options

54. Please use "drag and drop" to rank the attributes of the intersection design from most important to least important in your decision making process.

_______ Reduction in Accidents
_______ Change in time to turn left
_______ Change in total commute time

55. How realistic were the intersection scenarios we provided?

○ Not very realistic

○

○

○

○

○

○ Very realistic

56. In general how often do you utilize RCIs when you are driving?

○ Never

○ Sometimes

○ About half the time

○ Most of the time

○ Always

○ I don't know

57. In general, how safe do you feel on the roads you drive most often?

- ◯ Not very safe
- ◯
- ◯
- ◯
- ◯
- ◯
- ◯ Very safe

58. Have you used an RCI before?

- ◯ Yes, they are near my house and I drive through them often
- ◯ Occasionally in the past
- ◯ Not that I can remember
- ◯ I don't know

59. Reduced Conflict Intersections (RCIs) make using the roads near my house easier.

- ◯ Strongly disagree
- ◯ Somewhat disagree
- ◯ Neither agree nor disagree
- ◯ Somewhat agree
- ◯ Strongly agree

Imagine that somewhere near your home is a "Reduced Conflict Intersection" (RCI) where traffic patterns are limited by medians to increase traffic flow and improve safety. For example, vehicles wanting to turn left may need to turn right and then do a U-turn.

With this RCI scenario in mind please respond to the following statement.

60. Reduced conflict intersections (RCIs) would make using the main roads near my home easier.

- ○ Strongly disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Strongly agree

61. Thinking about the Reduced Conflict Intersections you regularly use, could you share comments on your experience with us?

____

____

____

____

____

62. When leaving your neighborhood and turning on to the "main road" which do you most often do?

- ○ turn left
- ○ turn right
- ○ proceed straight across

63. Approximately, how many hours a week do you spend driving a car? (Choose the closest answer)

- ◯ 1 hour or less
- ◯ 5
- ◯ 10
- ◯ 15
- ◯ 20
- ◯ More than 20

64. When thinking about the RCI intersection on Hwy 24-87, does the intersection affect your decision of whether to grocery shop at Food Lion vs. Walmart?

- ◯ Always
- ◯ Often
- ◯ Sometimes
- ◯ Rarely
- ◯ Never
- ◯ I don't grocery shop at Food Lion or Walmart

65. When considering making a quick trip to Food Lion, does the need to turn right and then make a U-turn keep you from making the trip?

- ◯ No, I make the trip when I need to
- ◯ Sometimes
- ◯ It often keeps me from going to Food Lion
- ◯ I often go to WalMart to avoid having to do a u-turn and come back

66. When considering making a quick trip to Walmart, does the need to turn right and then make a U-turn keep you from making the trip?

- ◯ No, I make the trip when I need to
- ◯ Sometimes
- ◯ It often keeps me from going to WalMart
- ◯ I often go to Food Lion to avoid having to do a u-turn and come back

67. If the RCI intersection factors into your decision making about where to grocery shop, please describe how the intersection affects your decision:

____

____

____

____

____

68. In which state do you currently reside?

- ◯ Alabama
- ◯ Alaska
- ◯ Arizona
- ◯ Arkansas
- ◯ California
- ◯ Colorado
- ◯ Connecticut
- ◯ Delaware
- ◯ District of Columbia
- ◯ Florida
- ◯ Georgia
- ◯ Hawaii
- ◯ Idaho
- ◯ Illinois
- ◯ Indiana
- ◯ Iowa
- ◯ Kansas
- ◯ Kentucky
- ◯ Louisiana
- ◯ Maine

- Maryland
- Massachusetts
- Michigan
- Minnesota
- Mississippi
- Missouri
- Montana
- Nebraska
- Nevada
- New Hampshire
- New Jersey
- New Mexico
- New York
- North Carolina
- North Dakota
- Ohio
- Oklahoma
- Oregon
- Pennsylvania
- Puerto Rico
- Rhode Island

- South Carolina
- South Dakota
- Tennessee
- Texas
- Utah
- Vermont
- Virginia
- Washington
- West Virginia
- Wisconsin
- Wyoming
- I do not reside in the United States

69. Please indicate your age range:

- 0-17
- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65-74
- 75+

70. What is the highest level of education you have attained?

- ◯ Some High School
- ◯ High School Diploma or GED
- ◯ Associate's Degree (2-yr degree)
- ◯ Some College
- ◯ Bachelor's Degree (4-yr Degree)
- ◯ Graduate Degree (Master's)
- ◯ Terminal Degree (PhD, JD, MD, etc.)

71. Please indicate your current relationship status.

- ◯ Single
- ◯ In a relationship
- ◯ Married
- ◯ Divorced
- ◯ Widowed
- ◯ Other ____

72. With which gender do you most closely identify?

- ◯ Male
- ◯ Female
- ◯ Non-Binary
- ◯ Prefer not to answer

73. Which of the following describes your total household income (before taxes) from last year?

- ○ Less than $25,000
- ○ $25,000 to $49,999
- ○ $50,000 to $74,999
- ○ $75,000 to $99,999
- ○ $100,000 to $149,999
- ○ $150,000 to $249,999
- ○ Over $250,000

74. How would you identify your race/ethnicity? (please check all that apply)

- ☐ White
- ☐ Black
- ☐ Latino (any race)
- ☐ Asian or Pacific Islander
- ☐ Native American
- ☐ Other (Please Specify) ________________________

75. How many children do you have?

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 or more

76. What is your current employment status? (you may check multiple answers if appropriate)

- ☐ Employed Full Time
- ☐ Employed part-time to earn necessary income
- ☐ Employed part-time for experience or to earn spending money
- ☐ Self-employed
- ☐ Unemployed
- ☐ Not working nor looking for work
- ☐ Retired
- ☐ Prefer Not to Say

77. Which description most closely matches your political views?

- ○ Very liberal
- ○ Liberal
- ○ Slightly Liberal
- ○ Moderate
- ○ Slightly Conservative
- ○ Conservative
- ○ Very Conservative
- ○ Prefer not to say

78. How many people live in your household?

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ Seven or more

79. How long have you been living in your current home or residence?

- ○ Less than 1 year
- ○ 1-2 years
- ○ 3-5 years
- ○ 5-10 years
- ○ More than 10 years

80. What type of home do you live in?

- ○ Single family stand alone home
- ○ Duplex
- ○ Condominium or apartment
- ○ Other

81. Do you own or rent your home?

- ○ Own
- ○ Rent
- ○ Live with family
- ○ Prefer not to say

82. How much longer do you anticipate living in your current residence after today?

- ○ Less than one more year
- ○ 1-2 more years
- ○ 3-5 more years
- ○ 5 or more years

83. If you don't mind sharing, we would appreciate you telling us one of the following:

- ◯ I am a renter and my monthly rent is: ________________

- ◯ I am an owner and my house/condo is valued at: ________________

84. We know that you might be hurrying through the survey but we'd love to know if we should use your data or not. Can you please let us know?

- ◯ I rushed through the survey, so my responses probably are not reliable
- ◯ I answered as best I could, so my responses are reliable

Unfortunately you do not qualify for this survey because of your age or how long you have lived at your current residence. Thank you and have a good day.

Appendix F – Residential Survey Additional Descriptives and Analysis Materials

Table 28a: Demographics of Residential Respondents

Age		
18-24	5	3%
25-34	17	10%
35-44	46	27%
45-54	39	23%
55-64	24	14%
65-74	26	15%
75+	12	7%
	169	100%
Education		
Some High School	2	1%
Associates Degree (2-yr degree)	17	10%
Some College	24	14%
Bachelor's Degree (4-yr Degree)	53	32%
Graduate Degree (Master's)	54	32%
Terminal Degree (PhD, JD, MD, etc.)	17	10%
	167	100%
Relationship Status		
Single	14	8%
In a relationship	9	5%
Married	134	79%
Divorced	5	3%
Widowed	3	2%
Other	4	2%
	169	100%
Gender		
Male	86	51%
Female	77	46%
Prefer not to disclose	6	4%

Table 28b: Demographics of Residential Respondents

Household Income		
Less than $25,000	5	3%
$25,000 t$49,999	12	7%
$50,000 t$74,999	26	15%
$75,000 t$99,999	35	21%
$100,000 t$149,999	49	29%
$150,000 t$249,999	32	19%
Over $250,000	10	6%
	169	100%
Ethnicity		
Caucasian	142	83%
Latino	12	7%
Other	7	4%
African America	5	3%
Asian or Pacific Islander	3	2%
Native American	3	2%
	172	100%
# of Children		
0	40	24%
1	31	18%
2	56	33%
3	30	18%
4	10	6%
5 or more	2	1%
	169	100%

Table 28c: Demographics of Residential Respondents

Employee Status		
Employed Full Time	95	55%
Retired	36	21%
Self-employed	14	8%
Employed part-time for experience or to earn spending money	8	5%
Prefer Not to Say	8	5%
Employed part-time to earn necessary income	6	3%
Not working nor looking for work	4	2%
Unemployed	1	1%
	172	100%
Political Views		
Prefer not to say	39	23%
Moderate	34	20%
Conservative	26	15%
Liberal	24	14%
Slightly Conservative	15	9%
Very liberal	12	7%
Very Conservative	10	6%
Slightly Liberal	9	5%
	169	100%

Table 29: Property Related Descriptive Data

Number of People in Household		
1	14	8%
2	65	38%
3	34	20%
4	34	20%
5	17	10%
6	3	2%
7 or more	2	1%
	169	1
Duration in Current Home		
Less than 1 year	15	9%
1-2 years	23	14%
3-5 years	22	13%
5-10 years	29	17%
More than 10 years	80	47%
	169	1
Type of Home		
Single family standalone home	158	93%
Duplex	5	3%
Condominium or apartment	1	1%
Other	5	3%
	169	1
Ownership Status		
Own	144	85%
Rent	17	10%
Live with family	3	2%
Prefer not to say	5	3%
	169	1
How long respondent anticipates staying in the house		
Less than one more year	8	5%
1-2 more years	24	14%
3-5 more years	39	23%
5 or more years	98	58%
	169	1

Table 30: Driving Data from Residential Survey

How roads are used		
I use them to commute to and from work or job sites	70	41%
I use them to transport family members, run errands, etc.	95	56%
other	4	2%
	169	100%
# of Accidents		
0	144	85%
1	24	14%
2	1	1%
	169	100%
Miles Per Year		
Less than 1000 miles	7	4%
3000 miles	21	12%
5000 miles	28	17%
7500 miles	31	18%
10,000 miles	27	16%
15,000 miles	39	23%
20,000 miles	12	7%
25,000 miles	1	1%
30,000 or more miles	3	2%
	169	100%
Type of Vehicle Driven on a Regular Basis		
Small or Mid-size SUV (Rav-4, CRV, etc.)	80	34%
4 Door Sedan	71	30%
Full Size SUV (Suburban or similar)	29	12%
Full Size Pickup Truck	23	10%
Small or Mid-size Pickup Truck (Tacoma, Ranger, etc.)	11	5%
2 Door Sedan or Coupe	9	4%
Motorcycle	6	3%
Sportscar or convertible	5	2%
	234	100%

Table 31: Road Usage Data for Commuters

Departure Time for Work		
Before 7:00 AM	20	29%
Between 7:00 AM and 7:29 AM	22	32%
Between 7:30 AM and 7:59 AM	11	16%
Between 8:00 AM and 8:29 AM	9	13%
Between 8:30 AM and 8:59 AM	4	6%
Between 9:00 AM and 9:29 AM	2	3%
Between 9:30 AM and 9:59 AM	1	1%
	69	100%
Commute Length to Work		
Less than 10 minutes	4	6%
10 minutes	1	1%
15 minutes	15	21%
20 minutes	25	36%
30 minutes	15	21%
45 minutes	4	6%
More than 45 minutes	6	9%
	70	100%
Commute Length for Typical Errand		
Less than 10 minutes	4	6%
10 minutes	1	1%
15 minutes	15	21%
20 minutes	25	36%
30 minutes	15	21%
45 minutes	4	6%
More than 45 minutes	6	9%
	70	100%

Table 32: Road Usage Data for Non-Commuters

Time of Day Roads Used - Noncommuter		
Early morning (before 7:00 AM)	1	1%
Morning (7:00 AM - 8:59 AM)	27	28%
Late morning (9:00-10:59 AM)	24	25%
Lunchtime (11:00 AM - 1:59 PM)	11	12%
Afternoon (2:00 PM - 3:59 PM)	17	18%
Later afternoon (4:00 PM - 5:59 PM)	9	9%
Evening (after 6:00 PM)	6	6%
	95	100%
Commute Length for Typical Errand - Noncommuter		
Less than 10 minutes	38	40%
10 minutes	24	25%
15 minutes	23	24%
20 minutes	8	8%
30 minutes	2	2%
45 minutes	0	0%
More than 45 minutes	0	0%
	95	100%

Table 33: Attitude Towards Traffic

Likelihood of making an unplanned stop when: (1=extremely unlikely; 5=extremely likely)	
- the road you are on is congested and traffic isn't moving	1.59
- the road you are on has moderate traffic and is moving along	1.99
- the road you are on has only light traffic and traffic is moving along at a high rate of speed	2.17
Likelihood of making a trip for a single time when: (1=extremely unlikely; 5=extremely likely)	
- the roads are congested, and you may have to wait through a couple cycles of a light	1.83
- the traffic on the road is moving but you'll have to make a u-turn around a median to get to the store	2.31
- traffic is moving but you have to cross a busy four lane highway	2.37
Level of satisfaction with the current traffic flow on the main roads nearest your home (1= never; 5= always)	2.51
Level of delight with the current traffic flow on the main roads nearest your home (1=never; 5= always)	1.96
How often RCIs are utilized when you are driving (1=never; 5 = always)	3.23
Level of safety on the roads driven most often (1= not very safe; 7 = very safe)	4.17

Table 34: Importance of Intersection Design by Ranking

	Rank1		Rank2		Rank3	
Reduction in accidents	106	63%	21	12%	42	25%
Change in time to turn left	29	17%	67	40%	73	43%
Change in total commute time	34	20%	81	48%	54	32%
	169		169		169	

Appendix F – Additional Background on Discrete Choice Experiments

Technical details for analysis of discrete choice experiment data

Analysis of DCE response data is based on random utility theory (McFadden, 1973), which recognizes that the satisfaction or "utility" from a given choice is a function of many characteristics, some of which are observable to the researcher and some that are unobservable. Formally, the utility derived by an individual from a particular alternative (i) is represented by a function that contains a deterministic component (Vi) and a stochastic component (ei):

(A1) $Ui = Vi + \varepsilon i$

Given a set of mutually exclusive alternatives (e.g., available alternatives in a choice set), the selection of alternative (i) over another alternative (j) implies that the utility from (i) exceeds the utility from (j). The probability of choosing alternative (i) can therefore be described as:

(A2) $P\{i\} = P\ \{Vi + \varepsilon i > Vj + \varepsilon j\}$

By specifying a functional form for the utility function in (1), multinomial logit (MNL) regression analysis can be used to estimate the probability of choosing alternative (i) (McFadden, 1973; Ban-Akiva & Lerman, 1985):

(A3) $P\{i\} = \exp(Vi) / \exp(Vj)$

Such a functional form is created by the researcher by identifying a set of attributes that comprise a good or service of interest and specifying various levels that those attributes can assume. To ease the cognitive burden on respondents, the number of attributes and levels is kept to a manageable number.

A good that can be described as comprised of m attributes with k levels has k^m possible combinations of attributes and levels. Combinations of attribute levels are selected from this "full factorial" set of possible combinations to create alternative treatment combinations ("profiles") of the good which are combined into a series of choice sets (e.g., pairs) to be presented to survey respondents. In the case of small designs (i.e. relatively few attributes and levels) it may be possible to include all possible combinations in a particular DCE survey. In the case of large designs, a subset of the possible combinations of attributes and levels is selected to be used in the survey based on maximizing the efficiency of estimating respondent preferences for the attributes and their levels. Orthogonality (minimal correlations between attribute levels) and balance (equality of presentation levels for each attribute) are common goals for this experimental design, which is typically facilitated by statistical software.

DCE data are commonly coded to facilitate multinomial logit regression of choice probabilities (A3), part-worth utilities (coefficient estimates) and estimates of the MRS between attribute levels. Data can be coded several ways, including dummy coding, effects coding and continuous coding. Dummy coding sets baseline levels of non-price attributes at 0 and delineates other levels with a value of 1 if they are present in the choice set. With effects coding, the baseline level of each non-price attribute is set to -1 (rather than 0) to prevent confounding with the opt-out alternative (where all attribute levels are coded as 0) when baseline levels are present in a choice set (Cooper, Rose, & Crase, 2012). Figure 59 shows a hypothetical paired choice panel for a 4-attribute, 4-level DCE.

Figure 59: Example of a Single Paired Choice

<table>
<tr><td colspan="4">Suppose that you could only choose from the options below (Option A, Option B or neither).
If all other factors were equal, which would you prefer?</td></tr>
<tr><td>ATTRIBUTES</td><td>OPTION A</td><td>OPTION B</td><td rowspan="5">NEITHER OPTION</td></tr>
<tr><td>Attribute 1</td><td>Level 3</td><td>Level 1</td></tr>
<tr><td>Attribute 2</td><td>Level 2</td><td>Level 4</td></tr>
<tr><td>Attribute 3</td><td>Level 1</td><td>Level 3</td></tr>
<tr><td>Attribute 4</td><td>Level 4</td><td>Level 2</td></tr>
<tr><td colspan="4">I prefer…(check <u>one</u> box below)</td></tr>
<tr><td></td><td>ϒ OPTION A</td><td>ϒ OPTION B</td><td>ϒ NEITHER OPTION</td></tr>
</table>

Surveys that contain DCEs typically also collect information on respondents such as demographic characteristics or ratings that can be used to understand how preferences vary across a population of interest. Among the principal benefits of DCEs is their ability to help researchers understand the relative value of different attributes that comprise a good, service or state of the world, and their ability to allow multidimensional attribute changes to be valued simultaneously (Huybers, 2004). Monetary valuation is facilitated by including a dollar-based attribute (e.g., price, fee, donation, cost) as one of the characteristics that describes the good or service that is the subject of research.

Using an indicator variable representing respondents' stated preferences (i.e. option A, option B, neither option) as the dependent variable and the attribute levels as independent variables, MNL regression produces coefficient estimates for each level of the attributes relative to a pre-determined baseline level. These coefficients represent the weight or marginal utility assigned to each attribute level relative to the baseline (omitted) level. The ratio of any two coefficients can be interpreted as the marginal rate of substitution (MRS) between the corresponding attribute levels, which represents respondents' willingness to trade attributes and levels.

A representative functional form for the utility derived from the hypothetical good shown in Figure 1 where the 1st (lowest) L of each A serves as the baseline would be:

$$U_i = \beta_1(A1, L2) + \beta_2(A1, L3) + \beta_3(A1, L4) + \beta_4(A2, L2) + \beta_5(A2, L3) + \beta_6(A2, L4) + \beta_7(A3, L2) + \beta_8(A3, L3) + \beta_9(A3, L4) + \beta_{10}(A4, L2) + \beta_{11}(A4, L3) + \beta_{12}(A4, L4)$$

Where U_i represents the utility or satisfaction from a particular choice, A1 = attribute 1, L1 = level 1, etc.

Commonly estimated MNL specifications include traditional conditional logit (CL), random parameters (mixed) logit (RPL), and latent class logit (LCL). The CL specification produces estimates of the marginal utility of each attribute level that are assumed to be constant across the sample, while the RPL specification treats utility coefficients as random parameters and produces estimates of both the mean and standard deviation of utility coefficients (Greene & Hensher, 2003; Train, 1999). Statistical significance of a coefficient's standard deviation indicates preference heterogeneity for the associated attribute level (SAS Institute, 2008).

Table 35: Discrete Choice Experiment Results

		mTurk sample			Mail sample		
Attribute	Level	Coefficient (standard error)					
Reduction in accidents (RIA)	RIA10	0.477*** (0.118)		0.479*** (0.117)	1.014*** (0.241)		0.991*** (0.236)
	RIA15	0.782*** (0.117)		0.785*** (0.116)	1.122*** (0.230)		1.224*** (0.228)
	RIA30	0.887*** (0.116)		0.907*** (0.114)	1.859*** (0.225)		1.919*** (0.225)
	RIA50	0.930*** (0.114)		0.958*** (0.113)	2.216*** (0.230)		2.326*** (0.228)
	RIA continuous		-0.016*** (-0.002)			-0.041*** (0.004)	
Change in time to turn left (TTTL)	TTTL15	-0.168 (0.137)			0.247 (0.242)		
	TTTL30	-0.082 (0.109)			-0.070 (0.186)		
	TTTL60	-0.118 (0.120)			-0.415* (0.218		
	TTTL120	-0.415* (0.126)			-0.155 (0.213)		
	TTTL continuous		-0.003*** (0.001)	-0.003*** (0.001)		-0.0035** (0.002)	-0.0030* (0.002)
Change in total commute time (CTCT)	CTCTM1	-0.015 (0.110)			0.085 (0.193)		
	CTCTM3	0.199* (0.119)			-0.0407 (0.212)		
	CTCTP1	0.195* (0.105)			-0.197 (0.178)		
	CTCTP3	-0.356*** (0.117)			-1.133*** (0.226)		
	CTCT continuous		-0.001*** (0.000)	-0.001*** (0.000)		-0.0027*** (0.0006)	-0.0029*** (0.0006)
Alternative -specific constants (ASC)	ASC TRIP1	-0.144 (0.146)	0.132 (0.087)	-0.147 (0.111)	-1.052*** (0.280)	-0.789*** (0.148)	-1.271*** (0.220)
	ASC TRIP2	0.021 (0.166)	0.306*** (0.085)	0.009 (0.110)	-0.850*** (0.311)	-0.537*** (0.140)	-1.064*** (0.223)
Psuedo R-squared		0.039	0.025	0.033	0.139	0.114	0.123
AIC		3471.6	3503.6	3480.3	1308.4	1327.9	1312.8
*, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.							