RESEARCH & DEVELOPMENT

URBAN APPLICATIONS OF INNOVATIVE INTERSECTION DESIGNS

Institute for Transportation Research & Education,
North Carolina State University

NCDOT Project 2021-11

FHWA/NC/2021-11

December 2023

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA/NC/2021-11	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle Urban Applications of Innovative Intersection Designs		**5. Report Date** September 15, 2024
		6. Performing Organization Code
7. Author(s) Christopher M. Cunningham, P.E.; Michael R. Brown, P.E., AICP; Celen Pasalar, Ph.D.; Guangchuan Yang, Ph.D.; Yanhua Lu; Brijesh Kukadiya		**8. Performing Organization Report No.**
9. Performing Organization Name and Address Institute for Transportation Research and Education, North Carolina State University, Centennial Campus Box 8601, Raleigh, NC Urban Innovators, PLLC, Bountiful, UT Department of Landscape Architecture and Environmental Planning, North Carolina State University, Raleigh, NC		**10. Work Unit No.**
		11. Contract or Grant No. NCDOT Project 2021-11
12. Sponsoring Agency Name and Address North Carolina Department of Transportation Research and Analysis Group 104 Fayetteville Street Raleigh, North Carolina 27601		**13. Type of Report and Period Covered** Final Report
		14. Sponsoring Agency Code NCDOT/NC/2021-11

15. Supplementary Notes
Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. Abstract
Communities across North Carolina want to create walkable mixed-use development along state highways, but they do not trust that NCDOT can convert today's auto-oriented major arterials into "Complete Streets" with sufficient ambiance to catalyze the walkable development they desire. To a large extent they are correct: the agency is not "well practiced" in how to deliver products that can catalyze walkable environments. But even if NCDOT can organize to support that objective, there is still a major engineering challenge: How to do it? Are there any tools available that can manage high traffic volumes with reasonable travel times, and at the same time create an environment that will catalyze walkable development? Are there tools that can help us to drive slower, but travel the same if not faster, through an impressively walkable environment?

This report focuses on three "Placemaking Alternative Intersection" families (PAIs) that can serve as the "bone structure" for that outcome: Quadrant, U-Turn, and One-Way Split Intersections. Using real-world locations in Greenville and Smithfield, NC, this report showcases both graphical and technical analysis to demonstrate that it is possible to manage much higher, urban-scale volumes of traffic, in ways that can catalyze the urban scales of development that communities desire due to the walkability of the result. The research team created an excel-based "Development Scale Calculator" to determine how much development an intersection area can support based on the vehicular capacity of the intersection design, and the "capacity equivalent" provided by alternative modes, connectivity, and internal capture based on density and diversity of uses. We conducted two focus groups with community stakeholders and experts in the field to weigh in on our diagrams and findings. They confirm that these PAI designs, combined with other actions such as form-based zoning, are highly likely to catalyze the walkable urban environments that communities desire.

17. Key Words Alternative Intersections, Stroad, Focus Groups, Safety, Traffic Operations, Land Development, Complete Street, Placemaking	**18. Distribution Statement** No restrictions. Document is available through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	**20. Security Classif. (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified	Unclassified	171	$250,806

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ACKNOWLEDGEMENT

The research team acknowledges the North Carolina Department of Transportation for supporting and funding this project. We extend our thanks to the project Steering and Implementation Committee: Joe Hummer (Chair), Mark Gibbs, Tony Tagliaferri, Mike Reese, Jim Dunlop, Clarence Bunting, Kelvin Jordan, Harrison Marshall, Joseph Furstenberg, Eric Lamb, David Hinnant, Andrew Barksdale, Kevin Lacy, and John Kirby.

In addition, we would like to give special thanks to the City of Greenville and Town of Smithfield staff who assisted and gave input throughout the project. Without their help, we would not have been able to fully vet research ideas with real case studies. Special thanks goes to Lisa Kirby and Eliud DeJesus from the City of Greenville for their invaluable assistance over this 3-year period.

Special thanks to research team members from North Carolina State University's Institute for Transportation Research and Education (ITRE), the College of Design, and from Urban Innovators:

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- Many other unnamed members with lesser roles

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1. Introduction

1.1. The Desire to Convert Auto-Oriented "Stroads" into Walkable "Complete Streets"

In North Carolina and across the United States, communities are increasingly frustrated with the deterioration of their auto-oriented suburban commercial areas. They are anxious to foster walkable mixed-use environments at urban-level densities because many older suburban land-uses adjacent to state highways are languishing. Local authorities hope to catalyze walkable, sustainable mixed-use development to rejuvenate economic development and provide the public with inviting and attractive spaces. However, such arterials often have 5-7-lane cross sections and carry 30,000 to 60,000+ vehicles per day. Engineers at the North Carolina Department of Transportation (NCDOT) tasked with traffic management and safety struggle with how to manage such high volumes of long-distance traffic, while at the same time creating conditions that can help communities achieve their walkable development goals.

Most 5-7-lane suburban commercial highways are increasingly referred to as "Stroads" *(Strong Towns, 2023)*, which is a street/road hybrid (**Figure 1-1**). A "street" is understood as a walkable corridor where residents and businesses interact. Vehicle speeds are slow and compatible with alternative modes. A "road" is for vehicles moving quickly from Origin to Destination at speeds of 40 mph or higher. Unfortunately, Stroads have neither the charm of great streets, nor the speed of great roads, due to congestion induced in part by complex 4-phase traffic signals.

Figure 1-1 Streets, Roads, and "Stroads" *Source: Urban Innovators*

1.2. Stroads Exacerbate Auto Dependency by Making Origins Too Far from Destinations

A Stroad's high speed encourages the market to spread out across more land: residents purchase larger lots and commercial also uses larger lots with more than enough parking. The result is low density, making Origins far from Destinations, and ensuring that everyone must drive to reach anything. In addition, high speed combined with minimal investment in aesthetics or alternative modes makes Stroads unattractive for residential uses, which further pushes commercial and residential apart. *The result is massive inequity in access to opportunity for those who can't drive, can't afford to drive, can no longer drive safely, or who don't want to drive.* Thus, one solution to the inequity of access to opportunity, and to improve energy efficiency, is to use strategies that can help the market bring origins physically closer to destinations, thereby reducing the average distance of a trip.

Origins and destinations can be brought closer together through increased density and diversity. Density increases the amount of activity per acre or per square mile. Diversity of uses, or the mixing of residential and commercial helps ensure more people will live closer to the goods and services they frequently need. But neither density nor diversity will happen unless maximum speeds become pedestrian friendly, and until the corridor becomes "livable" through beautification and investment in alternative modes. The concept of "15-minute cities" is born from the combination of density and diversity, helping ensure that most people will be able to walk to nearly everything they need daily within 15-minutes *(Abbiasov, 2022)*

Historically, state DOTs have avoided attempts to influence land use, considering it the prerogative of each community. But through a long history of delivering Stroad-like products, DOTs have strongly influenced land uses, even if inadvertently. Today, communities recognize that they cannot achieve their land use goals along Stroad-like corridors, unless those corridors can be made more walkable and livable. Thus, they are openly petitioning DOTs to help them convert Stroads into Complete Streets to achieve their land use visions.

1.3. The Fiscal Need for Suburban Mixed-Use Development

Growth patterns since WWII have skewed toward low density and a separation of uses. The result is a lot more infrastructure per capita, when compared to pre-WWII development. For most cities and state DOTs, it is proving to be fiscally challenging to maintain that much infrastructure in good condition when there are too few "taxpayers per square mile" to foot the bill.

As an example, **Figure 1-2** provides a block-by-block analysis of Lafayette, Louisiana. Blue blocks (in the higher density, older parts of town) raise more revenue than they cost to maintain. Orange is the opposite, where lower density means there aren't enough taxpayers there to cover the long-term cost of their infrastructure.

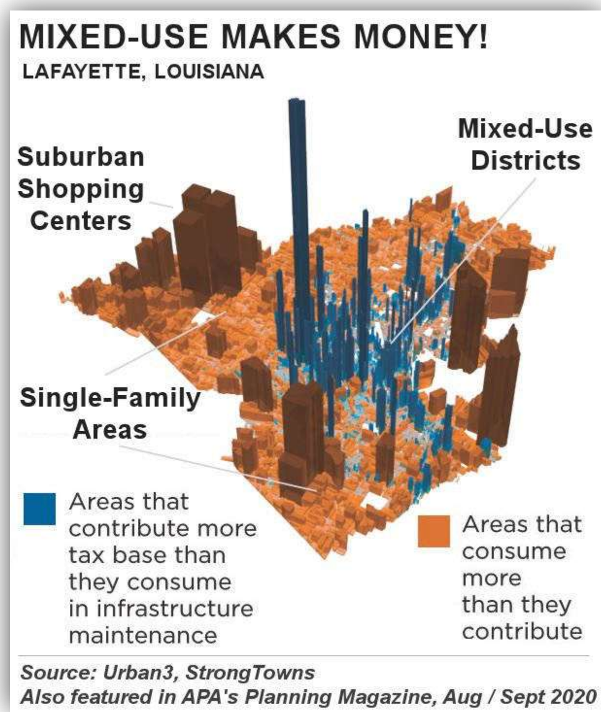


Figure 1-2 *Low income, high density areas often subsidize infrastructure in lower density, wealthier areas.*

Surprisingly, the older parts of town that tend to be lower income, are also the areas that contribute more to the tax base than they consume. In other words, the lower income neighborhoods are subsidizing the infrastructure of the higher income neighborhoods – a hidden systemic inequity. The firm Urban3 (2022) has studied dozens of cities and has found nearly all cities have more red than blue. The result is a combination of higher taxes, higher debt, minimal amenities, and differed maintenance. Strong Towns and Urban3 both advise regions to at least create enough blue areas to offset the orange areas, and ideally look for ways to reduce the systemic inequity of lower income areas subsidizing higher income areas.

1.4. The Default Four-Phase Intersection vs Alternative Intersections

What is an "alternative intersection?" It is not necessarily a new or uncommon design. It is best thought of as an "alternative to the default." When two Stroads cross, the default intersection has a 4 critical phase traffic signal, often with double-left turns, as shown in **Figure 1-3**.

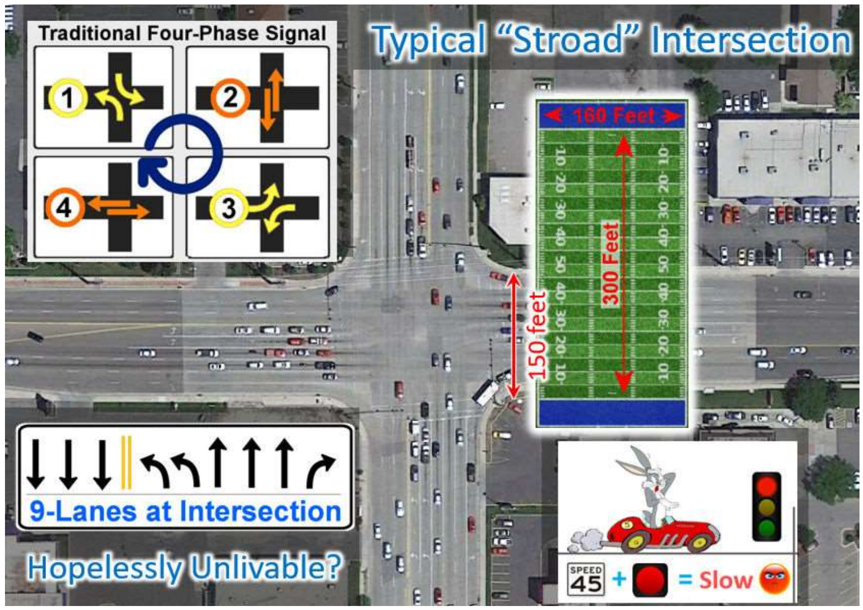


Figure 1-3 *Typical Crossing of Two Stroads* *Source: Urban Innovators*

There are two phases for through movements and another two phases for safely supporting left turns. In this case, each of the four approaches has a nine-lane cross-section, adding up to nearly 150 feet for pedestrians to cross – about half of a football field!

Figure 1-4 helps reveal why 4-phase signals have so much delay. Think of each movement as an electrical switch: If all four switches are on, it will overload the circuit breaker. Alternative Intersections are about strategies for reducing the number of switches, from 4 to 3 or 2. Doing so reduces the "lost time" from the red and yellow parts of the cycle. Delay is further reduced when there is no need to dedicate time to left turns at the main intersection.

With 4-phase signals, engineers will install more lanes to compensate for this inefficiency. If a left-turn phase needs 30-seconds but can only have 20-seconds, a "double left" is often the solution. If the two northbound lanes need 60-seconds but can only get 40-seconds due to the needs of the other movements, the solution is often to add a third lane.

With alternative intersections, the result is more green time for all movements, and they are also usually safer. It can even result in traffic operating better than before, often with slower speeds and with fewer lanes.

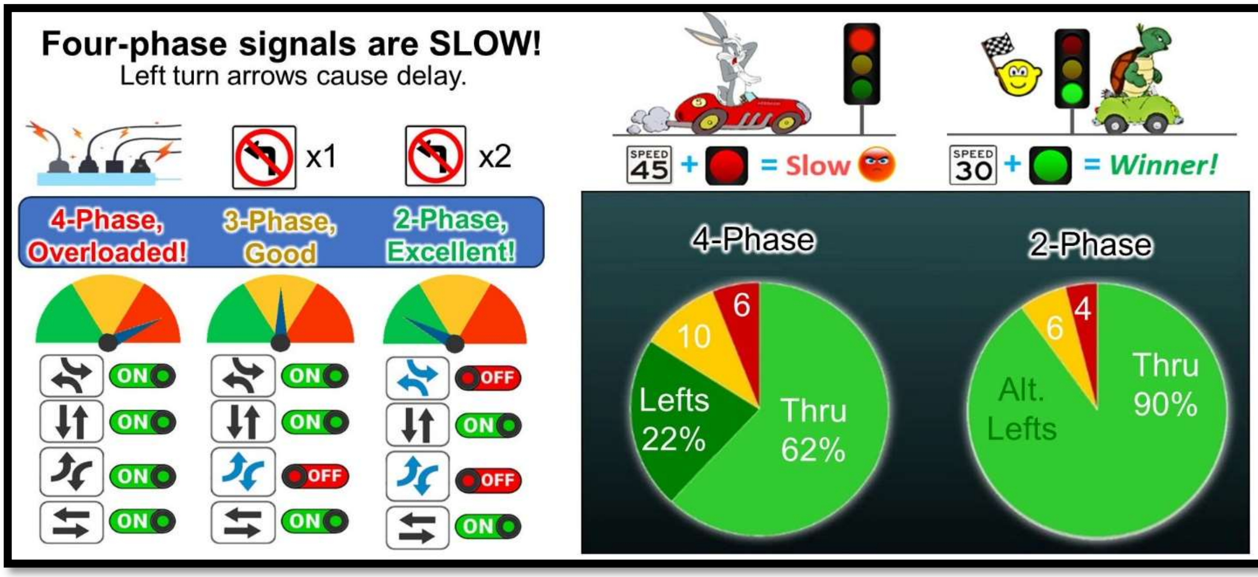


Figure 1-4 Two-phase signals have a lot more "green time" than four-phase signals. *Source: Urban Innovators*

1.5. Placemaking Alternative Intersections: Key to Win-Win

This research effort introduces the concept of "**Placemaking Alternative Intersections**" (PAIs), for the first time in the nation, as a strategy to create win-win opportunities. It demonstrates how communities can convert languishing auto-oriented commercial "Stroad corridors" into vibrant, walkable mixed-use boulevards. At the same time, PAIs can help traffic engineers manage high volumes of traffic at slower, safer speeds, with less congestion and delay (meaning similar if not faster overall travel times despite a lower speed limit). Thus, implementing this research will help Stroads become much better "streets," (vibrant and walkable), while still maintaining their road-like ability to manage high volumes of traffic at travel times comparable to today (a feature that will often prove essential for political viability).

The Alternative Intersection (AI) designs that have impressive "Placemaking" potential for urban environments include **Roundabouts, Quadrant Roadways, U-Turn strategies, and One-Way Split Intersections**. Within the U-Turn category there are many sub-designs such as Bowties, Median U-Turns, and Restricted Crossing U-Turns (RCUTs, but also known as Reduced Conflict Intersections, or RCIs in North Carolina). All of these have potential for managing high levels of traffic while also catalyzing walkable, mixed-use development. But of all of these, only roundabouts have made much headway in being seen as compatible with and catalysts for walkable environments. The other designs are still effectively unknown in most of America – especially in a Placemaking T4 (urban) construct (discussed in more detail later). Where these AI strategies have been built or studied, a "walk/bike-friendly" outcome has been rare – especially at a level sufficient to catalyze the transition from auto-oriented suburban to mixed-use urban densities.

The remainder of this section includes a brief overview of Quadrant, U-Turn, and One-Way Split Intersections, which are then explored more deeply later in this report.

1.6. Overview of Quadrant, U-Turn, and One-Way Split Intersections

In **Figure 1-5**, instead of managing left turns directly at the main intersection, a Quadrant redirects lefts along "backway paths" such as those shown here. The blue path has some out-of-direction travel, but the path will often still be quicker because the main intersection is now a 2-phase signal rather than a congested 4-phase. This is especially true if the distance to the Quadrant intersections is close to the main intersection.

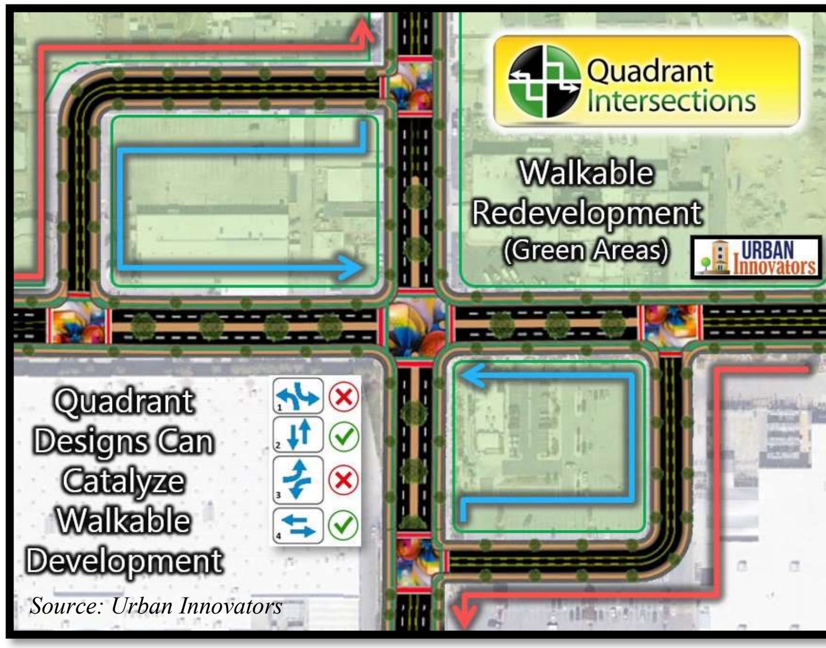


Figure 1-5 Concept for a "Kitty-Corner Double Quadrant" Intersection

Former left-turn lanes can now be converted into planted medians with trees and pedestrian refuge areas in the middle of crosswalks. The Quadrant backway improves access and visibility along that path, making adjacent land attractive for mixed-use development. Driveways can be relocated to the back, resulting in a better pedestrian environment on the main arterials. While the "kitty-corner double quadrant" concept is shown here, it is also possible to reroute any number of movements to one, two, three, or four quadrants. A four Quadrant option is shown later.

1.7. Overview of U-Turn Intersections

In the "Before" part of **Figure 1-6**, the purple paths require a left-turn arrow for safety. The result is a four critical phase signal that creates congestion and often requires Stroad-like double-left lanes. In the "After" image, lefts are converted to "Thru + U + Right." Safety hazards are also reduced for the blue and yellow paths. Similar to the Quadrant, the available right-of-way from old left turn lanes can now be repurposed with

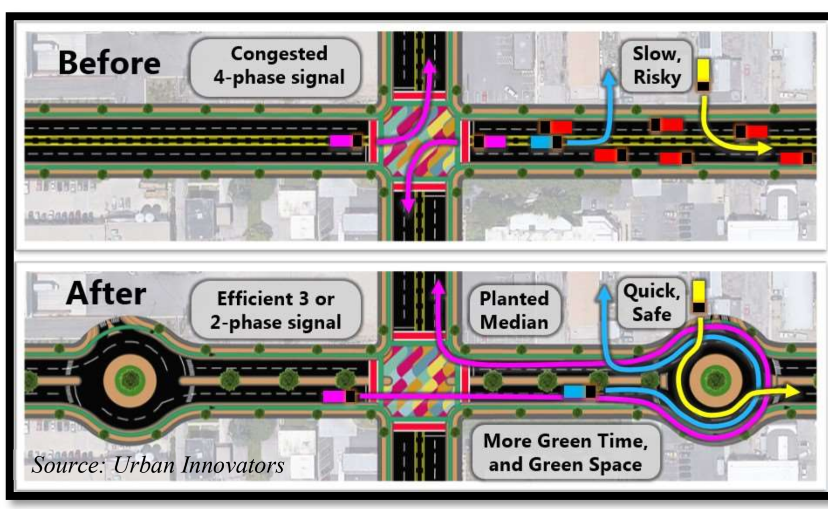


Figure 1-6 Before and After of a Stroad vs a U-Turn Design

planted trees and pedestrian refuge areas in the crosswalk. This novel use of roundabouts creates an effect similar to Median U-turns (aka "Michigan lefts") and Reduced Conflict Intersections (RCIs), which have similar (but not all) components.

In an urban setting, with the deflections on the mainline caused by the roundabouts on both sides of the main intersection, have led to the nickname of a "Bowtie." In addition to roundabouts, U-turns can be made using "Loons," and "Teardrops" (see "Appendix B: Top-View Drawings of Placemaking Alternative Intersections"). Last, one very important (but rarely discussed) advantage of an RCUT compared to the other U-turn alternatives is that it acts like a one-way pair on the mainline with (near) perfect progression – a huge efficiency boost for corridors. This makes it even more useful when paired with one-way streets where roads must come back together such as an urban area transitioning to a suburban or commercial zone. While U-turn intersections are increasingly common, especially in North Carolina and Michigan, it is still not a well-known strategy nationwide. Further, it is rare to use them intentionally to promote walkability.

1.8. Overview of One-Way Split Intersections

When a 5-7-lane arterial crosses another 5-7-lane arterial, the result is almost always a huge Stroad intersection with a very large footprint, a four critical phase signal, and double-left turn lanes. However, traffic can be managed much more efficiently and safely, with far less congestion, if one or both arterials are divided into one-way "couplets" for the crossing. **Figure 1-7** shows how four small one-way intersections can catalyze a walkable environment. This idea is sometimes called a "Square-about" because it works similar to a roundabout. One-Way Split Intersections are considered highly efficient because left turns on one-way streets do not need a left turn arrow since there is no oncoming traffic. Our research shows that four pedestrian-friendly 2-phase signals can handle much more traffic than had it been a single huge Stroad intersection with a 4-phase signal.

Figure 1-7 *One-Way Split Intersection design in San Marcos, California* *Source: Urban Innovators*

This design was used in San Marcos, CA (and in a few other locations) to catalyze walkable development, and it has succeeded very well. There are also many one-way couplets in America's highest density environments that manage high volumes of traffic in ways that are very compatible with walkable mixed-use development. There is a trend to convert many one-ways into two-ways for cases where the resulting two-ways would have only one lane each direction (thereby decreasing average drive speeds since you cannot pass slower drivers).

However, where the two-way alternative would be a large Stroad with two or three lanes each direction, the team wondered what walkability experts would think of one-ways for these cases. Mr. Jeff Speck, a popular walkability expert, was contacted and asked about such scenarios. He stated that for walkability he prefers a grid of many two-way streets with one lane in each direction over a system with highways that have at least two lanes in each direction. However, for cases where that is not an option – where the only alternative would be a two-way with multiple lanes in each direction – he agreed that one-ways can be designed at a level that will likely prove better for safety and walkability than such two-way alternatives.

Palm Canyon Drive in Palm Springs, CA, (**Figure 1-8**) is one of many such examples.

Figure 1-8 *Walkable one-way arterial: Palm Canyon Drive, Palm Springs, CA*

Implementing one-way streets, especially as retrofits, can be extremely challenging. To address this, Urban Innovators created memos in "**Appendix D: Addressing Negativity Toward One-Way Streets**," which is available in the appendix directories associated with this report.

1.9. Summarizing the Effects of Placemaking Alternative Intersections

Figure 1-9: Serving all four phases at a single intersection can become "tangled" when volumes are high enough, as engineers "solve inefficiency" by adding more lanes – think double, even triple lefts! It's similar to a circuit breaker: when too many "switches" are turned on, the overload trips the breaker, creating "Level of Service F". The placemaking designs studied here (three right images) each handle left turns in an alternative way.

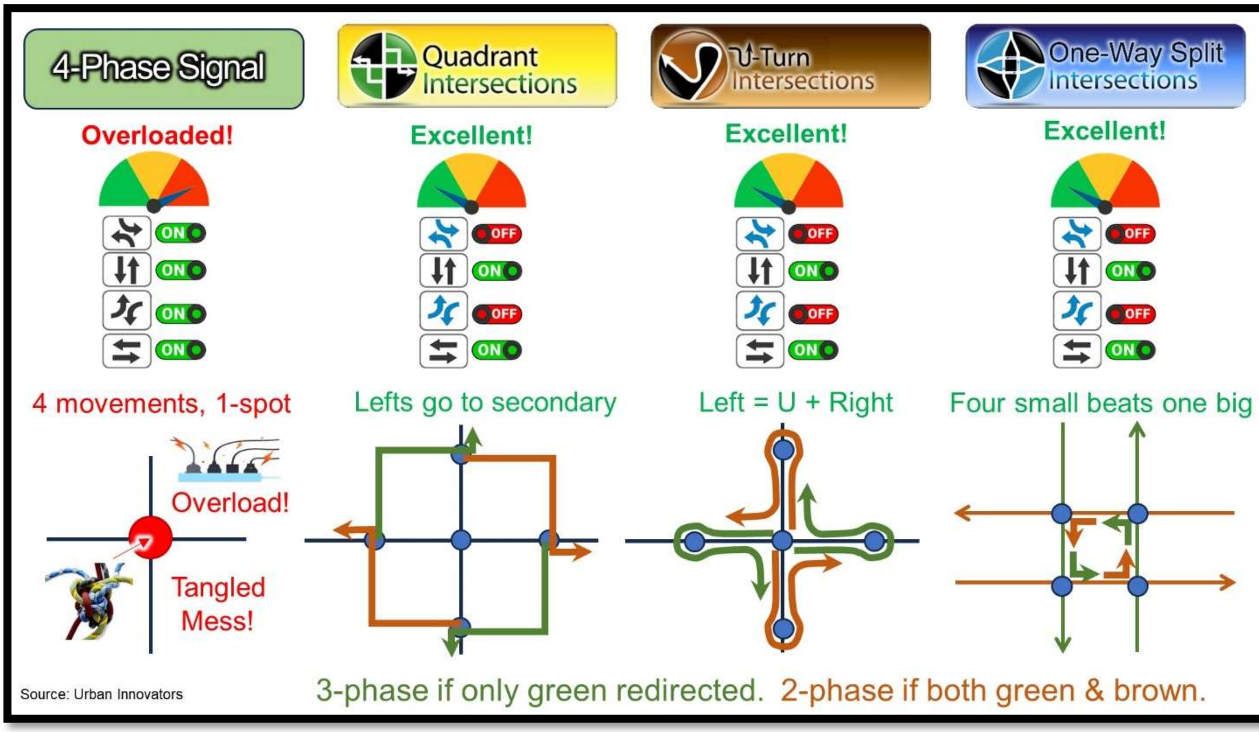


Figure 1-9 Four-phase signals tie traffic in knots. The others untangle the mess and create great "Places."

Figure 1-10: The blue curve illustrates how today's "Stroads" often serve traffic perhaps as a 5 on a scale of 1 to 10 and they tend be poor at walkability – maybe 1 or 2 on a scale of 1 to 10. When communities "pull hard to fill the walkability tank," engineers often identify ways to make it a little better, perhaps a 3 on the scale, but there is only so much they can do.

This research demonstrates how Placemaking Alternative Intersections are making it possible to reach the green curve, where both traffic and walkability can each perform much better.

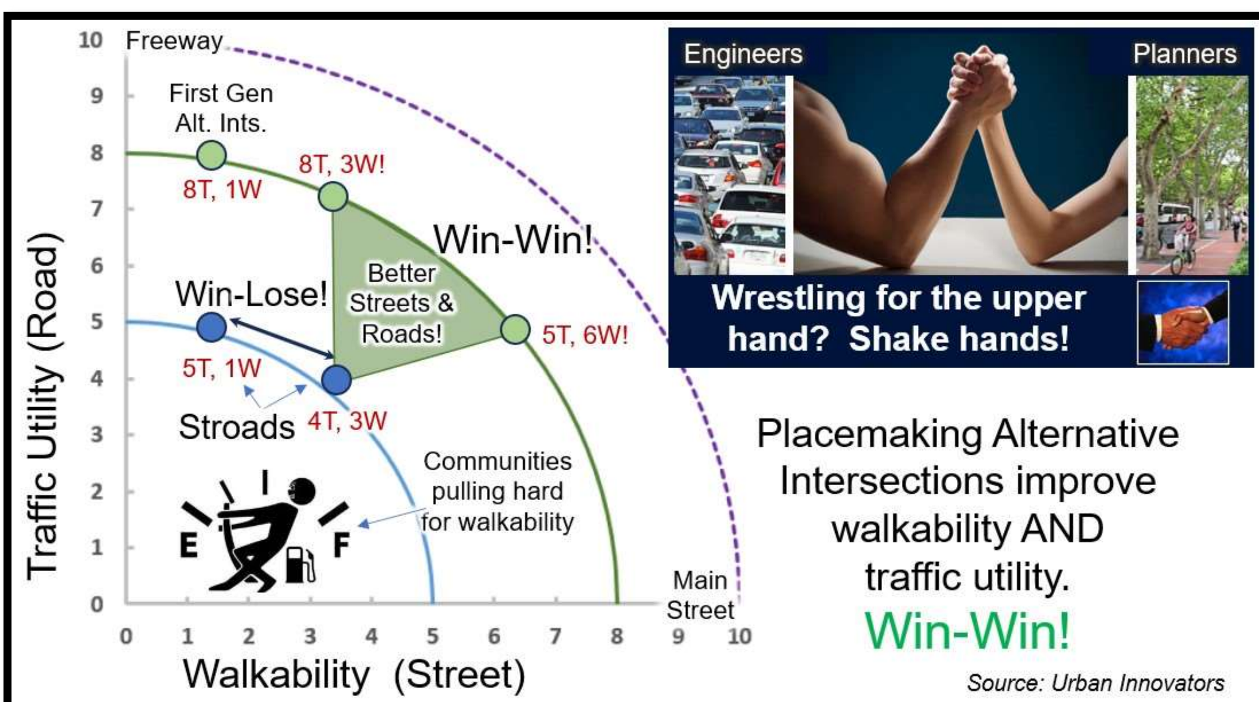


Figure 1-10 PAIs open a new frontier of Win-Win for both traffic and walkability.

1.10. Top-View Library of Placemaking Alternative Intersections

A product of this study is a top-view library depicting a wide variation within across Quadrants, U-Turns, and One-Way Split Intersection designs. This library is part of "**Appendix B: Top-View Drawings of Placemaking Alternative Intersections**," available as a PowerPoint file within the Appendix directories.

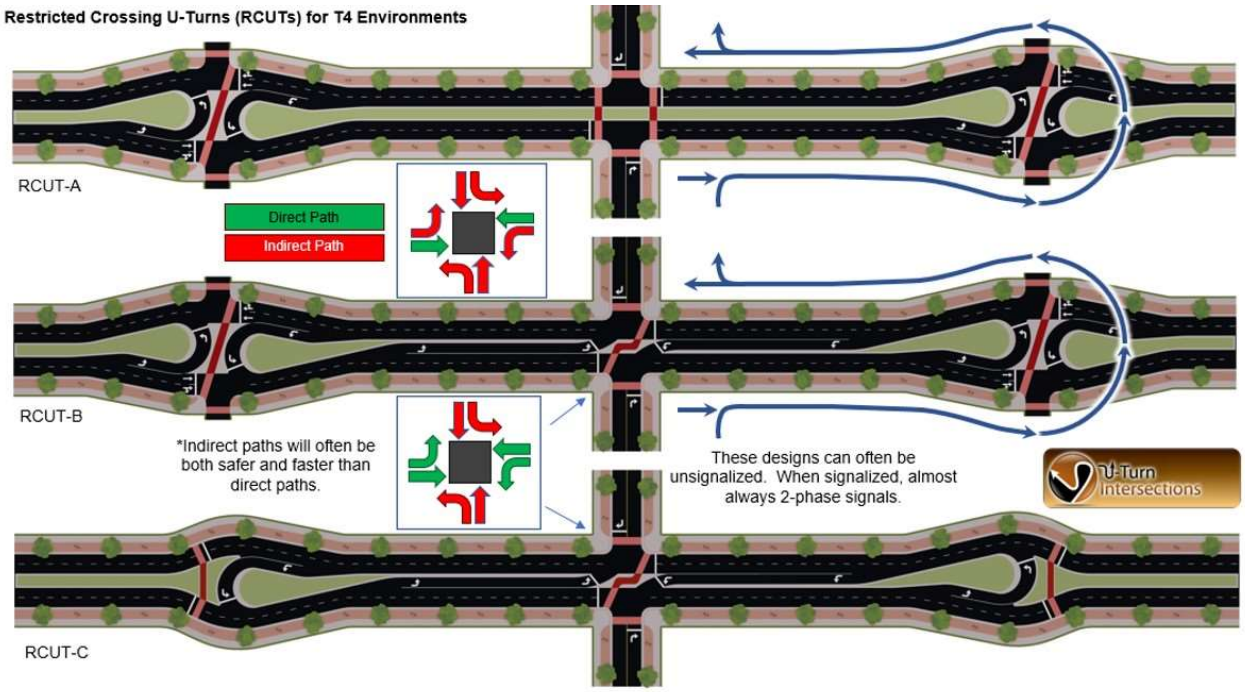


Figure 1-11 Example of three variants for T4 urban-appropriate RCUT-style U-Turns.

Also within Appendix B, each top-view diagram has been converted into a transparent .png image, which users can load into Google Earth as a sketch-visioning exercise to communicate basic ideas and get some sense of potential right-of-way impacts, spacing issues, etc.

Figure 1-12 Overlaying transparent .png files within Google Earth for sketch planning.

1.11. Overview of Contents in Report

This report covers the following tasks:

- Develop 2D/3D visualizations along with performance analysis to demonstrate how to use AI designs to create "win-wins" for all interested parties. This research centers on three specific families of Alternative Intersections: Quadrant Roadway Intersections, U-Turn Intersections, and One-Way Split Intersections. Roundabouts are excluded because they are already well researched and have significant market penetration. Many designs are modeled on real-world locations in Greenville and Smithfield, North Carolina.
- Compare AI designs with the traditional design not only visually, but also numerically in terms of overall footprint, operational (Level of Service, LOS) performance, maximum 1-hour entering capacity, expected speed and safety effects, and expected cost ranges.
- Discover the pros and cons of AI designs in urban settings and communicate both the good and bad effectively to NCDOT and subsequent stakeholders.
- Discover and articulate the strengths and weaknesses of AIs in helping transition "Suburban Stroads" into walkable, livable, functional "Urban Streets" that still help NCDOT with managing the high traffic loads that they may have no choice but to manage.

The remainder of this report is organized as follows:

Chapter 2: State-of-the-Art and Best Practice Review

The research team did an extensive search to locate the nation's complete streets and best T4 (urban) walkable examples of corridors that include AIs. The team conducted a comprehensive review of the typical AI designs.

Chapter 3: Placemaking Alternative Intersections: Idealized Depictions

Based on the review of best practices, the research team created both 2D/3D visual renderings and graphics of the most promising AI candidates for urban walkability. Cross sections, top views, and bird's eye views were created for all designs deemed capable of advancing objectives identified by focus groups.

Chapter 4-5: Placemaking Alternative Intersections: Greenville and Smithfield

2D/3D visual renderings, graphics, and discussion regarding real-world sites in Greenville and Smithfield, North Carolina.

Chapter 6: Performance Comparison Analysis

The team established a "Conventional vs. Alternative" performance analysis. This investigates traffic operational performance from three perspectives: 1) Level-of-Service improvements, assuming no fundamental change in number of lanes or overall traffic volume, 2) Lane-drop opportunities: thresholds at which AI efficiency gains make it possible to transition an existing traffic lane to alternative uses, 3) Higher traffic support – assessing maximum flow at LOS E should reveal that given the same number of lanes, AI designs can support more overall traffic. Eventually, by determining how much more traffic an AI design can handle over conventional design, we identified how much more economic development could be accommodated (Chapter 7).

Chapter 7: General Economic Analysis

This chapter describes the "Development Scale Calculator," which is a spreadsheet tool that was developed as part of this effort to obtain a reasonable estimate of the development potential that can be supported by an intersection area at the point where the system functions at Level of Service E. The tool takes into consideration efficiencies gained from land use density and diversity, from alternative modes and street connectivity, and new vehicle capacity gained by Placemaking Alternative Intersections (or by any mechanism that results in new capacity).

Chapter 8: Focus Groups

The research team presented the 2D/3D visuals and analyses to several potential stakeholders including commercial real estate agents, appraisers, market analysts, developers, municipal planners, etc. to determine typical goals, values, objectives, and performance measures these stakeholders would generally use to define success for an NCDOT roadway as it moves through their most sensitive urban spaces.

Chapter 9: Conclusions and Discussions

Finally, major findings from this research and insights for urban implementation of AIs are summarized. Future research ideas are also discussed.

Chapter 10: Future Research Needs

Ideas for further exploration.

2. State-of-the-Practice

2.1. The Conundrum of Decaying Suburban Commercial Arterials

The six-phase "Transect" has emerged as a preferred mechanism among planners for describing landscapes. **Figure 2-1** presents a diagram of each transect phase, along with typical photos.

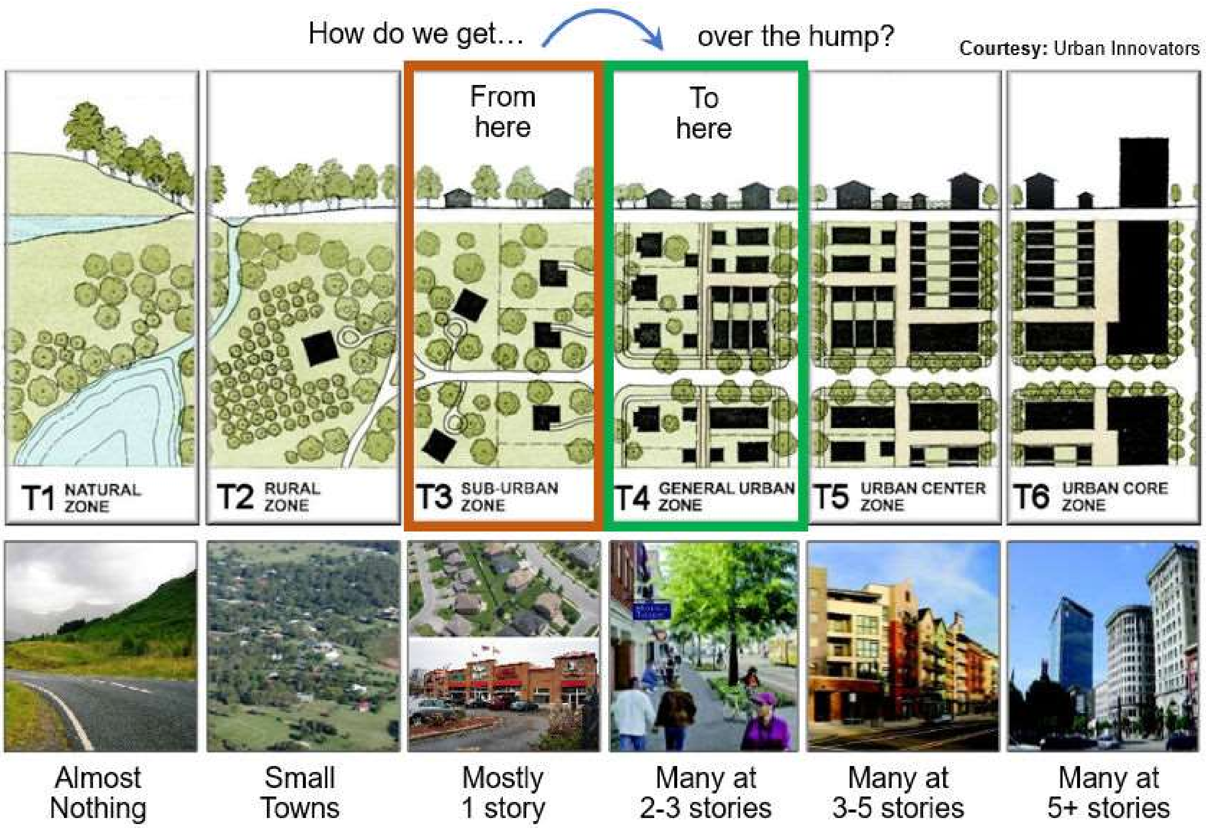


Figure 2-1 *Illustration of the six-phase "transects" or "context zones."*

Prior to automobiles, popular "Activity Centers" would transition naturally and incrementally all the way to T6 (if it were destined to be a large city). After automobiles became ubiquitous, commercial activity centers would often stop at T3 (suburban). Automobiles made it easy for the market to access low-cost buildings on virgin land rather than wrestle through the expense and difficulty of intensifying "strip commercial." In many cases, areas that had achieved T3 or higher actually reduced their overall activity density, since cars made it easier for residents and businesses to relocate as a means of avoiding deteriorating situations (i.e., flight to the fringe).

Figure 2-2 shows this phenomenon in terms of accumulated real estate value. The blue line reflects the general trend of pre-WWII Activity Centers. Since they reached critical mass before automobiles, their cumulative value would keep growing as they moved T3 on up to T6. However, post-WWII, suburban T3 commercial areas rarely moved on to T4. Instead, they tend to lose cumulative value (moving backward toward T2), as businesses and residents of means move on to the next "new and shiny" suburban location. This phenomenon is what creates "greyfields," defined as struggling commercial areas with under-utilized parking lots and nearby homes in disrepair. It also creates duplicative infrastructure that is hard to maintain, because there is now infrastructure in two or more areas, but less tax revenue available within the original service area.

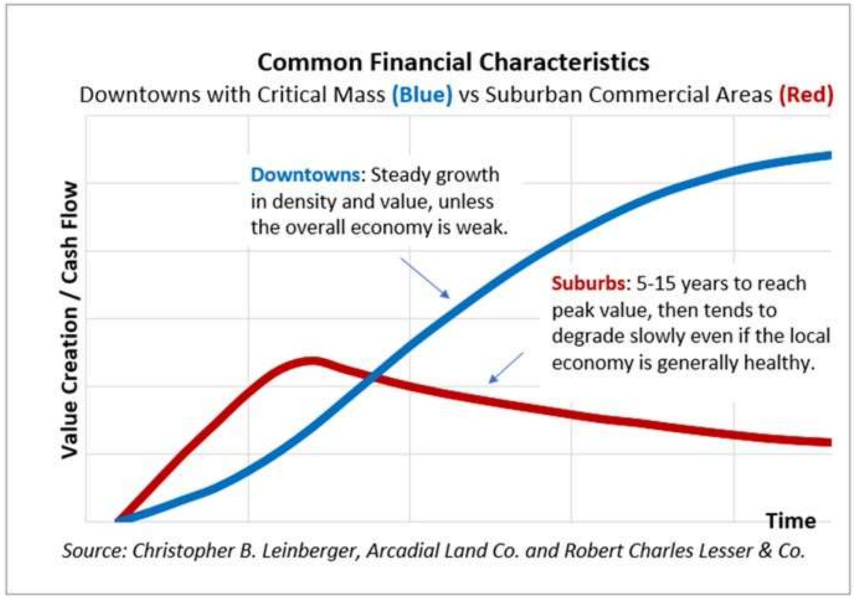


Figure 2-2 *Auto-oriented commercial areas peak then lose value. Mixed only grows.*

Figure 2-3 (below) shows the first three phases of a Stroad corridor, along with a potential "Complete Street" fourth phase that can occur – if effective tools can be found to help collapsing T3 to "make the jump" to T4.

Phase 1 shows a rural highway traversing virgin "greenfield" land. This eventual Stroad starts its life with speeds of 55 mph or higher. As development increases, DOTs end up widening the road to relieve congestion. The widening contributes to a boom in development - "Goldfields" for developers. In this **Phase 2**, auto-oriented commercial increases until the area is 100% suburban (defined as 1x activity density). The boom creates new traffic signals and congestion returns. Thus, despite a relatively fast speed limit, average point-to-point peak period speed is often slow.

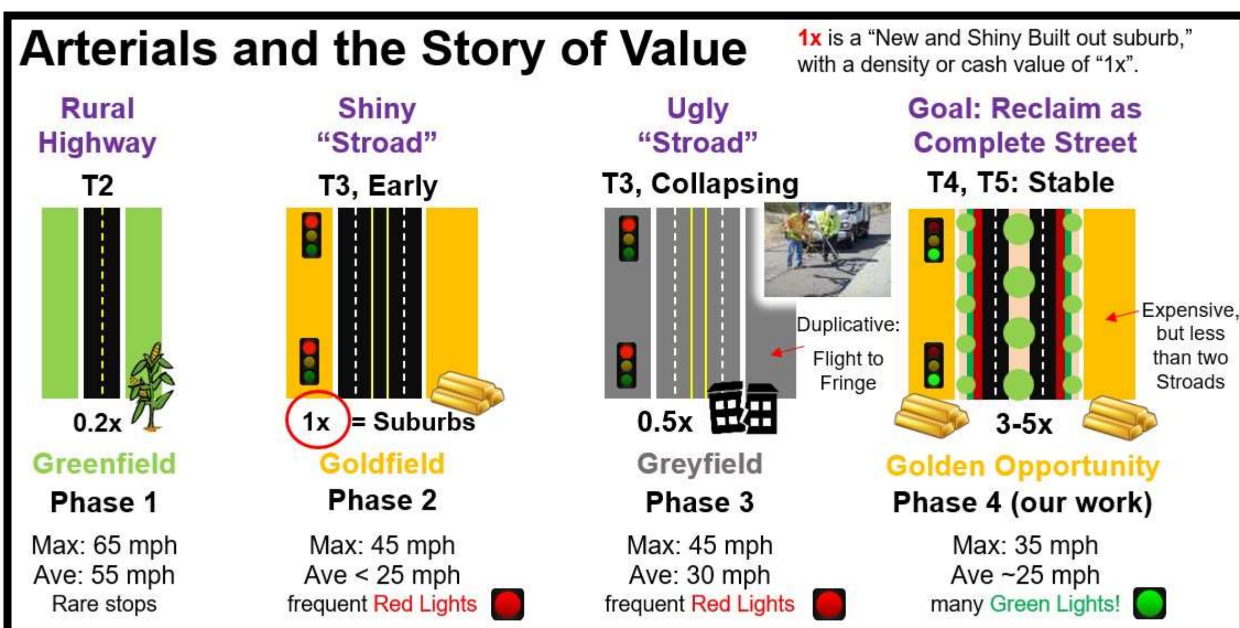


Figure 2-3 *Arterials and the story of nearby real estate value* *Source: Urban Innovators*

Phase 3 occurs after the "shine" wears from right-of-way features and adjacent properties. Weeds, potholes, and pawnshops are likely endemic. Buildings still open may be underutilized. These greyfields are often detectable by a great many underutilized parking lots. Drive times often *improve* through such decaying places (from 25 mph to 30 mph as shown here), because adjacent activity might be half of what it was before (0.5x in the example). Ironically, from a DOT's typical delay and safety-based performance metrics, the decaying situation appears better! But it is only "better off" because businesses and residents of means have "fled to the fringe," where they are once again creating pressure to widen for yet another Stroad. The result is duplicative infrastructure, where NCDOT is on the hook to maintain more overall "lane miles" of infrastructure.

Phase 4 represents what communities increasingly hope to achieve - a return of their "Goldfield" glory-days. They petition NCDOT for "Complete Streets" to improve the aesthetics of the environment, and the attractiveness and safety of alternative modes. The goal is to attract economic development that will move the area from floundering T3 into thriving T4. *But engineers face a serious problem that can prevent this revitalization: even if given money and a mandate, they still don't have tools for achieving the objective.* It isn't easy to remodel a decaying Stroad with traffic calming strategies to catalyze walkable development, and at the same time offer at least similar overall travel times to drivers. The main point of this effort is to do exactly that – demonstrate how to "Drive Slower but Travel Faster."

2.2. Comparing Decaying T3 Suburban in Greenville to Vibrant T4 Urban in New Bern

Later sections of this research will demonstrate how Placemaking AIs can be foundational for creating a "bone structure" on which T3 suburban Stroads can transition into T4 walkable mixed-use. To demonstrate the potential, sites were selected in Greenville and Smithfield, NC for "hypothetical projects" that would need further community vetting before they could proceed.

The team compared downtown New Bern, NC (a very walkable location), against the much less walkable Greenville Mall area (**Figure 2-4**). After studying the comparisons in **Figure 2-5** to **Figure 2-9** (discussed in more detail below), it becomes obvious that while PAIs may be an essential foundation for transitioning auto-oriented commercial into walkable T4, many other aspects are also essential. After discussing the differences between these areas, we will discuss key strategies to pursue when aiming to move from T3 to T4.

Downtown New Bern

Greenville Mall Area

Figure 2-4 *Walkable mixed-uses in New Bern vs Auto-oriented commercial near Greenville mall.*

Figure 2-5 compares a walkable mixed-use block in New Bern to the auto-oriented commercial study area in Greenville, revealing how each square foot of each study area is utilized. **Figure 2-6** to **Figure 2-9** compare each component in a "waffle graph" format. All graphics in this section were created jointly by ITRE and Urban Innovators.

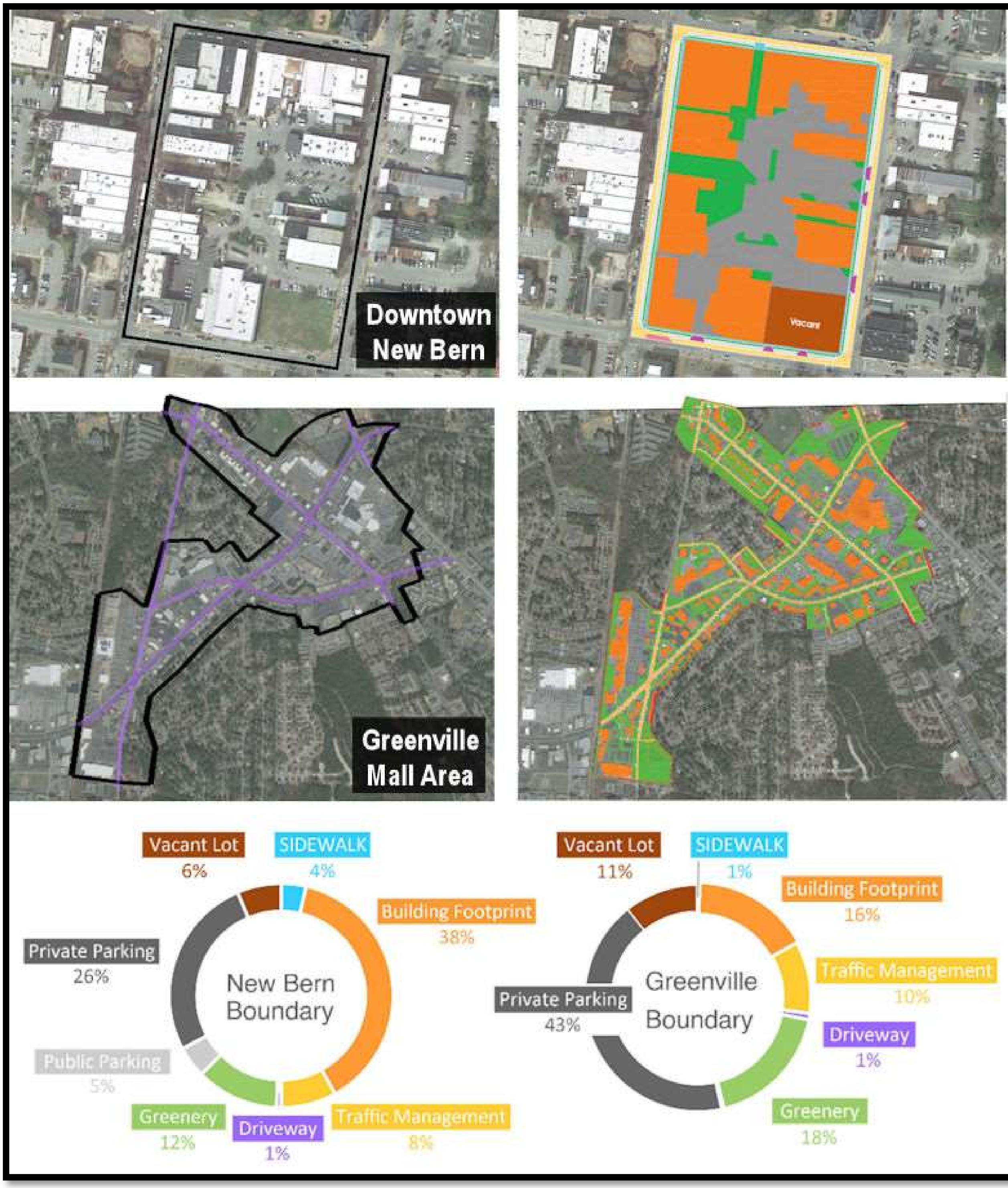


Figure 2-5 New Bern Walkable Mixed-Use vs Greenville Auto-Oriented Commercial *Source: ITRE & Urban Innovators*

<u>Building Analysis</u>: Figure 2-6 shows that for every 100 acres of urban environment, building footprints in New Bern cover 38 of those acres (i.e., 38%), while the Greenville area has only 16% building footprints. In New Bern, there are another 42 above-ground "acre equivalents" (building levels 2 or greater), while Greenville has only about 3% above ground (meaning nearly all buildings are single-story). In New Bern, there are 80 acres of floor space (38 ground level + 42 second story or greater) for every 100 acres of land, or a Floor Area Ratio (FAR) of 0.80. Greenville's FAR is 0.19 (16+3). *To be fair, this is New Bern's most intense block; however, including a few more blocks would likely reduce the FAR to the 0.3 to 0.5 range.* In general, T4 walkable areas tend to have a floor area ratio of about 0.3 to 0.5, when measured over many blocks and when including streets and other incidental uses. T3 auto-oriented commercial tends to be around 0.14 to 0.20 *(Duany, Plater-Zyberk, & Speck)*.

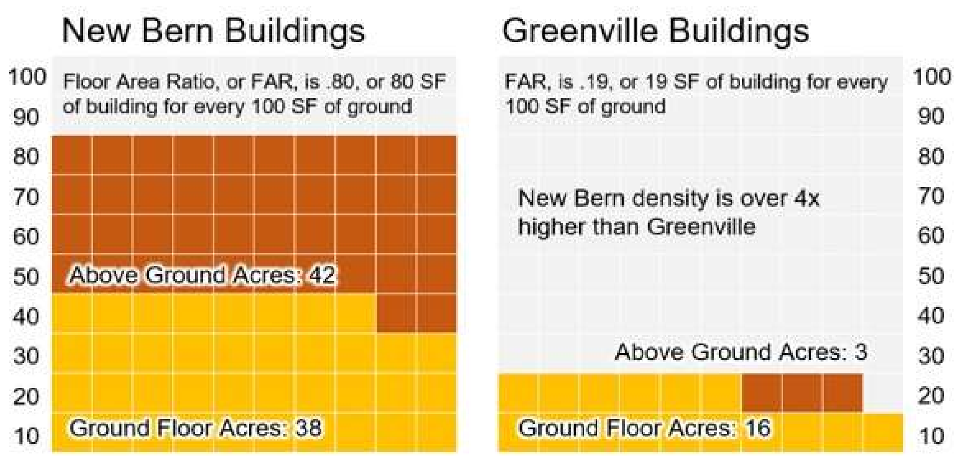


Figure 2-6 Comparison of floor area ratios

<u>Parking</u>: Even though the FAR is half that of New Bern, Greenville has 60% more parking! The Greenville area has almost twice as much off-street parking as downtown New Bern (grey), and New Bern has far more on-street parking (blue). However, even in this very walkable area, 31% of all land is dedicated to parking, not counting any parking garages which we were unable to discern. This suggests that walkable areas tend to reserve a lot of land for parking, but much of that parking tends to be on-street. Greenville's parking is likely heavily under-utilized on any given day as there are 60% more acres of parking than in downtown New Bern.

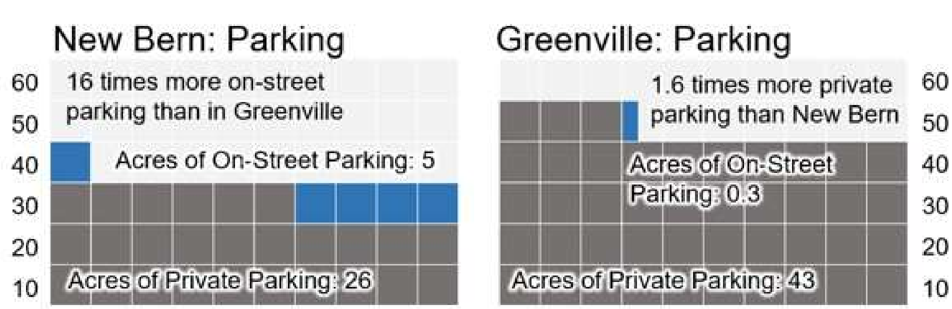


Figure 2-7 On-street and off-street parking comparison

Open Space and Plazas: New Bern dedicates about 12% of its area to parks, plazas, and general greenspace, while Greenville has about 19%. While 19% may seem more people-friendly, it tends to be drive-by landscaping rather than pedestrian-interactive. This suggests walkability doesn't necessarily need large parks or open space, as long as what it does have is well designed and interactive. Both areas have similar amounts of "vacant lots" that do not appear to be preserved as open space, but instead will likely be developed if the market for that ever emerges.

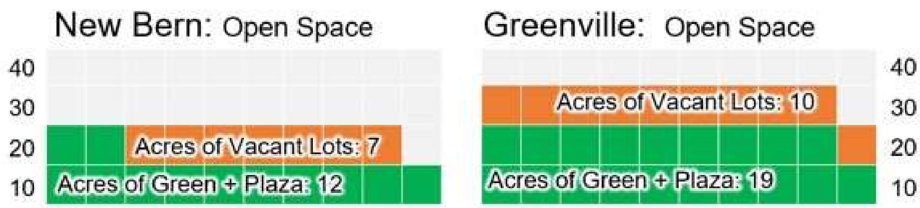


Figure 2-8 Open space and vacant lot comparison

Acres per Block: New Bern has about 4.8 acres per block, while the Greenville study area averages about 21 acres per block. Historic downtown grids can range from just one acre per block (Portland, Oregon) to as high as 10 acres per block (Salt Lake City, UT). *Note that Salt Lake City is actively dividing their "superblocks" with alleys and pedestrian paths whenever possible, as they are too large for walkability. Stroad-like areas would also do well to plan on dividing their superblocks, aiming for around 3-8-acre blocks as much as possible.*

Figure 2-9 Average block size

Pedestrian Space: This includes sidewalks as well as "furniture zones" where street trees, benches, and other pedestrian-oriented features exist. New Bern has 4% of its land available for these uses, while Greenville has only 0.6%. Noted earlier, this is largely a function of block size. New Bern has small blocks, meaning more sidewalks per acre. Greenville has huge blocks, and many of these huge blocks do not have any sidewalks along some streets.

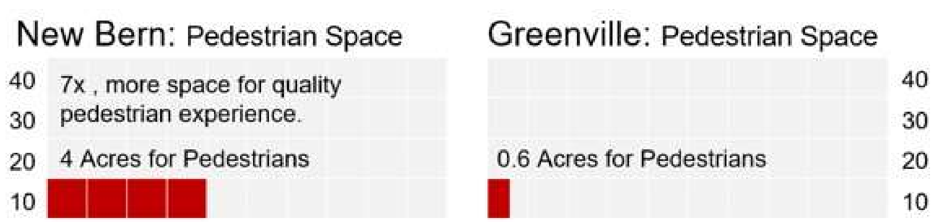


Figure 2-10 Pedestrian-specific space (sidewalks, furniture zones)

Traffic Management: Notice that both have about the same amount of land dedicated to traffic management (10 vs 11 acres). This excludes parking lot circulation lanes, which are counted as part of off-street parking. A key difference is in how this pavement is utilized for "traffic". New Bern has more (but smaller) "Streets," while Greenville has fewer (but larger) "Stroads."

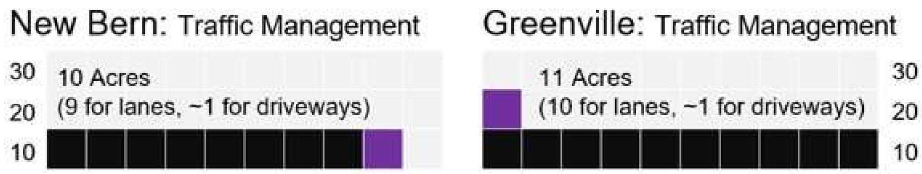


Figure 2-11 Percent of area dedicated to traffic management (lanes, turning lanes, driveways)

Conclusion: An area that aspires to T4 urban mixed-use walkability must find a way to reduce the percentage of land consumed by off-street parking, and ideally increase the presence of on-street parking. This can be done in large measure by removing minimum parking requirements, or offering developers payment in lieu of parking, which might go toward a public parking garage, transit, or some other nexus expense.

Converting a T3 auto-oriented commercial area into a T4 walkable area also requires improving connectivity (i.e., reducing average block size). Impressive street trees, plazas, and other pedestrian features are also essential. Step one in reducing block size is to divide large parking lots into smaller parking lots through a combination of formal city streets, alleyways, pedestrian zones, and multimodal paths, making it more inviting to walk. Form-based zoning codes can then require new mixed-use buildings to front these new streets, with minimal setbacks from the sidewalks. It will be very hard to achieve any measure of walkability unless block sizes can be brought down, ideally into the 3 to 8-acre range.

In our research and consultation with development experts, it appears that transitioning T3 auto-oriented development into T4 walkable development will require active coordination both inside and outside the right-of-way lines (inside usually controlled by NCDOT, and outside controlled by a city). For example, if a city requests a Complete Streets investment from NCDOT, hoping it will spur T4 development, NCDOT should only prioritize that investment if the community has taken steps that are likely to result in a safer, more efficient, more walkable T4 outcome:

- Is there a form-based zoning code that allows higher density and diversity of uses?
- Are they committed to dividing large blocks into smaller blocks?
- Have they removed minimum parking requirements or otherwise created a plan that will result in high utilization of parking?
- Is there a good plan for creating and maintaining uniform street trees in the area?
- Is there a good plan for increasing alternative mode usage?
- Is there a "Placemaking Alternative Intersection" opportunity for managing high traffic loads while at the same time helping to catalyze walkable development?

2.3. Complete Streets

Transportation is expected to provide and contribute to safety, well-being, comfort, convenience, health, economic growth, and social development in communities by increasing mobility, connectivity, and accessibility to services, resources, people, opportunities, and markets *(Hickman et al., 2013; Steg, 2007)*. It also has a very significant role in catalyzing sustainable development and contributing to a sense of place.

Over the years, poor transportation strategies and insufficient roadway infrastructure, weak cooperation between land use planning, urban design, and transportation planning contributed to evolving social, economic and environmental issues in our communities *(Buehler & Pucher, 2012; Gossling, 2013; Hickman et al., 2013)*. Transportation infrastructure needs alteration to accommodate multiple travel modes that will better fit to the community context that it is part of. It is also essential to develop policies, planning/design processes, and behaviors reducing transportation related negative impacts *(Babalik-Sutcliffe, 2013; Dehghanmongabadi & Hoskara, 2020; Prillwitz & Barr, 2011)*.

"Complete street" as a concept and design provides safe and comfortable means of commuting and transporting by all users of all ages and abilities via any mode, including those that use the street as public space for leisure and socialize *(Vandegrift & Zanoni, 2018; Yu et al., 2018)*. Complete streets provide more opportunities to use active modes of transportation (*MacLeod et al., 2018; Vandegrift & Zanoni, 2018)* and they aim to make communities more active, livable, and sustainable *(Anderson et al., 2015; Zavestoski & Agyeman, 2015)*.

Complete Streets can help transform the traditional thinking and practices in urban design. Current street design standards prioritize auto access by focusing on vehicle movement. The design of complete streets can encourage active transportation modes, particularly biking and walking, which in turn can improve overall health by promoting exercise, lowering obesity and chronic disease rates, improving air quality, and creating safer, equitable, and more livable communities *(Dehghanmongabadi & Hoskara, 2020)*. Complete streets create balance through different types of movement and modes, including narrower lanes and decreased motor vehicle speeds, as well as a landscape that includes ample greenery and trees that helps to create better public spaces, traffic safety and a better quality of living.

Most attention on complete streets has focused on urban cores, however, complete streets are not limited to the urban context *(Rutkowski and Hemme, 2021)*. Suburbs are commonly known for their lower-density development, separated uses, automobile-oriented infrastructure, and wide roads. While this is a setup that allows for ample space and distancing, it often falls short when it comes to having a forward-looking street design. Changing this infrastructure is imperative as communities continue to look for ways to minimize climate emissions, improve quality of living for all residents, and encourage healthier, more active living *(Rutkowski and Hemme,2021)*. However, these roads have developed with tight property lines, limited rights-of-way, and lack of safe bicycle and pedestrian facilities. These limitations can make these areas especially challenging, and even contentious *(Rutkowski and Hemme,2021)*.

NCDOT has one of the strongest Complete Street policies in the nation and agrees that adapting a strong complete streets policy and design is important to organize efforts between all agencies that manage activities related to transportation *(Carissa Schively & Cindy, 2013)*. The policy and design of streets must characterize all modes including walking, cycling, public transit, and automobile use plus all users including pedestrians, cyclists, transit passengers, and drivers of all ages and abilities. According to *Seskin and Gordon-Koven (2013)*, developing a vision and effective planning/design strategies for implementing complete streets that build on community's needs and goals is important. Building a comprehensive, integrated, and well-connected road network, as well as all transportation modes is also essential. Connectivity of road networks is a main feature of complete streets. Successful complete streets offer a situation in which everyone can safely and confidently move through the transportation network.

Implementation of effective design strategies for complete streets to achieve maximum flexibility is essential. However, establishing a balance between users and various transportation modes needs to be a main aim of the design approaches. The surrounding community and properties also play a crucial role in the success of complete streets. Understanding the existing context via proper site analysis, as well as identifying the current and expected transportation needs in communities are very important. Adapting streets to fit the character of the surrounding neighborhood is also essential that also builds on the comprehensive understanding of the context.

Although working with the existing context conditions is expected, planning for the predicted future around a vision is equally important. According to *Rutkowski and Hemme (2021),* a newly designed road will likely stay the same for many decades, during which businesses will change, new developments will appear, and the needs and demands of travelers on the roads will transform. This is especially the case along suburban commercial corridors, where sprawling residential and strip commercial developments, surface parking lots, and vacant land often change ownerships multiple times.

As *Rutkowski and Hemme (2021)* state *"Planning for the unknown may be challenging, particularly with new technologies such as autonomous vehicles and microtransit forthcoming. However, future land use plans can help to forecast what the development will look like, and the impacts it will have on the community. Accounting for what a road should be, not merely what it is, can ensure that the street serves the needs of its future community as well".*

2.4. Alternative Intersections

Alternative Intersection and Interchange (AII) designs aim to improve efficiency and safety, usually by reducing signal phases and conflict points *(Fitzpatrick et al., 2005; Hughes et al., 2010; Shumaker et al., 2012; Stephens et al., 2017)*. They often use innovative or uncommon geometric or control features, such as restriction of movements, crossover of traffic to the opposite side of the road, separating left turning movements to minimize conflicts, and combining non-conflicting movements into fewer critical signal phases, etc. *(Shin 1997; Hummer 1998a, 1998b; Hummer and Reid 2000)*. In the last two decades, AII designs have been increasingly popular in the United States, with particular versions championed in North Carolina.

This section presents a summary of the design and operational features, advantages, applicability, and the state-of-the-practice implementation of typical alternative at-grade intersections, as shown in **Table 2-1**. From the U-Turn family, at-grade intersections discussed include: the Median U-Turn (MUT), also known as Michigan U-turn *(Reid et al. 2014)*; the Restricted Crossing U-Turn (RCUT), also known as Superstreet *(Hummer et al. 2014)*; and the Bowtie *(Boone and Hummer, 1995)*. Also featured are the Continuous Flow Intersection (CFI), also known as Displaced Left-Turn Intersection (DLT) *(Steyn et al. 2014)*; the Quadrant Roadway Intersection (QRI) *(Reid 2000; Reid et al. 2019)*; the One-Way Split Intersection *(Reid and Hummer 1999, 2001)*; and the Roundabout *(Rodegerdts et al. 2010)*.

Table 2-1 State-of-the-Practice of Various Alternative Intersection Designs

AI Design	Design and Operational Features	Advantages	Traffic and Geometric Applicability	Pedestrian and Bicycle Environment	Deployment History
One-Way Split Intersection	• divides traffic on a two-way major street into two one-way street. When one-ways meet the cross street, it creates two three-phase signals (vs one four-phase before). • If both streets are split, the result is four two-phase intersections. • Similar to a traditional diamond interchange without grade-separated roadways. • Can be deployed with RCUT to keep perfect progression	• Spreads out conflict points where vehicles and pedestrians may cross paths. • Separates traffic flow on major street resulting in operations with less delay. • Better signal coordination possible on major street as well as minor street improving travel time of entire corridor.	• Excellent for locations with extremely high traffic volumes. • At congested suburban intersections with heavy left-turn traffic volumes. • In urban areas where two-way streets can be converted to one-way streets. • Intersections that may require grade-separation in the future.	• Excellent for bicycle and pedestrian environment, (relative to a two-way multi-lane arterial) • Easily supports higher densities and a diversity of uses, which is necessary for alternative modes to increase their share of trips.	• First deployed in Tel Aviv, Israel in 1975 • Major deployment region(s): TX, CA, UT, Canada
Roundabout	• A circular, unsignalized intersection where all traffic moves counterclockwise around a central island • Traffic entering the roundabout yields to circulating traffic inside the roundabout • Design options allow for right turns to be channelized to bypass the circulating lanes	• Reduced number of conflicts and lower speed improve safety. • Increased efficiency due to fewer stops. • Allows for landscaping and beautification • Long-term cost effectiveness for operations and maintenance	• With heavy left-turn traffic or with similar traffic volumes on each leg • With crashes involving conflicting through and left-turn vehicles • With limited room for storing vehicles • With complex geometry (e.g., more than four approach roads • Not ideal for the highest volumes, due to multiple interior lanes and a very large footprint required for managing movements.	• Low to medium impacts to peds and bicyclists • Sidewalks and crosswalks separated from the circulatory roadway to separate ped/vehicle conflicts • Bike ramps and additional pavement markings are needed • Raised crossings encourage drivers to yield and provide peds and bicyclists with a continuous accessible path of travel • Ped/ped: some challenges compared to traditional intersection	• First modern Roundabout was built in 1990 in Las Vegas. • Widely applied across the U.S.

Table 2-1, continued: State-of-the-Practice of Various Alternative Intersection Designs

AI Design	Design and Operational Features	Advantages	Traffic and Geometric Applicability	Pedestrian and Bicycle Environment	Deployment History
U-Turn: Bowtie / Teardrop	• Uses roundabouts, loons, or teardrops both before and after the main intersection, but not directly in the intersection. • Main intersection left-turn movements are completed at an adjacent roundabout • Traffic entering the roundabout yields to circulating traffic	• Reduced # of conflict points • Improved safety for pedestrians and bicyclists • Reduced delay due to fewer # of signal phases and shorter cycle lengths • Suitable in limited ROW locations • Low construction costs	• Consider at sites with high arterial through traffic while relative low left turn volume and minor street through traffic • Suitable for arterials with narrow or nonexistent medians and no prospects of obtaining extra right-of-way for widening	• Pedestrians and Bicyclists may have out-of-direction travel due to curvatures • Two-stage crossing at the roundabouts • Bike/Ped: better than traditional intersection • Can be leveraged to catalyze walkable development	• Two bowties in design stages in NCDOT projects, one in design stages in VDOT project.
U-Turn: Median U-Turn (MUT)	• Nearly the same as a Bowtie, but the median is generally consistently wide. • Two phase signal at the main intersection • Signing, marking, and geometric design elements should promote safe and efficient movements, particular for unfamiliar drivers	• Reduced # of conflict points • Reduced delay due to fewer # of signal phases and shorter cycle lengths • Low construction costs	• A wide median is often needed to facilitate the median U-turn movements • Locations where heavy side street through volumes, relatively low to medium side street left-turn volumes, and moderate to heavy left-turn volumes from the major road.	• MUTs typically have multiple lanes, so may need two or more stages to cross the intersection • Major street RTOG vehicles conflict with peds • Bike/Ped: Reduces conflict points and can create new staged crossing opportunities at the U-turn location. • Can be leveraged to catalyze walkable development	• First introduced in early 1960s • First deployed in Michigan in 1960s • Major deployment region(s): MI, UT, NC, VA, NY
U-Turn: Restricted Crossing U-Turn (RCUT)	• Side street left-turn and through vehicles must all turn right, then make a U-turn at a dedicated downstream median opening to complete their desired movement • Each direction of the major street can operate independently, creating two one-way streets • Prefer shorter cycle lengths to reduce average queues and thus shorter storage bays	• Reduced # of conflict points • Improved capacity since each direction of major road operates as one-way street • Reduced delay due to fewer # of signal phases and shorter cycle lengths • Low construction costs	• Suburban arterials where high through volumes conflict with moderate to low cross-street through volumes, particularly when the arterial has a 50/50 through-traffic splits • Designing a RCUT intersection should consider the number of intersection legs, median width, number of through lanes, intersection angle, turning traffic demands, and pedestrians and bicycle demands	• Minor street peds and bicyclists have to travel out-of-direction to cross the intersection • RCUTs typically have multiple lanes, so may need two or more stages to cross the intersection • Major street RTOG vehicles conflict with peds • Bike/Ped: Reduces conflict points and can create new staged crossing opportunities at the U-turn location. • Can be leveraged to catalyze walkable development	• First introduced in early 1980s • First deployed in North Carolina in 2000 • Major deployment region(s): NC, MD, MN, MI, IN

Table 2-1, continued: State-of-the-Practice of Various Alternative Intersection Designs

AI Design	Design and Operational Features	Advantages	Traffic and Geometric Applicability	Pedestrian and Bicycle Environment	Deployment History
Continuous Flow Intersection, (CFI) **or Displaced Left Turn (DLT)**	• Left-turn vehicles cross to the other side of the opposing through-traffic in advance of the main intersection • Left turns and opposing through movements occur simultaneously at the main intersection • Main intersection and crossovers are coordinated to minimize stops	• Reduced # of conflict points • Allow for simultaneous operation of protected left turns and opposing through-movements thus increase capacity • Better signal coordination hence lower delays	• suitable for high through volumes and light U-turns • Need to have sufficient right-of-way along the arterial near the intersection • Main intersection should have appropriate turning paths for the displaced left-turns • A good option for intersections that may be upgraded to freeway interchange, due to their large footprint.	• LT vehicles arrive from an unexpected direction which may confuse peds and bicyclists • CFIs typically have multiple lanes, so may need two or more stages to cross the intersection • Bike/Ped: very challenging, and very unlikely to work well with walkable mixed-use development	• First introduced in in 1990s • First deployed in New York in 1995 • Major deployment region(s): UT, MD, OH, LA, TX, NY
Quadrant Roadway Intersection (QRI)	• Uses one or more "backage roads" with secondary intersections so that left turns can be removed from the primary intersection. • Can be designed as a single quadrant intersection or multiple quadrant intersections • Allows driveways to be relocated to the backage road	• Reduced # of conflict points • Reroutes left-turn traffic result in fewer signal phases at the main intersection and reduced delay • Coordination of 3 signalized intersections improves corridor travel time	• The spacings of the quadrant intersections from the main intersection should balance the left-turn travel distance and time versus available storage for the left-turn movement • High volume major streets, particularly at intersections with substantial left-turn volumes • Appropriate signage and pavement markings to indicate the prohibition of left turns and detour routes for right and left-turn movements	• Former left-turn lanes at main intersection can become planted medians with pedestrian refuge. • Creates new mid-block crossing opportunities at secondary intersections. • Expanded connectivity helps catalyze mixed-use development along backage roads, which increases the density and diversity of uses, which in turn increases walking and biking.	• First introduced in 2000 • First deployed in Ohio in 2012 • Major deployment region(s): OH, NC, VA, UT, OR, MI

3. Placemaking Alternative Intersections: Idealized Depictions

This research identified three Alternative Intersection design families to focus on: Quadrant Roadway Intersections, U-Turn Intersections, and One-Way Split Intersections. All have significant potential for transitioning Stroad-like T3 environments into walkable T4 mixed-use urban environments (or also for designing greenfield areas for T4 activity from the beginning). All offer impressive efficiency gains for traffic and safety gains for multimodal environments, which will be demonstrated later.

Idealized Before / After concept drawings were created for each of these designs and are depicted in this section. Later sections demonstrate how these designs were applied to real world locations in Greenville and Smithfield, North Carolina.

3.1. Idealized Kitty Corner Quadrant Retrofit

Quadrants are extremely versatile. It is possible to reroute all four lefts using one, two, three, or even four quadrant backways. **Figure 3-1** depicts a “kitty corner quadrant” where lefts from the east-west arterial have no out-of-direction travel. The main signal would then be 3-phase if lefts from the north-south arterial are not rerouted. It would become two-phase if those lefts are rerouted as through+left+right, or right+left+through.

In the top diagram, notice that there is already one backway available, though it would need to be upgraded for better sidewalks, street trees, etc. The other pathway is not yet a formalized roadway, but it is also generally unobstructed. The second diagram is shortly after opening, before any new buildings have been catalyzed by the impressive new infrastructure. The third shows how market excitement causes redevelopment of smaller commercial buildings into mixed-use buildings typically of 2-4 stories, supported with nearby parking garages and parking under some of the new buildings.

Items of Note:

1. Diverting lefts allows for a planted median with pedestrian refuge in the crosswalks at the main intersection. It also facilitates removal of driveways since backway access is now possible.
2. While secondary intersections will be three-phase signals, they will sync well with the 2-phase at the main intersection because they have less volume to manage.
3. While traffic calming and the new secondary intersections reduce cruise speeds, drivers still get through the system faster than before due to less accumulated delay at the sum of all signals. This drive slower, travel faster effect is demonstrated later in the section on traffic analysis.
4. The secondary signals create new pedestrian crossing opportunities, which in turn help to catalyze walkable development. The backways offer accessibility and visibility, which catalyzes a larger activity center.
5. The last diagram shows the primary intersection artistically painted, which not only helps with placemaking, but also creates “visual friction” that motivates drivers to slow down. Initially the main intersection may not start this way while still in an auto-oriented environment, but eventually it could transition.

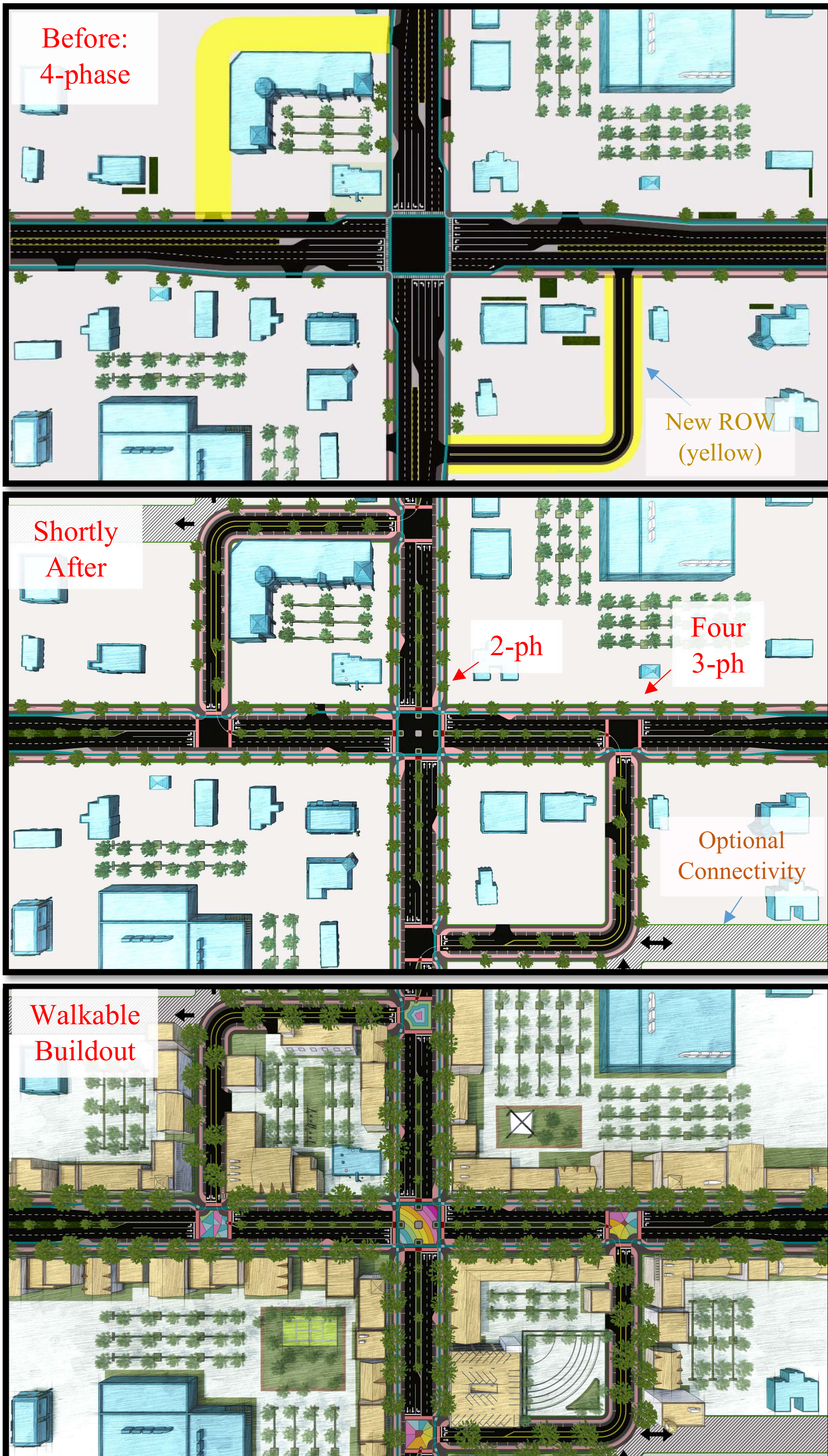


Figure 3-1 Transition from Stroad to Walkable Boulevard using Kitty-Corner Quadrants

Figure 3-2 *Comparison: Quadrants shortly after construction vs market-driven redevelopment years later*

3.2. Idealized U-Turn Retrofit

In **Figure 3-3**, the top diagram depicts a typical auto-oriented Stroad with scattered commercial buildings surrounded mainly by parking lots, and a small north-south collector. The second diagram shows one method of installing U-turns (bowtie format) which in this case requires new right-of-way only from parking lots. The third diagram shows how, after many years, the street trees, lower speeds, and safer pedestrian environment, combined with form-based mixed-use zoning and relaxed parking requirements, can transform the area into a walkable Activity Center.

Items of Note:

1. The U-turns diflect the main travel lanes, creating a chicane that is effective for reducing speeds going into the primary intersection. Other U-turn formats such as Loons are likely to be less expensive, but also less effective at reducing speeds through this sensitive area.
2. The U-turns in this case connect to new right-in / right-out local streets. Increased connectivity introduced as part of the U-turn project, or later, will help catalyze walkable development. Such streets also make it easier to remove many of the driveways that inhibit walkable development.
3. There are many two-stage crossing opportunities for pedestrians, because they can wait on the dark-red islands if necessary. The U-turns create a crossing opportunity that did not exist before.
4. The crossing collector is downsized from 4-lanes to just 2-lanes. This happens because the through lane is eliminated (movement converted to Right+U+Right), and the left is also eliminated (converted to Right+U+Through).
5. The last diagram shows the primary intersection artistically painted, which not only helps with placemaking, but also creates "visual friction" that motivates drivers to slow down. Initially the main intersection may not start this way while still in an auto-oriented environment, but eventually it could transition.

NOTE: ALL OF THESE BEFORE & AFTER DIAGRAMS ARE COMPARED USING SLIDERS AT URBANINNOVATORS.COM
CLICK ON "PROJECTS" THEN LOOK FOR "NCDOT" .
THE DIRECT LINK IS:
WWW.URBANINNOVATORS.COM/PR-NCDOT-AI-RESEARCH

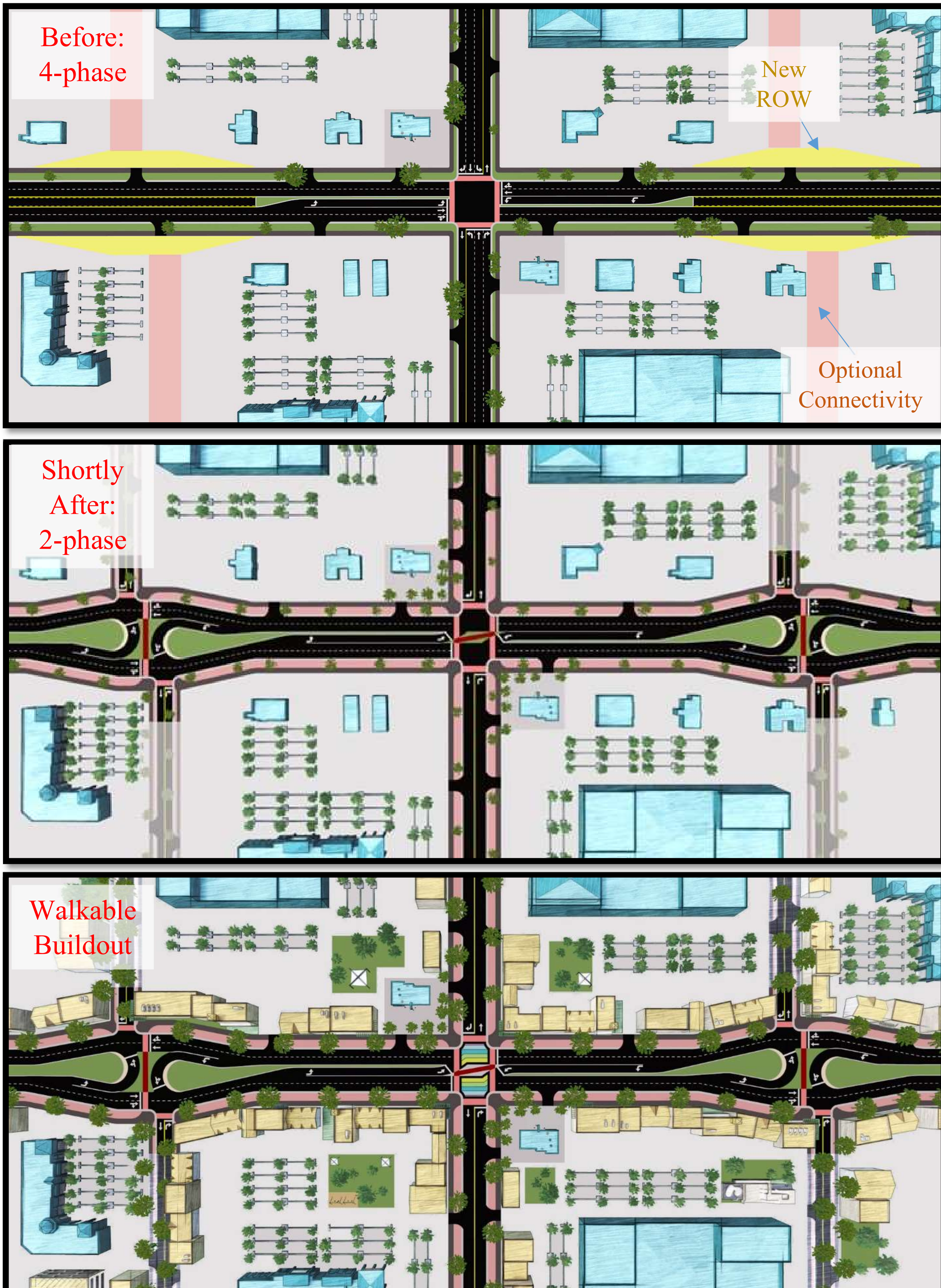


Figure 3-3 *Transition from Stroad to Walkable Boulevard using U-Turns*

Figure 3-4 shows closer birdseye views of the U-turn environment after walkable development is fully constructed. Note that many of the more valuable existing buildings and a gas station or two are likely to remain, while other less valuable commercial buildings eventually give way to higher density mixed-use development. Much of the surface parking is converted into parking garages and tiny "pocket parks."

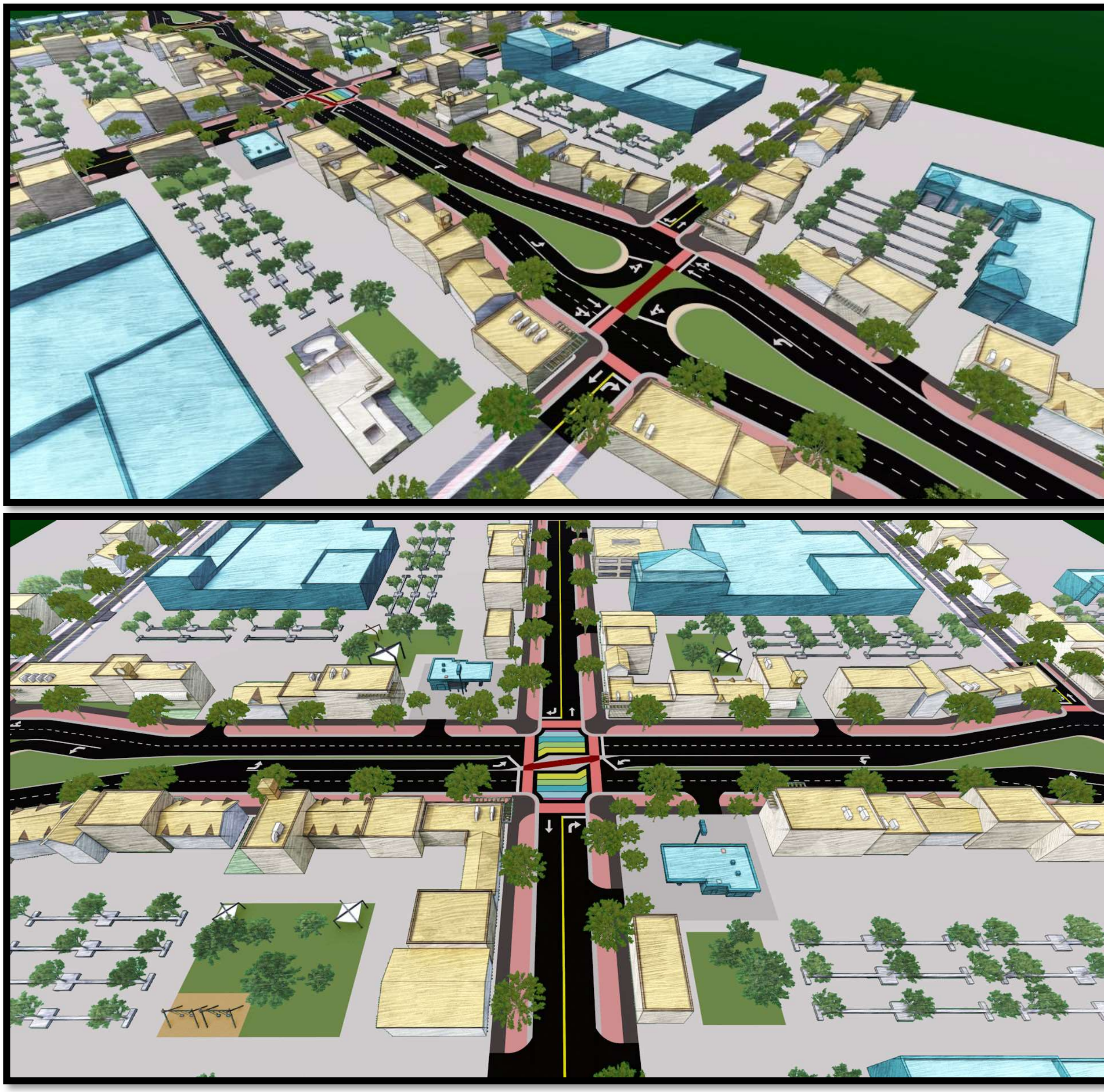


Figure 3-4 *Birdseye details of the walkable environment created by U-Turns*

3.3. Idealized One-Way Split Retrofit

One-way streets do not need left-turn phases because there is no oncoming traffic. This makes them naturally high capacity even at walkable speed limits. But one-ways are rarely thought of as solutions to a massive 4-phase Stroad intersection, probably because there is no obvious parallel path. When there is such a path, it can still be a "hard sell" as the number of affected properties gets higher when the transition opportunities to and from that path are far apart.

Thus, **Figure 3-5** was designed as the "smallest conceivable one-way split" to help demonstrate that a parallel roadway is not necessary when there is a "relatively unobstructed" pathway through parking lots and underutilized land. The yellow path in the top diagram shows how to locate a path. In this case, two small commercial buildings and a significant amount of parking will be impacted.

If the area needs revitalization, odds are the impacted parking is under-utilized anyway, so businesses are likely to focus on fair compensation for the value of lost land. The City and DOT can use a before / after market study to convince property owners to reduce their asking price, and maybe even donate the land. How? If the post-project value of remaining land, despite their donation, exceeds the current value, then owners will be more likely to reduce their price (to free if necessary) to ensure project viability.

Cities and DOTs often worry that the longer the couplet becomes, the more impractical it will be even if it is win-win for the vast majority. This is due to the hurculean effort required to convince so many stakeholders that their positives will outweigh any negatives. A "short couplet" such as this has far fewer stakeholders, making it more manageable. With only a few stakeholders, it will be easier to form a public-private partnership with developers to reduce congestion, improve safety, and set up the area for a strong market investment in walkable development.

Another point: Even though this design consumes a lot of off-street parking, it can also create a lot of better utilized on-street parking at least along the two-way segment that is downsizing from five-lanes to just two or three. You may also be able to locate under-utilized land that can be converted to parking to make up for whatever is lost to new right-of-way. Use these factors to help convince stakeholders that it is truly win-win for everyone.

Two small 3-phase intersections is a great way to cure a massive 4-phase Stroad intersection.

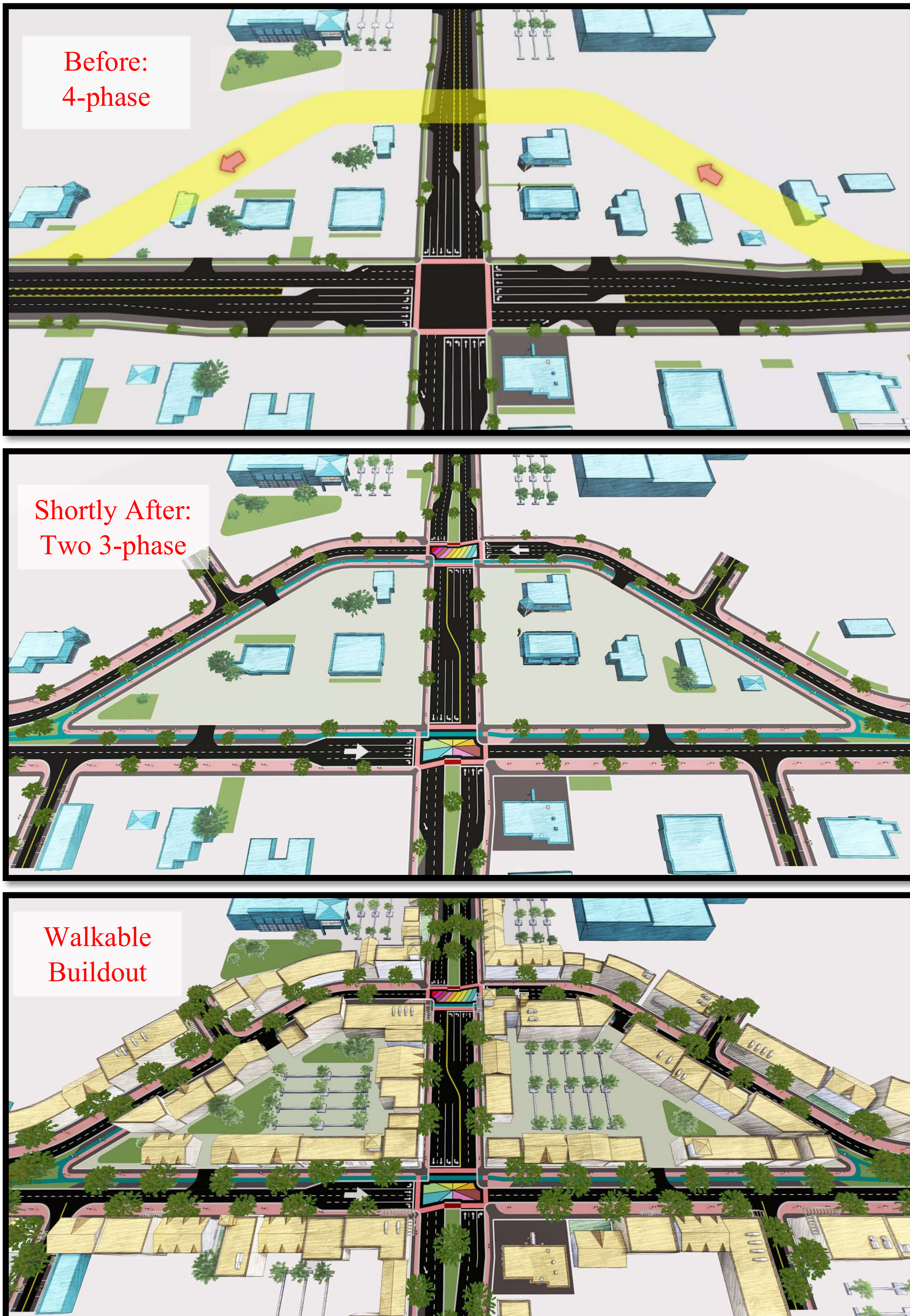
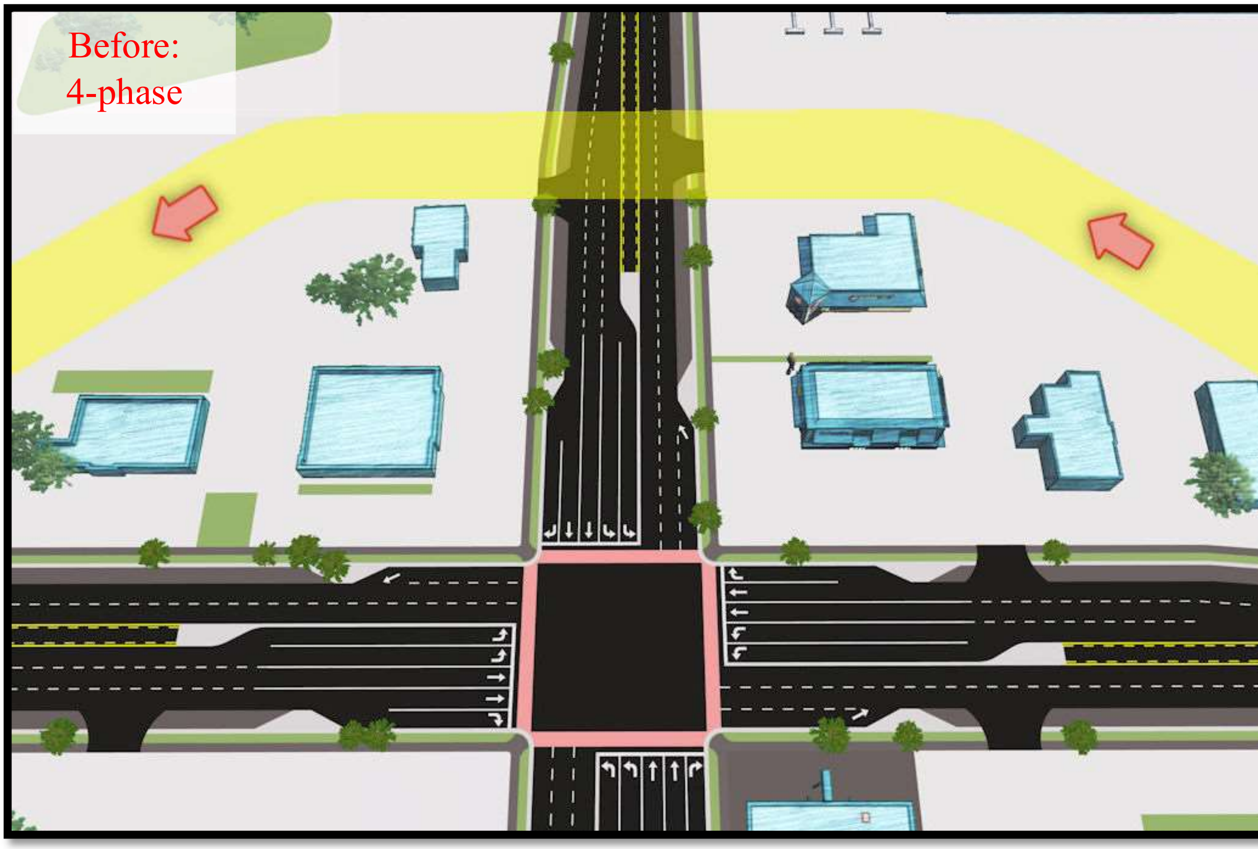


Figure 3-5 Transition from Stroad to Walkable Neighborhood Using Shortest Conceivable One-Way Split



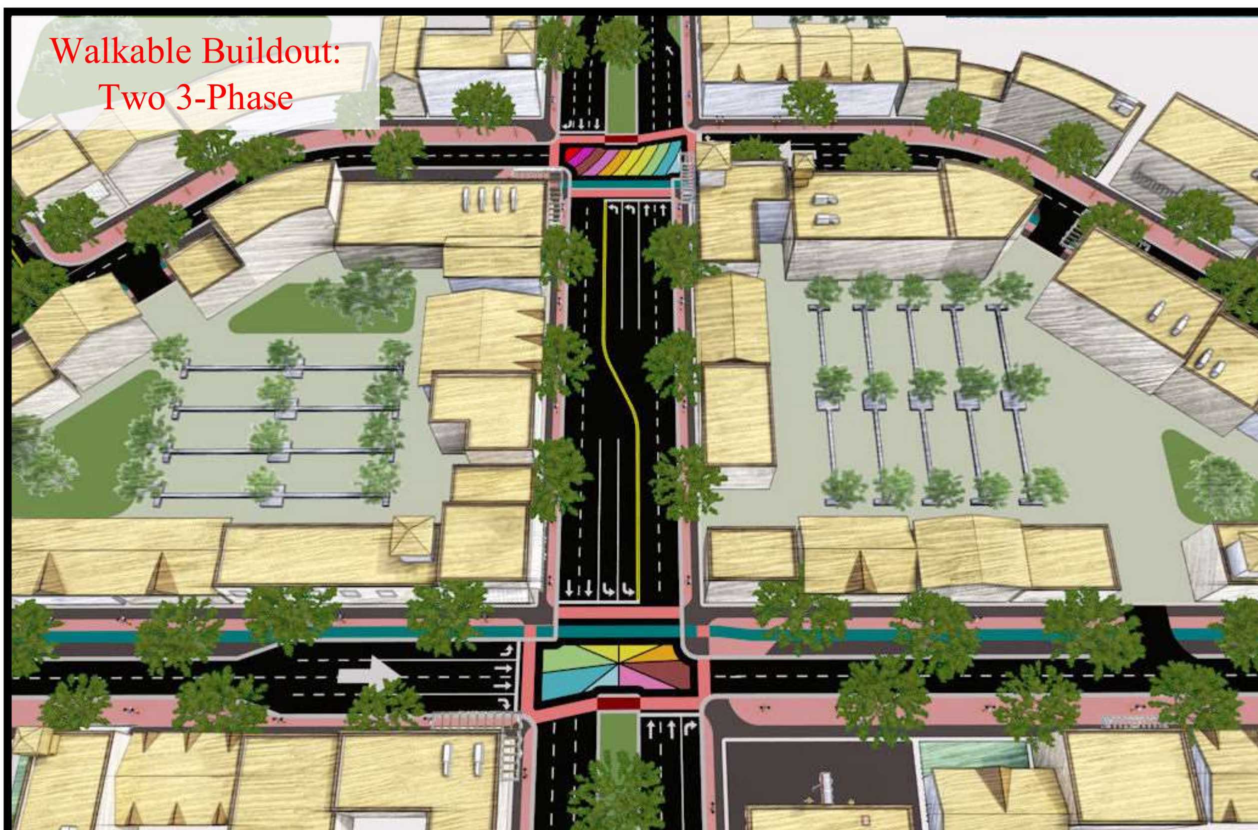


Figure 3-6 *Closeup view of before and after*

4. Placemaking Alternative Intersections: Greenville Examples

The team began the effort intending to develop designs for hypothetical, idealized locations such as the diagrams just shown. Ultimately it was decided that real world applications would also prove to be very insightful. A search of the entire state revealed many practical opportunities for all three design styles. The team settled on study areas in the city of Greenville (this section) and the town of Smithfield (next section) for two primary reasons: 1) it was easy to demonstrate all three design styles within close proximity; 2) both communities agreed to accept "free ideas," and 3) both would allow NCDOT to reference graphics and other results as being modeled on their area, provided it was made clear that those graphics have not been vetted with stakeholders and thus do not constitute official plans.

Both 2D and 3D graphics were created for these cities to showcase how Placemaking Alternative Intersections could help catalyze walkable environments. Cross sections, top views, and bird's eye views were created for all designs deemed capable of advancing objectives identified by focus groups.

Note 1*: all examples for Greenville and Smithfield shown herein were created for research purposes only and have not been formally presented to any local stakeholders, nor endorsed by any official NCDOT or local governing body. However, both communities have agreed to let NCDOT utilize these graphics and associated research as examples of what may be possible for similar situations across the state.*

Note 2: *"Appendix C: Potential Locations Across North Carolina" shows many "stick figure" opportunities at potential locations around the state. The purpose in showing these is not to suggest these designs are necessarily appropriate, ideal, or a priority for each location. Instead, the goal is simply to convey that it isn't particularly hard to find locations where these designs might be applied. The record of these sites may also give NCDOT staff and city staff options to explore further, if desired.*

4.1. Overview of Greenville

Greenville is the county seat for Pitt County, with an estimated 90,000 residents as of 2023. It is 84 miles due east of Raleigh. Those reporting "non-white" were 47% in the most recent census. Greenville is the home of East Carolina University, and the ECU Health Medical Center. The team briefly explored Stantonsburg Road, next to ECU medical, as a candidate site, but ultimately settled on Greenville Blvd near the mall as the preferred site to study.

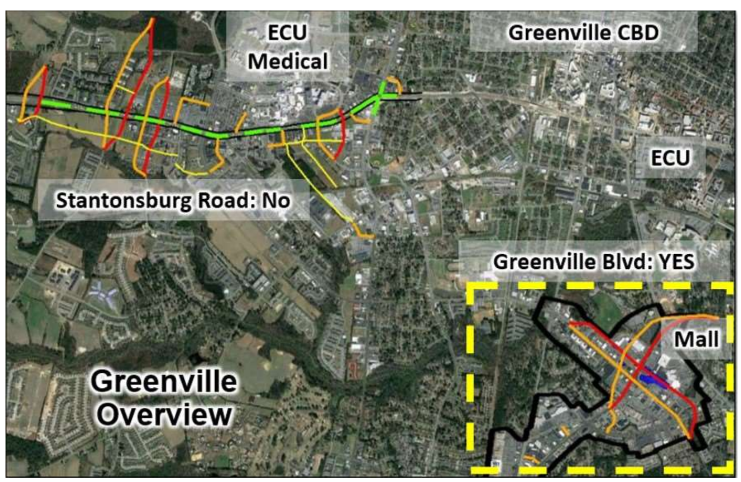


Figure 4-1 *Overview of Greenville, NC*

Figure 4-2 shows the Greenville Mall and surrounding environment, overlain with 1) a 4-leg Quadrant in the top-left, 2) a combination U-turn / Quadrant along the "diagonal" Greenville Blvd in the bottom-left, and 3) crossing one-way couplets (a.k.a "One-Way Split Intersections") at the mall itself, shown in red and orange. In the graphic, the blue represents buildings that might be impacted if there were ever an actual plan to construct the roadways we investigated. Notice that the biggest impact would be the western half of the mall. For each of the three designs, this section features key before and after graphics.

Note that these designs may make the most sense as a phased implementation. For instance, the N-S one-way pair along Greenville Blvd. would make more sense to consider first because it may be easier in the short term. Then, the E-W one-way pair would only be considered after the mall is ready for redevelopment.

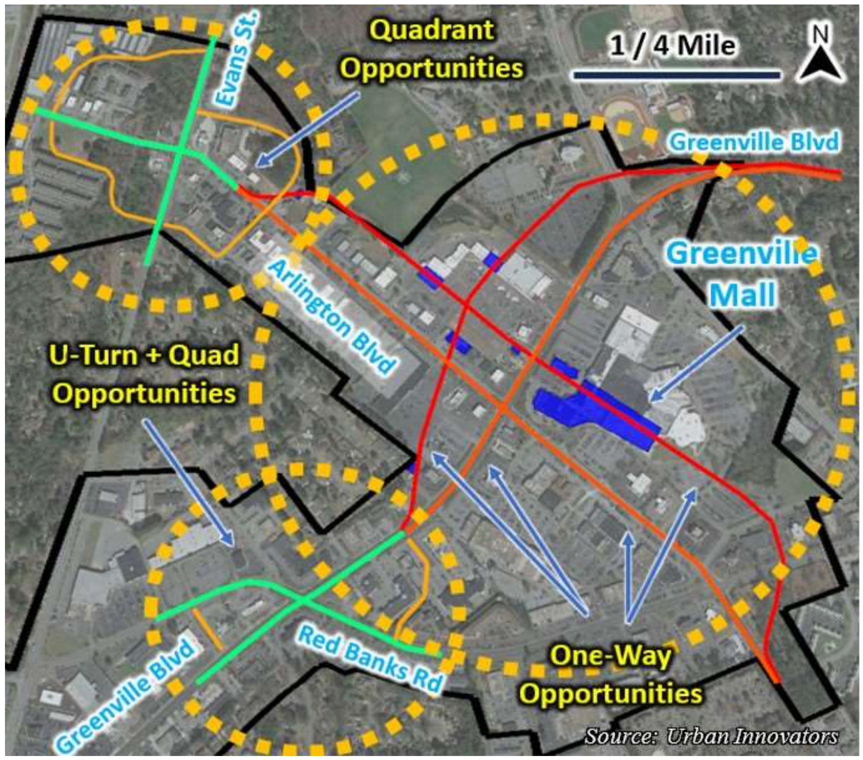


Figure 4-2 *Alternative Intersection Opportunities at the Greenville Mall Area*

4.2. "Slow Lanes" Concept

Figure 4-3 highlights what the research team calls "slow lanes" – i.e. the teal-color lanes separating the bypassing traffic from parking. The idea is that rather than exclusive "bike lanes" or "cycle tracks" (as bikes will always have a limited appeal due to difficulty carrying larger objects and exposure to the elements), this lane could accommodate bikes, scooters, golf-cart-sized electrics, and potentially even standard vehicles that need access to businesses and parking. Speed limits can be set at 10-15 mph, and governed with speed humps to ensure cyclists are as safe and comfortable as possible. Reverse-angle parking helps drivers see oncoming cyclists. The planted median is made possible by either U-turns or a Quadrant design.

Note: in our focus groups, bicycle planners and advocates preferred exclusive space that would not be mixed with large vehicles accessing parking, as it may require speed humps and create an intimidation factor. Graphics with slow lanes and angle parking also distract from the main message, which is that PAIs can help create win-win for managing traffic and placemaking. The focus groups agree this design may be good in cases where it is the best balance for overall needs.

To address this, we created a second set of graphics without slow lanes or angle parking. Some graphics show parallel parking, and others show no parking. This is to make it more realistic for most North Carolina situations.

Figure 4-3 *Closeup view of the "Slow Lanes" concept*

****Note 1:*** *This graphic depicts "Slow Lanes" where standard vehicles mix with bikes to access angle parking. Focus group feedback suggested that this may be a great idea, but it distracts from the main message, so a new set of graphics was created to remove this.*

****Note 2****: Throughout this document, all graphics of this style were created jointly by NCSU, ITRE, and Urban Innovators*

Figure 4-4 *Updated view without Slow Lanes or Angle Parking.*

****Note:*** *This shows parallel parking, but another similar graphic is also available in the PowerPoint files in the appendix showing no parking.*

Figure 4-5 reveals the value of rethinking “Bike Lanes” as “Slow Lanes” – because there are a large number of “tiny cars” that are emerging that behave like eBikes but have four wheels.   concept

Figure 4-5 "Slow Lane" networks in Peachtree, GA have led to one car families.

Slow Lanes in Peachtree, GA, have led to an explosion of residents purchasing tiny cars and golf carts for short trips. Improved batteries are facilitating stylish vehicles with climate-controlled interiors. A focused effort to accommodate these can greatly reduce the amount of land required for parking.

4.3. Graphics and Analysis of Quadrant Concepts

Figure 4-6 is a top view of the Stroad intersection (to the northwest of our focus area) today vs an unvetted four-quadrant concept design (meaning it has not yet had any formal planning process). In both graphics, white buildings represent existing buildings, and tan are hypothetical representations of how the market may react to form-based zoning codes and the new infrastructure. The existing design uses single left turn lanes and a 4 critical phase signal. The new condition would route all left turns along four backway paths with good driver expectation and zero out-of-direction travel. Two of the four backway paths “mostly exist” today. The other two would be brand new and are relatively unobstructed. The result is a 2-phase signal at the primary intersection, and four new 3-phase signals at the secondary locations. These four are 3-phase because the cross-arterial through movement of the minor streets would not be accommodated.

Figure 4-6 *Four Quadrant concept for Arlington Blvd and Evans Street in Greenville*

Discussed in more detail in **Chapter 6**, the existing intersection configuration can serve up to 3,700 vehicles per hour (vph) at Level of Service E; however, the new design can accommodate up to 5,700 vph with the same average time in the system (same overall delay). See **Chapter 6** for a full explanation of how this 5,700 was determined. The secondary intersections, while 3-phase, act more like the 2-phase primary because they have less volume to manage.

Note: More vehicle capacity may not seem "walkable," but it creates the ability to increase Floor Area Ratio by a factor of <u>four</u> (FAR – which is building floor space relative to ground space – a common measure of density). Without vehicle accessibility, this density cannot be supported.

4.4. Comparing to General Suburbs

Using the Development Scale Tool created for this project (described later), the team determined that this Quadrant concept could catalyze walkable development on about 111 acres around this site. Today, these 111 acres contain about 100 single family units and 150 multifamily, which is about 350,000 square feet of residential space assuming 2,000 SqFt per single family unit and 1,000 SqFt per multifamily unit. It also contains 320k square feet of commercial space, for a total of 670k SqFt of constructed floor space (Res+Com). 111 acres in square feet is 111 x 43,560 = 4,835,000 SqFt, which means today's FAR is 670k / 4,835k = 0.14.

The Quadrant concept, combined with enhancements to alternative modes, would make it possible for the key intersection to still function well even if development on these acres increases substantially, with multifamily going from 150 to 1,400 units, or about 1,600k SqFt for overall residential, and commercial going from 320k to 900k square feet. Adding both residential and commercial, this would be 2,500k SqFt of constructed floor space vs 670k today. 2,500k / 670k = 3.7, or roughly 4x the size of today's development. The new FAR would be 0.52, which is also 3.7 times larger than today's 0.14. This is roughly four times as much development as exists today, all with the traffic system functioning the same as it does today.

Since it is costly to develop this Quadrant concept, along with the myriad of street trees, connectivity, and other multimodal features that would be necessary to attract and support that much development, it is necessary to demonstrate that it would be money well spent, meaning "cheaper than the alternative." While it was beyond scope to estimate costs, it was relatively easy to determine how many acres of new greenfield land it would take to construct a similar amount of development at typical suburban densities. Then, GIS could help determine miles of road per acre of suburban development, from which we could determine overall miles of road and utilities needed for a similar amount of development. While this is not a substitute for actual costs, new roads and utilities do cost money, and this approach demonstrates the scale of new roads and utilities required in lieu of a strong multimodal investment at this 111-acre site.

The team calculated that it would require about 350 acres of new greenfield land at a 0.14 FAR to contain the same development that would otherwise increase the 111-acre site from 0.14 to 0.52 FAR. Then using GIS, we drew a 250-acre square over a random site in Greenville that was fully developed at suburban densities, and calculated that within this 250 acre square there were 7-miles of general roadway infrastructure, or about 35 acres of development per mile of roadway. Since the Quadrant would offset 350 acres, this means it would also offset about 10-miles of roadway.

The team did not attempt to estimate the cost of upgraded infrastructure for the 111-acre site, nor the cost of 10-miles of new infrastructure that the Quadrant concept could offset. However, it seems likely that upgrading the Quadrant site is likely to be far less expensive than 10-miles of new infrastructure, which typically includes not only sidewalks, asphalt, and right-of-way, but also utilities such as storm drain, water, sewer, natural gas, fire, electric, and communications, along with ongoing maintenance of it all. Thus, while "cost per mile" for a major overhaul of existing infrastructure at this 111-acre site will certainly be higher than cost per mile at lower densities, the fact that the low-density alternative could require 10 additional miles probably means that upgrading the 111-acre site will be significantly cheaper overall, when measured on a cost per capita basis, which is a much better measure of overall affordability and fiscal sustainability.

Figure 4-9 is a "bird's eye" view of the southernmost of four secondary intersections. The "before" case shows an existing street on the right where WB to SB lefts will be rerouted. It also shows a pathway, not yet developed, where NB to WB lefts will be rerouted. The "After" situation shows how this would function.

Note: All of these Before/After scenes, and more, can be seen with "sliders" at:
urbaninnovators.com/pr-ncdot-ai-research

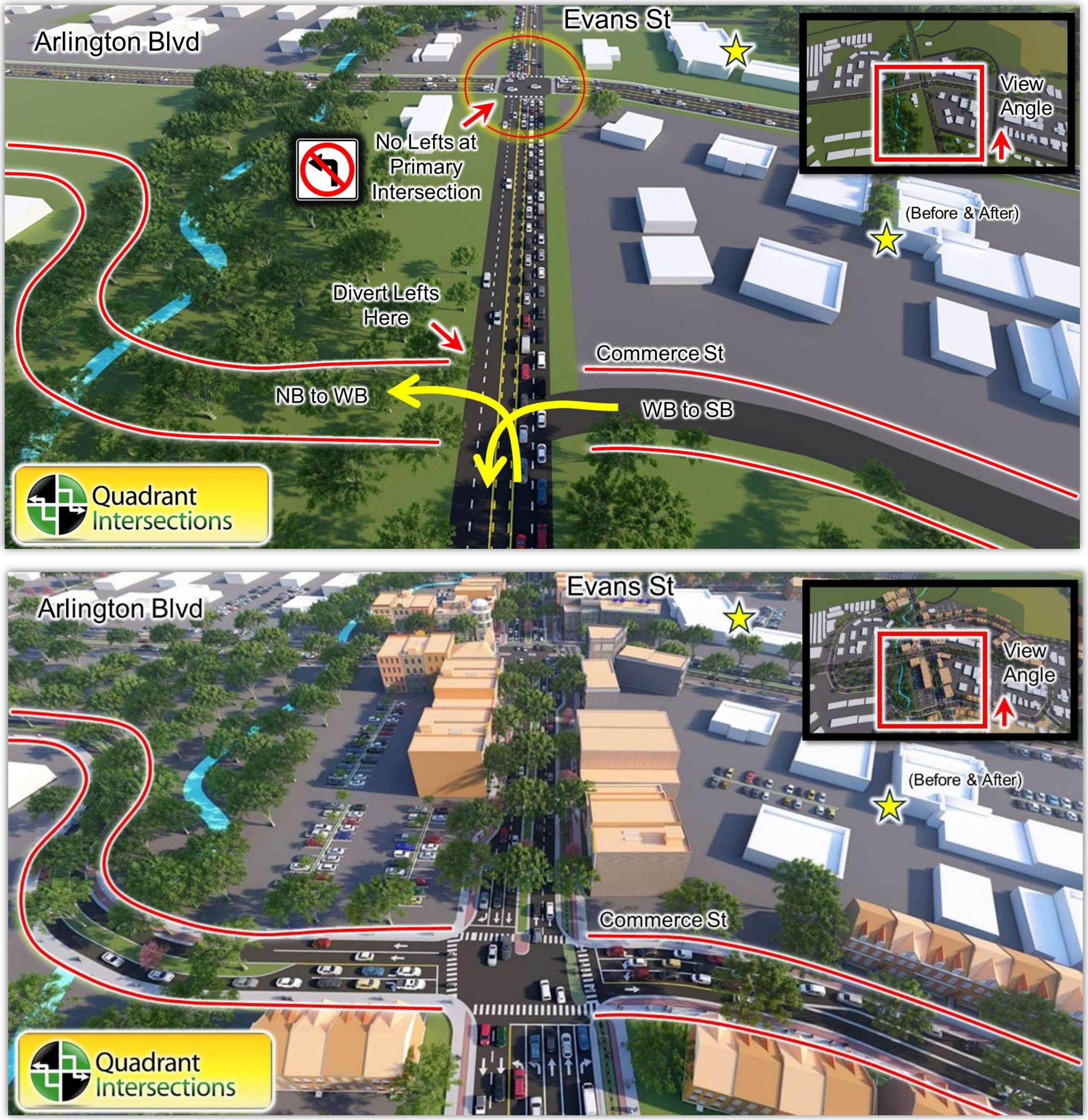


Figure 4-7 Four quadrant concept at Evans & Arlington: Closeup of southernmost secondary intersection.

Figure 4-10 is a "bird's eye" view of the primary intersection. The left-turn lanes from "Before" are replaced with a planted median, since lefts are relocated. The intersection now offers pedestrian refuge in each crosswalk, with five mountable islands to discourage lefts for all but emergency vehicles. Driveways are relocated to backage roads. The scene also shows on-street parallel parking, premium street trees, and bike lanes. The project would be expensive due to the new roadways and impressive amenities. Yet in the long run, it will prove cheaper than 10-miles of additional sprawling infrastructure.

Figure 4-8 *Four quadrant concept at Evans Street & Arlington Blvd: Closeup of primary intersection.*

4.5. Financing with Value Capture

Value capture could also be considered to help pay for amenities. Value capture recognizes that major public investments will often increase the value of land, making it desirable and profitable to build there. Thus, rather than a public agency financing the entire project, only to watch land owners and developers secure windfall profits, value capture involves negotiation with land owners and businesses: "You can have some profit, if you help us pay for the infrastructure that will elevate the value of your land. Otherwise we can't do it, and you'll get no profit."

Thus, value capture is often organized as a public-private partnership, where agencies and communities express a desire to construct an environment with strong multimodal features likely to bring them value, but also express that the project will not be possible unless the private side agrees to divert a portion of their probable profits to help construct and maintain the premium features. If enough stakeholders from the private sector agree, then the city or agency can help organize a business improvement district or some other structure where new development will be taxed to help pay for the features that made the development possible.

The result is intended to be win-win: the public gets great places and premium multimodal features, along with reduced costs (relative to sprawl alternatives), and developers secure profit that would not have been possible had they killed the project by failing to help finance it.

4.6. Graphics and Analysis of U-Turn Concepts

Figure 4-9 demonstrates a combination U-Turn / Dual Quadrant design (to the southwest in our focus area). Unobstructed paths through parking lots show where new city streets could be constructed for Quadrant backways which take advantage of the diagonal Greenville Blvd. that creates a skewed intersection, making the "shortcut" even shorter. U-Turns are also carved out from parking lots. Discussed in more detail in **Chapter 6**, the existing system supports 3,800 vph and an auto-oriented density of 0.20 Floor Area Ratio. The new system can support approximately 6,000 vph with the same average travel times, despite lowering the speed limit. This 6,000 vph was determined through microsimulation described in **Chapter 6**. The design supports 0.67 FAR (more than 3x today's FAR), which could save as much as 19-miles of future infrastructure. The next several pages show 3D views of notable areas from **Figure 4-9**.

Figure 4-9 *Concept for Placemaking U-Turn Intersection, combined with a Quadrant.*

Figure 4-10 *Birdseye view of U-Turn design. Chicanes near intersection ensure safer speeds at crossing.*

Figure 4-10 shows U-turns directly at the intersection. In this case, U-turns would not accommodate large trucks. Trucks would need to continue to the next U-turn (**Figure 4-12**, **Figure 4-11**). These "teardrop style" U-turns create a chicane, or a deflection, which reduces speed going into the intersection, which increases safety. Combine these traffic management features with multimodal placemaking investment, and there is finally a way to overcome "Mount Stroad."

In **Figure 4-12**, the "Today" graphic shows how making a left from an uncontrolled driveway or side street is very dangerous because you need a safe gap in both directions. Engineers often install a raised median to force "right-in / right-out," but this often angers businesses – concerned that their access will be far more difficult, causing customers to shop elsewhere. By combining a raised median project with U-turns, circulatory accessibility is greatly improved without a need to wait for the left turn signal at the main intersection.

By designing these U-Turns with chicanes and planted medians as shown, a T4 mixed-use environment can start to replace today's T3 commercial parking lots. Notice that the Teardrop turnaround on the right is larger than the one on the left. By making every other U-Turn large, trucks that were denied a left opportunity at the main intersection will be able to U-Turn within a reasonable distance, while smaller vehicles can use any U-turn location.

Figure 4-12 Combining a typical raised median project with U-turns improves circulation and walkability.

Figure 4-11 shows how a U-Turn large enough for a truck can be designed to fit with walkable T4 mixed-uses. The chicane created by the U-turn helps with traffic calming, and the reduced delay at signals (going from 4-phase to 2-phase) helps ensure higher capacity (i.e., reduced stop delay), so that the overall drive trip is similar if not faster, despite the use of traffic calming features.

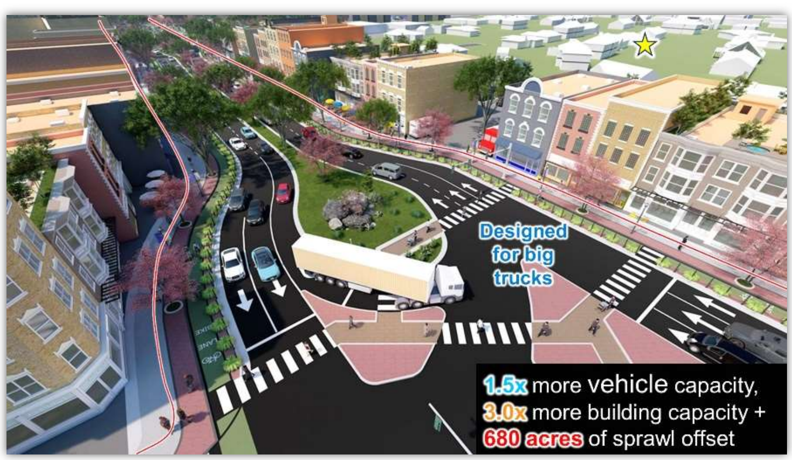


Figure 4-11 Accommodating trucks in a walkable, mixed-use environment.

4.7. New Type of Road Diet: How to Narrow Medians Using U-Turns

Figure 4-13 shows how Teardrop, Loon, or Roundabout U-Turns can be used to reclaim underutilized space otherwise dedicated to two-way turn lanes (TWTLs). Instead of 12-14 ft for a TWTL, narrow to just 2-3-ft with raised concrete or a Jersey barrier. Drivers then pass their destination slightly and make a U-turn.

Note: adding U-turns as part of any raised median project is helpful whether the center median is narrowed or not. This is because they reduce circuitous paths, reduce the number of vehicles forced into overloaded signals, reduce "curb bashing" and "three-point-turnarounds" on arterials from people who attempt tight U-turns anyway. It also helps to improve business and public acceptance of a raised median project. For cost practicality, most U-turns would not accommodate trucks.

Figure 4-13 *U-Turns can help with "road diets" by facilitating the removal of two-way turn lanes (TWTL)*

This "narrow median" construct could be very useful in cases where extra room is needed for better sidewalks, street trees, slow lanes or cycle tracks – anything where space on the sides is more necessary than "quasi-dead space" in the middle.

Note*: The research team was informed that NCDOT is starting to add U-turns as part of raised median projects and may be the first in the nation to programmatically start to do so. The graphic above, where U-turns are used to minimize the median (perhaps to 3 to 8-ft instead of 12 to 14), then reallocate the recovered space to the sides for better street trees, parking, etc., and to add chicanes to the mainline as a traffic calming strategy, would likely be a "first-in-the-nation" strategy for traffic calming and pedestrian-friendly design.*

This technique can be used to convert 5-lane arterials into 4-lane, without compromising capacity. Or, instead of a "road diet" that converts a 4-lane into 3-lane, this achieves 5-lane capacity with just a 4-lane cross-section. Use it also to give 2-lane roads a 3-lane capacity, or converter 3-lanes back into 2-lanes without consequence.

4.8. Graphics and Analysis of One-Way Split Designs

Figure 4-14 shows how to split two large Stroads into four walkable, one-way boulevards (to the northeast of our focus area). In this case, the new westbound path would need to be coordinated with the mall owners, and only activated if they ever decide they need to reinvent their property (i.e., the NB+SB can go first, then EB+WB later). This concept should be easy to implement in greenfield settings. For retrofits, it becomes more practical when applied to a struggling area with dilapidated properties, since property owners, businesses, and the general community may be more likely to welcome the "extreme makeover" that this will create in an already dying "greyfield."

Figure 4-14 Relacing two Stroads with four One-Ways, after mall owners need a reinvention plan.

Note: All of these Before/After scenes, and more, can be seen with "sliders" at:
urbaninnovators.com/pr-ncdot-ai-research

Zooms in on today's two-stroad intersection. The red lines show how pavement here will be reduced, even though the overall system will have nearly double the amount of vehicular capacity. The resulting four intersections creates connectivity and 16 popular corners rather than just four. The vastly superior accessibility via all modes, across many more acres, can support up to 5x more development than before.

Figure 4-15 *Before / After context when replacing two Stroads with four walkable One-Ways.*

Note that instead of a very large intersection with four critical phases, this system has four simple and walkable intersections, each with 2-phase signals. Discussed in more detail in **Chapter 6**, analysis revealed that the system can easily accommodate 50 to 70% more traffic than the previous two-way Stroads, even with the same number of lanes. In our case, it can handle 97% more vehicles (i.e., double) because the team added a third lane in each direction since there was plenty of room, and the extra capacity will help the area support roughly five times as much development as it currently has. Assuming the market could develop 5x densities, the result could reduce 1,200 acres of suburban greenfield development and reduce as much as 34 miles of general infrastructure.

Thus, while it requires a significant up-front investment to create new pathways and multimodal features, it will ultimately prove far less expensive than the general sprawl alternative. Further, value capture strategies can help ensure that attractive development pays back much, if not all, the initial investment. This system creates a grid with connectivity where there was none before. It also results in 16 high-value corners instead of just four. If it proves too difficult to create four one-way streets like this, much of the benefit will still be achieved if only a single one-way couplet can be created (because two 3-phase signals are still easier to manage and better for a walkable environment than one 4-phase signal).

Figure 4-16 shows the results of a TransModeler microsimulation, discussed in more detail in **Chapter 6**. As a single large 4 critical phase signal, the system supports 3800 vehicles per hour with an average "time in system" of 100 seconds per vehicle (roughly 40 seconds in motion, and 60 seconds stopped at the signal). After introducing the One-Way Split Intersection, time in system drops to just 60 seconds per vehicle (the same 40 in motion, but only 20 seconds stopped at signals). We then discovered the system could support up to 6,400 vph when it gets back to 100 seconds per vehicle (40 in motion, and 60 at signals). This is an incredible gain of 70% capacity with the same number of through lanes, left lanes, and right-turn pockets.

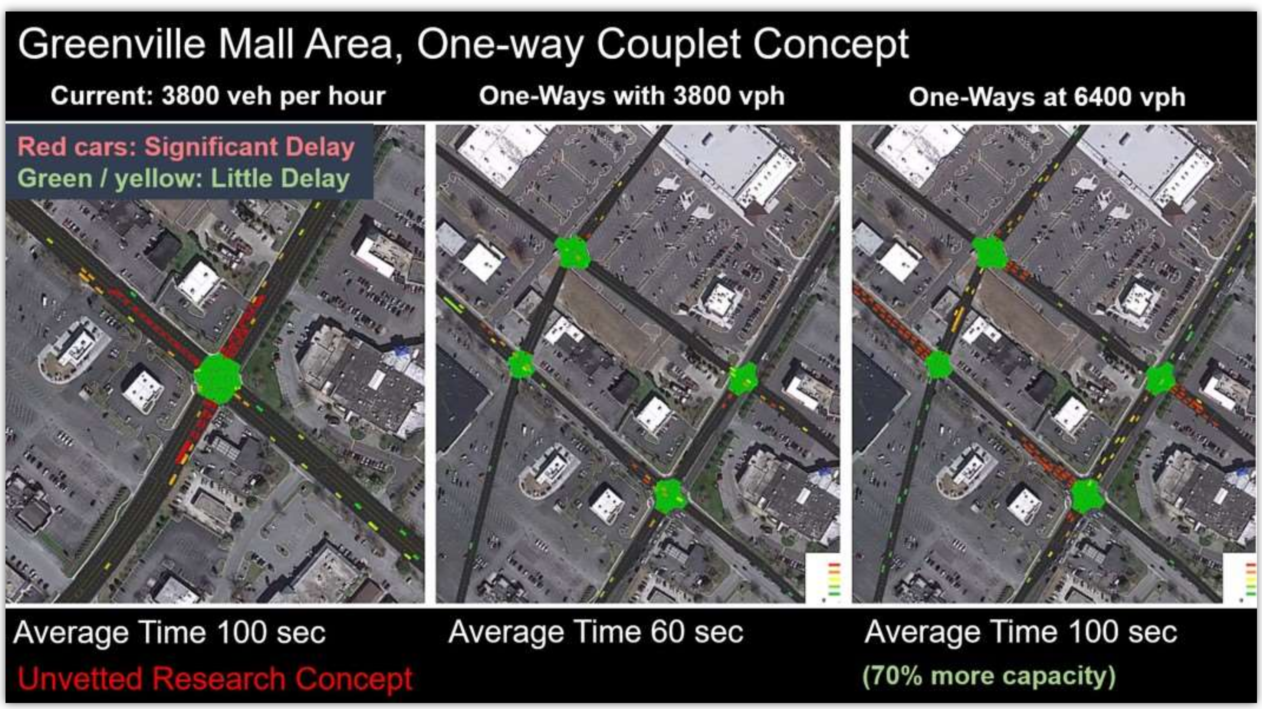


Figure 4-16 *TransModeler comparison of key statistics for one-way system.*

Figure 4-17 Shows how the four-quadrant design and the four-one-ways work together in the same space to create a significant "Activity Center" with high vehicle capacity arranged in a "Drive Slower, Travel Faster" format. The additional vehicle capacity, combined with other multimodal improvements, helps the market move from T3 auto-oriented suburban Floor Area Ratios in the .14 to .17 range to .52 to .92 range (T4 and T5 walkable mixed-use). The overall activity center has potential to offset more than 1500 acres of suburban sprawl (saving farms and open space) and eliminates the cost of about 44 miles of general infrastructure. The cost of housing + transportation should be more affordable than had it emerged randomly in Greenfields at a T3 suburban scale.

Sufficient Parking? Many may be concerned that these graphics do not appear to offer enough parking. Parking can be addressed in a small area plan: 1) parking garages in lieu of some mixed-use buildings; 2) parking tucked under new buildings, 3) more on-street parking either through frontage access along arterials, or on internal local streets; 4) mixing residential and commercial to optimize space utilization throughout the day; 5) conscious effort to minimize reserved spaces; 6) transit circulation, and 7) increased implementation of sharing strategies (car sharing, bike sharing, and golf-cart-sized electric vehicle sharing). These all minimize the need for parking.

Figure 4-17 Existing vs Potential for the Greenville four quadrant (left) plus four one-ways (right)

5. Placemaking Alternative Intersections: Smithfield Examples

Smithfield is a semi-rural town of about 13,000 residents located 34 miles southeast of Raleigh. They have a lot of room to grow, and with better ability for remote working, towns like this will be increasingly popular. **Figure 5-1** focuses on Smithfield's Market Street – the town's historic "Main Street" which has many beautiful mixed-use buildings. Market Street has a four-lane cross-section with parallel parking, along with narrow sidewalks and a few random street trees. It is reasonably walkable as it is, but it is also increasingly congested.

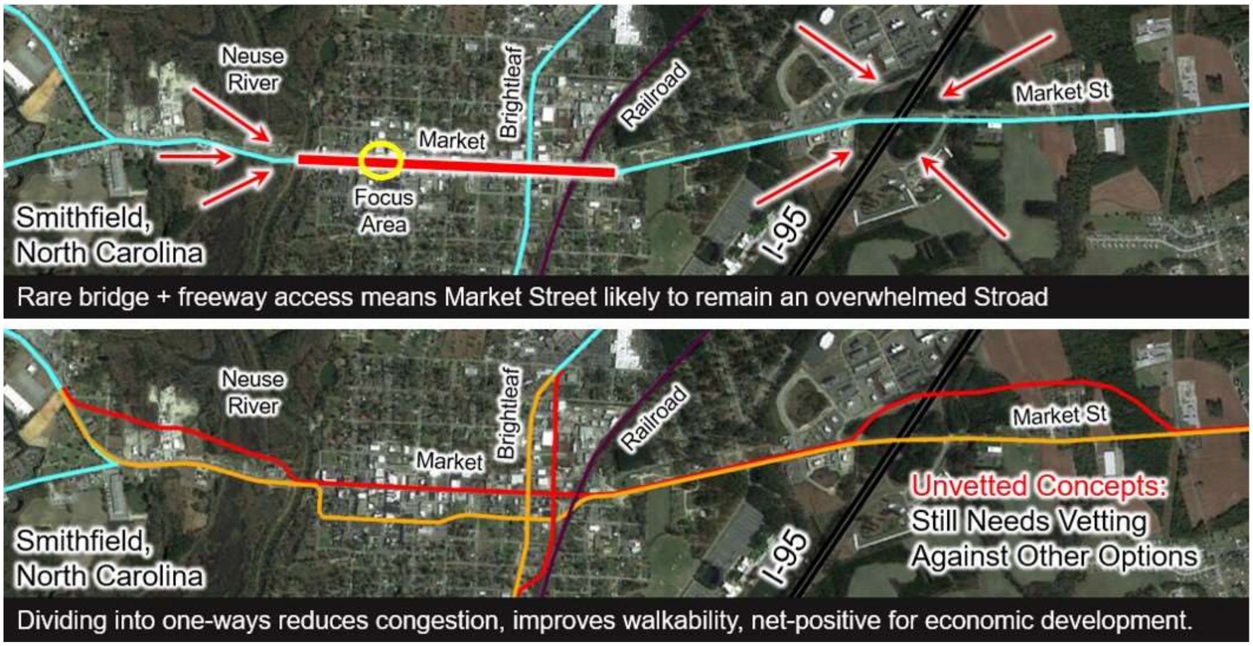


Figure 5-1 *As pressure increases on Market St., one-ways could offer win-win for Placemaking and Traffic*

The east end of Market Street connects to I-95. The west end is a rare crossing of the Neuse River. As the city grows west of the river, there will be increasing pressure for drivers to traverse Market Street to reach the freeway and commercial outlets near it. There are emerging concepts to divert some of this traffic elsewhere, but it is not clear if these efforts will prove sufficient to offset future growth. There is strong potential that traffic will keep growing on Market Street regardless of whatever else NCDOT and the community can do to divert traffic. Without another solution, the day could easily come where NCDOT and the community together default to a solution that eliminates on-street parking in favor of a 5 or 6-lane cross-section – a Stroad even worse than at present through their most walkable environment.

Figure 5-2 *Focus of yellow circle in the previous figure.*

The research team noticed that it is reasonably possible to install a one-way couplet system using the east-west red and orange paths in the figure. Shown are three connected one-way segments of an east-west couplet (west of the river, downtown, and across I-95). Each has independent utility, so no need to eliminate all of them if one or two fail to win public support. The two western couplets are separated by a bridge. ***The downtown and I-95 couplets merge together into an***

RCUT. This is important to note because an RCUT functions like two one-way streets (but the "block" separating the streets is only the width of the median). In other words, the segment from the bridge over the river to I-95 can act like two one-way streets with perfect progression. It is also possible to create north-south one-ways as well in the Brightleaf Blvd corridor.

5.1. Graphics and Considerations for One-Ways in Historic Environments

Figure 5-3 shows the most sensitive part of Market Street, and how eastbound traffic might be rerouted along the blue path on Johnston Street to both improve traffic capacity and free up space on Market Street to create a more walkable environment. Eastbound would connect Johnston St. to Massey St. with a new street segment through the orange box. There is a single small home in the pathway and potentially some parking and a detention basin, but otherwise it is a clean path. It is the opinion of the research team that the city would do well to plan for this connection regardless of whether it is used for this one-way concept or not.

Figure 5-3 Diverting eastbound traffic reduces congestion and frees space on Market St.

Figure 5-4 highlights existing conditions vs two potential futures. The location featured is within the yellow circle of **Figure 5-3**, and a similar cross-section would be created on the new eastbound Johnston / Massey Street.

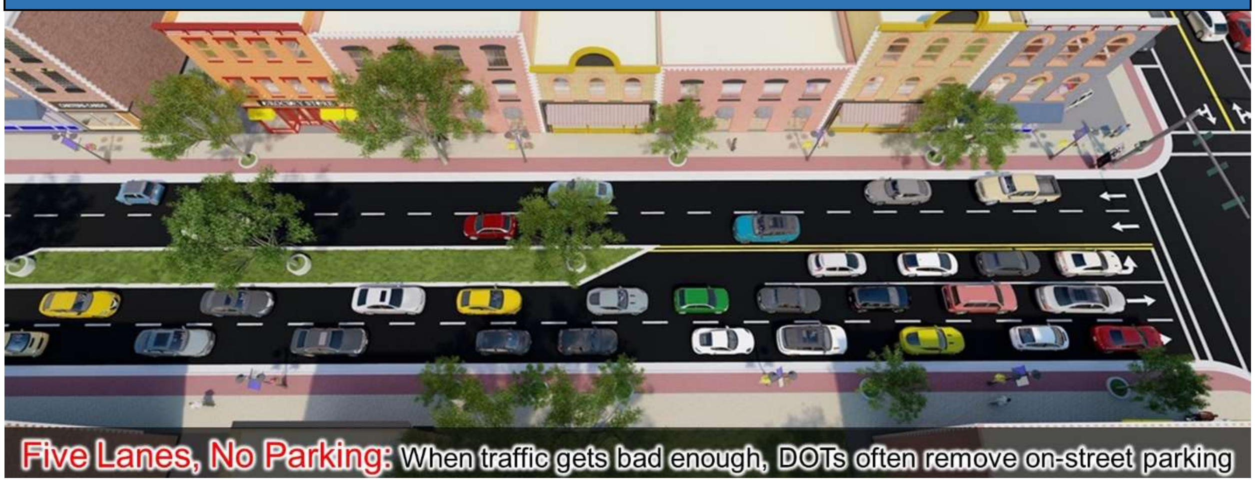
Going from 4-lane to 5-lane is what DOTs often do to improve both safety and traffic operations, but in this case, it would come at the expense of on-street parking. One-way operation releases space for other uses, and it also improves safety and traffic operations even better than the 5-lane would.

In contemplating the idea of relocating eastbound traffic, it helps if the candidate street is one that already has businesses rather than single-family homes, as it will likely be less controversial. However, a community might still support the conversion, despite any angry homeowners, due to stronger ability to catalyze significant mixed-use development throughout the corridor.

In this case Johnston/Massey is very compatible with the change, being mostly businesses already.

This 4-lane allows for parking, but it also functions poorly as left turns block thru traffic.

5-lanes improve traffic and aesthetics, at the expense of parking, but still a “Nicer Stroad”.



One-Way creates “Driver Slower, Travel Faster,” with parking, bike lane, transit, & dining.

Figure 5-4 *Today’s two-way Stroad w/Parking, vs default future (5-lane), vs One-ways w/space for other uses.*

Figure 5-5 shows a street-level view where the top graphic is a 5-lane cross-section that could happen if parking is removed, vs a one-way that works better for traffic and all other modes.

Speeds on One-Ways vs Two-Ways: These graphics depict hypothetical speeds to help demonstrate the benefits of perfect multi-signal coordination, which is possible with one-way streets but not possible with two-ways. In the "before" two-way, speed limits on major arterials are often set at 30-35 mph. But drivers often go significantly faster, say 40-45 mph, if they perceive it to be safe and believe they are unlikely to get a speeding ticket.

In the one-way system, a high share of drivers are likely to obey the limit even if it is intentionally set at just 25 mph for walkability. Why? They obey because they easily discover that signals are set to turn green at 25 mph. Anything above that and they arrive at the next signal a little too early.

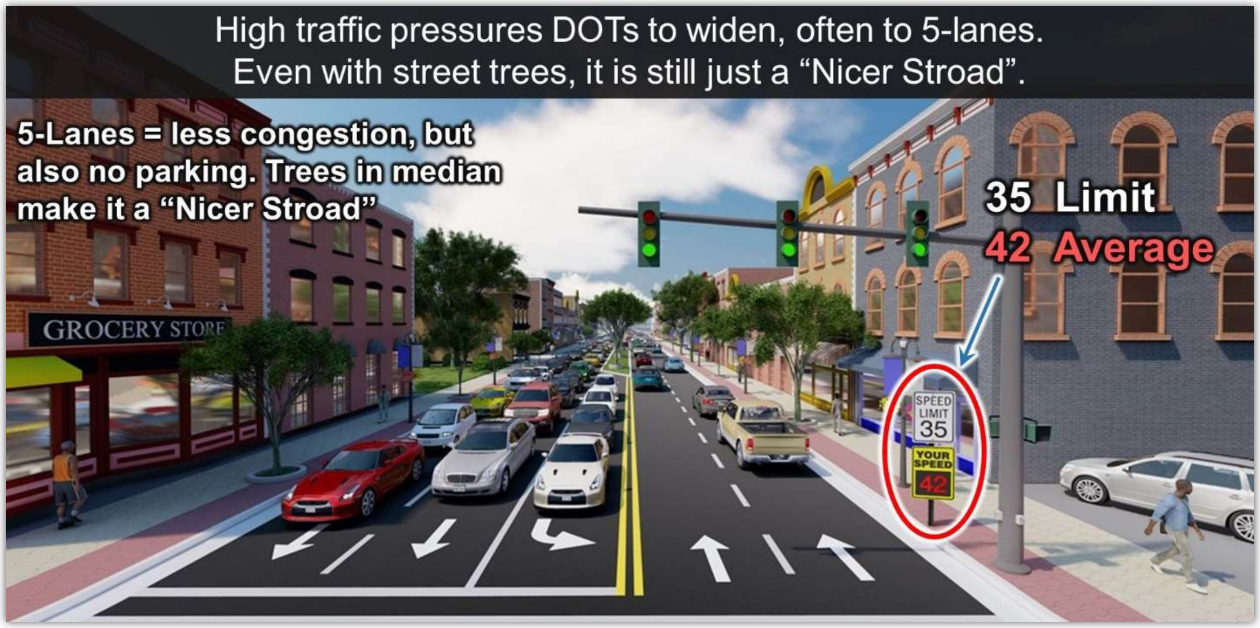


Figure 5-5 Drivers likely obey speed limits, even if slow, due to perfect synchronization.

It is impossible for drivers to discern synchronization in a two-way system, and thus they cannot be motivated to obey the speed limit. This is one of the key benefits of one-ways. On top of that, there is a lot more space for other uses!

Other Features Depicted: While the top condition has some street trees and decent sidewalks, the bottom condition has even more room for better street trees, outdoor dining, reverse angle parking, and a "slow lane" (enforced with speed humps) so that bikes, narrow four-wheel electrics, trolleys, and vehicles accessing parking will all travel between 10 and 15 mph.

Other cross-section options also exist. The main point is to show that if oncoming lanes can be relocated to a parallel corridor, there will be less congestion, better compliance with speed limits, and communities recover a lot of room for alternative uses.

Community Challenges with One-Way Retrofit Implementation: A change like this could affect hundreds of property owners along both pathways. It may be true that a full analysis could reveal that the pros would outweigh the cons for most of those property owners and for the larger community. However, it may also be true that a few specific businesses or residents will experience more negatives than positives. Further, even if there will be far more "winners" in the long run, many could nonetheless endure short-term negatives while the market adjusts to the new situation and starts to create a "rising tide that will lift all boats."

What seems certainly true is that even guaranteed winners will initially worry about ending up net-negative. Thus, in the early stages of a stakeholder process, they may prefer to tolerate "the devil they know" rather than entertain a potential new devil. Even if that devil is really an angel, it will take time and effort to convince them of that. Thus, if a one-way couplet retrofit opportunity is discovered and looks to be an excellent solution for both traffic and economic revitalization, and if it is more than a few blocks in length, then a study should be crafted that allows for extensive time, analysis, and more stakeholder involvement than a typical planning study may require.

Experience with Smithfield: Regarding the perceptions above, the research team experienced this hesitancy firsthand. At the start of the project, city staff agreed to accept "free ideas" such as this, to potentially be evaluated later, in trade for allowing associated graphics and analysis to be available to NCDOT for use statewide. However, as they saw the results and contemplated the scale of such a change, they became concerned about the barrage of questions and worries that could ensue. It is clear they can only entertain this as a potential solution within a well-structured, unbiased alternatives analysis that has an adequate budget for addressing community concerns. ***Because of this, any identification of these graphics as inspired by the situation in Smithfield must emphasize this is NOT currently their plan but is exclusively for research!***

As a small community where today's congestion is tolerable, Smithfield is not yet facing traffic difficulties sufficient to motivate them to create anxiety among their citizens. To move this idea forward now, a strong case would need to be made (through a planning study) that 1) they are growing fast and will soon be in trouble, 2) alternative solutions are not sufficient, 3) a one-way solution will create more positive than negative, and 4) a mitigation plan is in place to help any who experience net-negative impacts. Larger cities with more congestion and more need for revitalization may be more willing to entertain such a major change, if the "congestion and auto-oriented devil they know" is bad enough already.

Opportunities in greenfield settings: Where two rural-but-urbanizing roads cross, planning early to split this into four one-ways has major advantages over the default alternative (a single, large two-way Stroad intersection). Thus, for highways on the fringe with a lot of land soon to be urbanized, NCDOT and associated communities would do well to consider intentionally creating parallel alignments for one-way couplets on any roadway that is likely to be widened to a 5-lane cross-section or larger at some point in the future. If this is done before much development is there, it will prove to be a lot easier to implement.

5.2. How to "De-Stroad" Using Crossing One-Way Couplets

Slightly east of the site just explored, Market Street becomes more auto-oriented. **Figure 5-6** shows today's environment where Market Street crosses with Brightleaf Blvd. But rather than tolerating the crossing of two Stroads in the large red circle, there is an opportunity for four one-way streets (a.k.a. "One-Way Split Intersection), creating four small intersections similar to the situation explored earlier in Greenville. But different than in Greenville, this would be a much smaller implementation, and it would not impact any existing buildings or private property of significance.

Figure 5-6 *Existing situation where Crossing Couplets are possible.*

Figure 5-8 shows the current view looking south at Brightleaf Blvd from Market Street. **Figure 5-7** shows how that same location might be reinvented with a one-way "bone structure."

Figure 5-8 *Looking South at Brightleaf Blvd from Market Street*

Figure 5-7 *Looking South at Brightleaf, Reconfigured as a Walkable One-Way Boulevard*

Figure 5-9 shows how the auto-oriented space shown in **Figure 5-6** could be reinvented using one-way streets. **Figure 5-10** shows more street-level details.

Figure 5-9 *Birdseye view of the potential for reinventing languishing areas using four one-way streets.*

Figure 5-10 *One-Ways can make space for protected cycle tracks and street trees.*

Figure 5-11 depicts what two Stroads often look like at their crossing: double-left turn lanes and dedicated right-turn lanes. Alternatively, the red lines depict the pavement that is necessary for traffic management in a one-way scenario. **Figure 5-12** is the same area as it could be if reconfigured as four one-way "walkable boulevards".

Figure 5-11 Typical Stroad Intersection with Double-Left Turns and Dedicated Right Turn Lane

Figure 5-12 Same Location, Reconfigured with four One-Way Streets

Note: All of these Before/After scenes, and more, can be seen with "sliders" at:
urbaninnovators.com/pr-ncdot-ai-research

Figure 5-13 shows how the historic district on the left could be revitalized and combined with a new mixed-use district on the right side, which would eventually replace today's auto-oriented space. White buildings exist today, and tan buildings depict how the market could eventually create new buildings within the larger downtown area. The two darker buildings on the left represent parking garages, which make it easier to convert surface parking into buildings and plazas.

Figure 5-13 *Rejuvenation of historic district (left side), and replacement of auto-oriented (right side)*

Caution: To restate, Smithfield has agreed to let NCDOT utilize the graphics and analysis associated with these one-way concepts, provided it is explained that these have not been presented to their businesses and residents in any formal setting. As such, this is NOT their current plan, and may never be, unless a formal planning process eventually determines there is a need to solve a capacity problem on Market Street, and that a concept like this eventually gains community support as the best option for balancing traffic needs with community needs.

5.3. Concepts for Quadrant and U-Turn Concepts near UNC Health Johnston Hospital

Figure 5-14 shows a concept area that combines the one-way streets shown earlier (the northern convergence of Brightleaf and 9th), with Quadrant roadways and with a U-Turn opportunity. The result would be greater connectivity and accessibility, along with street trees and pedestrian refuge areas that could activate senior living spaces and services along with other medical-related residential in the area, so that anyone living in this area could accomplish most of the things they need daily by walking or biking. *Note: This concept was not as concerning to city staff who reviewed it as the east-west one-way couplet concept for Market Street, but the same caution applies – this is not their current plan, and it would need extensive vetting before it could be.*

Figure 5-14 Combining One-Ways, Quadrants, and U-Turns to activate a walkable "medical district."

6. Traffic Operational Analysis

Due to unavailability of empirical data, the operational performance of AI designs was assessed through microscopic simulation modeling. This chapter illustrates the analysis and modeling framework, describes the key attributes of each AI design, and presents the traffic operational analysis and land-use activity density analysis for demonstrating how alternative intersection designs can make it possible to both manage traffic and catalyze great mixed-use developments.

6.1. Analysis Scenarios

The latest edition of *"Highway Capacity Manual (HCM)"* recommends using control delay as an intuitive measure for determining signalized intersection LOS and using capacity as a planning-level analysis of design sufficiency. For AI designs with secondary intersections, the HCM method employs "Experienced Travel Time (ETT)", which consists of control delay at each intersection and Extra Distance Travel Time due to rerouting, for determining LOS.

To conduct a comprehensive and systematic comparison of traffic operational improvements gained from AI designs, we did several things. First, we conducted a standard "Before-After" comparison of *operational improvements*, assuming no change in demand, and no increase in number of lanes. Second, we determined the *additional capacity* the design could support at the point where delay is similar to no-build. Third, if new lanes could be easily supported (due to excess right-of-way), we added them to reveal *maximum capacity* (which may be needed to support increased density). Last, we determined how much mixed-use development could be supported by the increased capacity using a process described later. The performance measures used for traffic operational assessment include:

Operational Improvements in terms of Weighted Average Travel Time

- ✓ Assuming no fundamental change in number of lanes and traffic demand

Additional Capacity

- ✓ Additional traffic flow that AI designs can accommodate at Level of Service (LOS) E without adding lanes

Maximum Capacity

- ✓ Maximum flow at LOS E by adding additional lanes within the available Right-of-Way (ROW)

To satisfy these performance measures, for each of the three case study sites, the following four simulation scenarios were tested:

***Scenario A*: Current Design, LOS E Threshold:** proportionally increase traffic demand to generate 60s average delay per vehicle (i.e., time-in-system = 110s = 60 stopped + 50 in motion)

***Scenario B*: Design Efficiency (New Design, Similar Lanes, Similar Traffic):** determine if there are efficiencies or delay reductions attributable exclusively to the design by matching Scenario A lane configuration and demand by movement, as closely as possible.

***Scenario C*: Design Capacity: (New Design, Similar Lanes, LOS E):** Same as Scenario B, but increase traffic to the point where the average time-in-system is at the LOS E threshold (110 seconds). This reveals the maximum capacity of the design, which is then compared against Scenario A.

***Scenario D*: Maximum Capacity: (New Design, Sized for Vision, LOS E):** Previous scenarios assess the design by keeping the number of lanes as close to the current design as possible. This scenario is not held to that constraint, but instead lanes are increased if right-of-way is available, to help serve expected boost in demand associated with increased development – anywhere from 3-5 times present development in most cases. This is the "maximum build" that can be accommodated within a walkable context.

6.2. Simulation Modeling Framework

After determining the simulation scenarios, microsimulation modeling was performed with Trafficware Synchro 11 and Caliper TransModeler 5.0 software. An overview of the analysis, modeling, and simulation framework is presented in **Figure 6-1**.

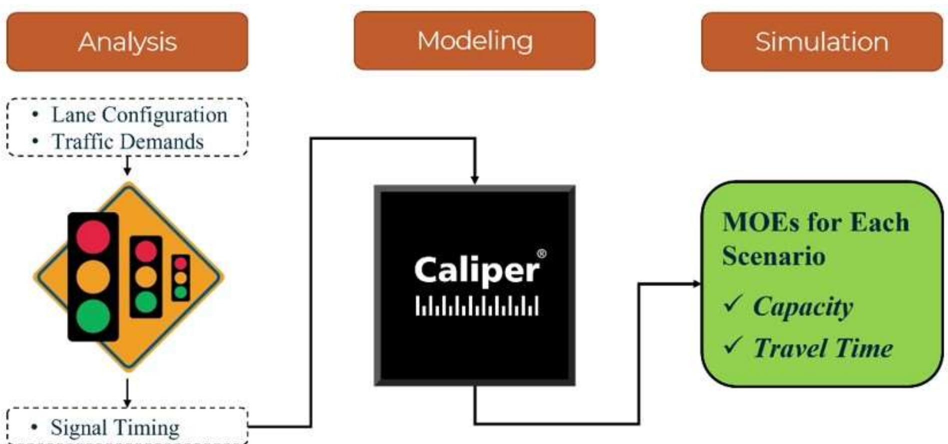
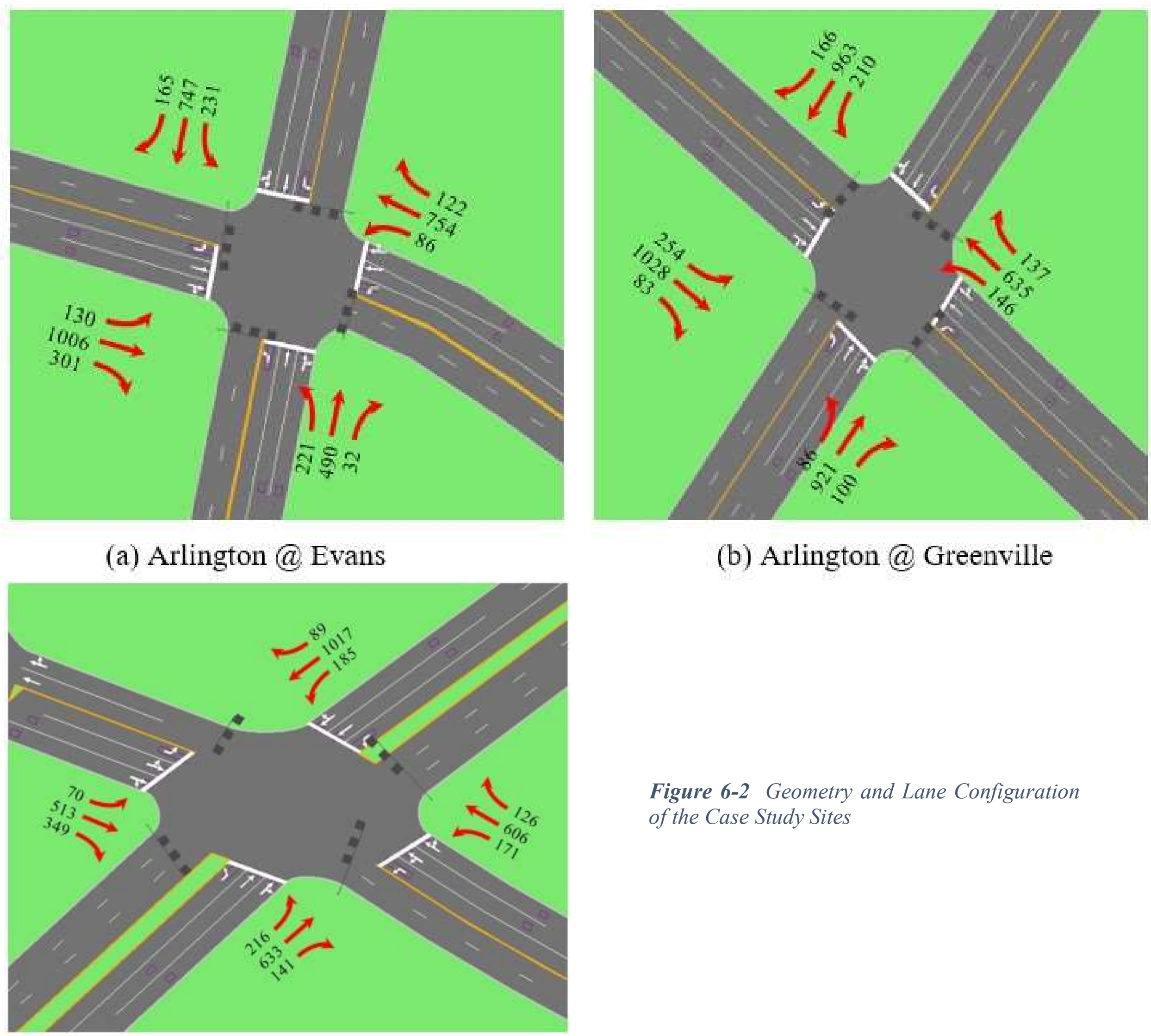


Figure 6-1 *Analysis, Modeling and Simulation Framework*

The research started with the development and calibration of the baseline models based on the actual geometry configurations of three conventional intersections in Greenville, NC: 1) Arlington Blvd and Evans Road intersection, 2) Arlington Blvd and Greenville Blvd intersection, and 3) Greenville Blvd and Red Banks Road intersection. The geometric layout for each intersection and research team's estimated turning volumes are shown in **Figure 6-2**. For all three sites, a 4 critical phase signal was adopted to accommodate protected left-turn phases.

For each case study site, the existing conditions "baseline" was created to show current lane configurations and peak hour movements. When converting the baseline model to the proposed alternative intersection model, the original number of turning lanes for each movement were kept as closely as possible. The Synchro 11 software was employed to optimize the cycle lengths, splits, and offsets for each model. Eventually, these modeling parameters were coded into TransModeler for microsimulation to generate travel time and capacity for each scenario. For each scenario, 10 simulation runs with various random seeds were conducted to minimize the stochastic errors of microsimulation.



(a) Arlington @ Evans

(b) Arlington @ Greenville

(c) Greenville @ Red Banks

Figure 6-2 *Geometry and Lane Configuration of the Case Study Sites*

It should be noted that for the Placemaking AI models to reflect the installment of traffic calming features, the models assumed a lower posted speed limit in comparison to the baseline condition (e.g., in the baseline models, a link travel speed of 45 mph was used; while in the AI models, we reduced the link travel speed to 35 mph). This was done on the theory that the Placemaking designs would reduce stopped delay so much that it would be ok to increase the time-in-motion slightly (i.e., reduced speed limit), and overall travel times may still end up shorter.

6.3. Traffic Analysis

6.3.1. Left-Turn Treatments

This research effort proposes three typical alternative intersection designs (illustrated in **Figure 6-3**) for the aforementioned three case study sites based on their geometry and land-use characteristics:

(a) Case Study 1: Arlington Blvd and Evans Road Intersection: analyze changing to a ***Full Four Quadrant Roadway*** design resulting in a two-phase signal at the primary intersection, and four three-phase signals at secondary intersections.

(b) Case Study 2: Arlington Blvd and Greenville Blvd Intersection: analyze changing to a ***One-Way Split Intersection*** design, resulting in four small, pedestrian-friendly two-phase signals.

(c) Case Study 3: Greenville Blvd and Red Banks Road Intersection: analyze changing to a ***Reduced Conflict U-Turn with Dual Quadrant Roadway*** design. The result is a two-phase signal at the main intersection, and three-phase signals at secondary intersections. Quadrant paths will also help reduce left-turn travel distances for this skewed intersection.

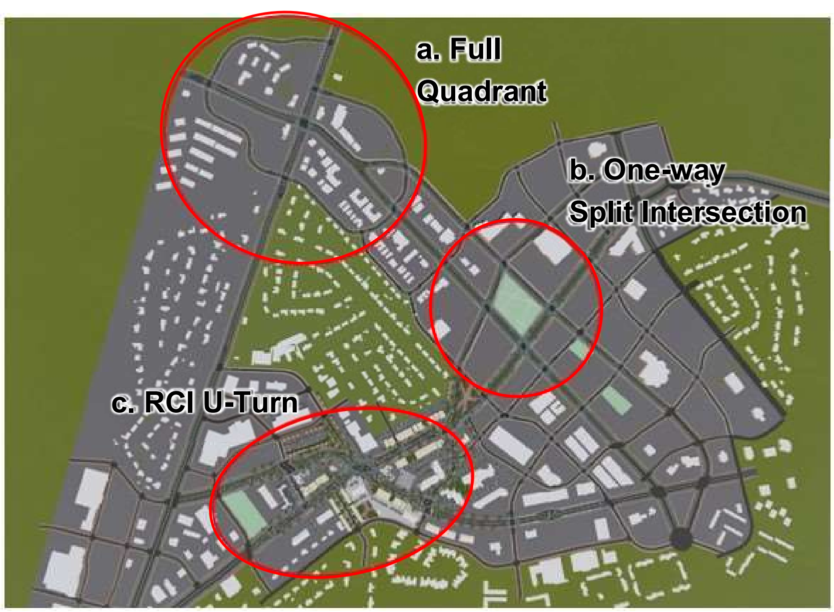
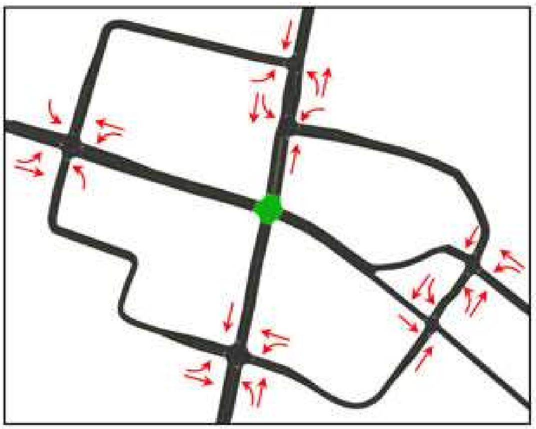


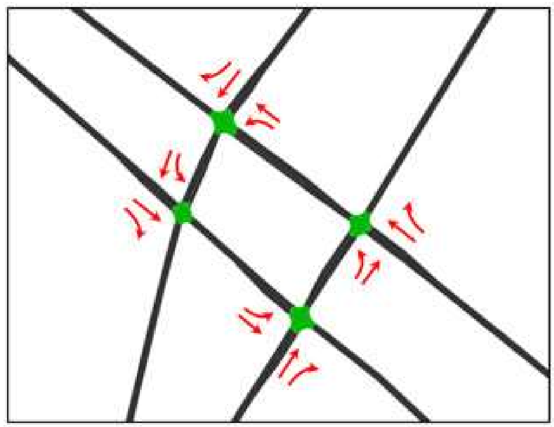
Figure 6-3 *Proposed Alternative Intersection Designs*

For all AI designs, this research assumed a two critical movements (CM) phasing scheme at the main intersection. The left-turn treatments at each AI design are specified in **Figure 6-4**.

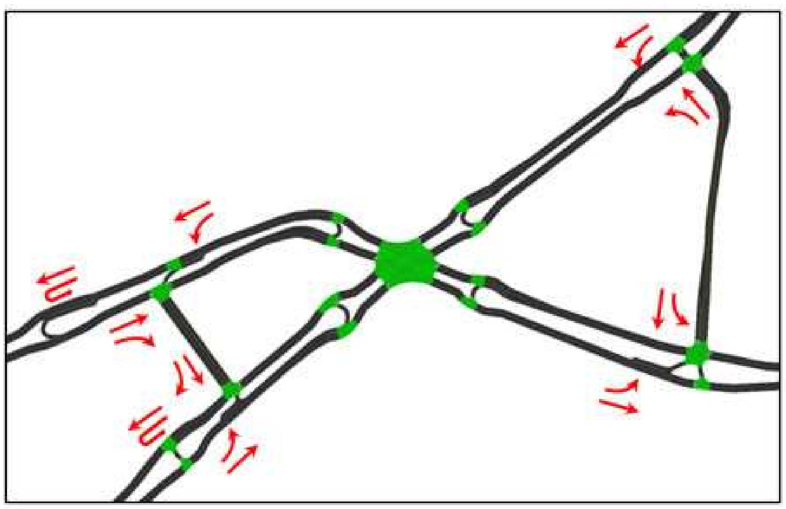
At Arlington Blvd and Evans Road, the new condition would route all four left turns along a backway path (i.e. a "Quadrant"), which resulted in 3-phase signals at the secondary intersections, as shown in **"A"**. These four intersections are 3-phase because the through movement of the minor street would not be accommodated, as it wouldn't be many trips anyway. At Greenville Blvd and Arlington Blvd, there is the potential of dividing two large Stroads into four walkable one-way streets (i.e. a "One-Way Split Intersection"). As depicted, this would replace one inefficient 4 critical phase signal with four 2-phase, highly efficient, signals, as shown in **"B"**. At Greenville Blvd and Red Banks Road, it appears possible to construct a combination U-Turn / Quadrant design. Presently, there is a wide setback on roads, which should make it relatively easy to construct the U-turns shown in **"C".** There are also open pathways through the parking lots where new city streets could be constructed for the Quadrant pathways.



A: Four Quadrant Design



B: One-Way Split Intersection



C: U-Turn with Two Quadrants

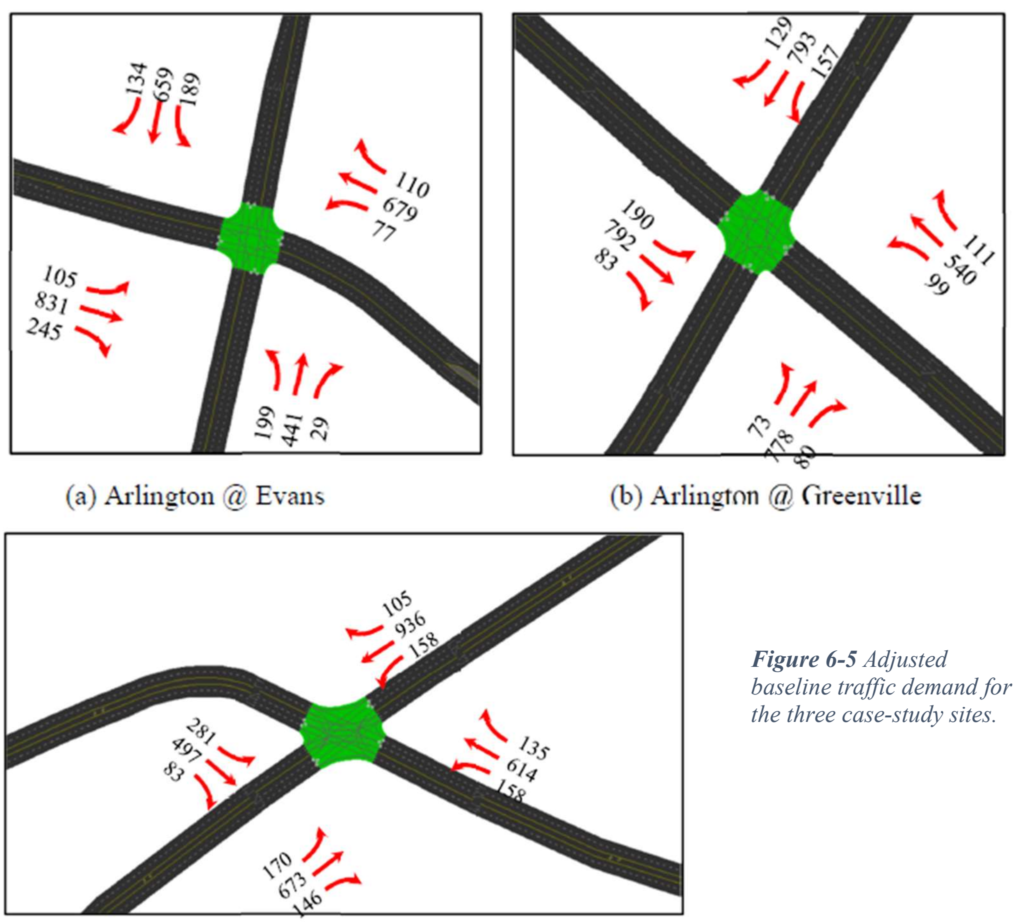
Figure 6-4 *Left-turn treatments at the case study sites.*

6.3.2. Traffic Volume Development

Scenario A (existing geometry, 60-seconds delay): The first step was to adjust field observed turning volumes to generate an average intersection delay of 60s (Level-of-Service E). Volume adjustment was done through a "trial-and-error" process, where field observed traffic was proportionally reduced or increased in TransModeler until the average delay matched 60s. The adjusted baseline traffic demands for the three case studies are illustrated in **Figure 6-5**.

Next, for each case study, baseline traffic demand was directly imported into the AI model in Scenario B for traffic operational performance analysis. Since TransModeler employs an Origin-Destination (O-D) matrix to model turning traffic demands, this allows for direct use of the O-D matrix instead of manually inputting turning volumes at each intersection when modeling AIs with secondary intersections. When modeling Scenario C, we used the same simulation model as Scenario B; the difference is that we adopted the "trial-and-error" process again to proportionally increase or decrease the baseline traffic demand until the simulated travel time was the same as (or close to) Scenario A.

When modeling Scenario D, we developed a new AI simulation model where we increase the number of lanes for the arterials (e.g., increase from 2-lane per direction to 3-lane per direction). By doing so, it is expected that intersection capacity will be improved so that it can either further reduce system travel time or is able to accommodate more traffic demand. Again, the "trial-and-error" process was employed to adjust traffic demands until the simulated travel time was the same as (or close to) Scenario A.



(a) Arlington @ Evans (b) Arlington @ Greenville

(c) Greenville @ Red Banks

Figure 6-5 *Adjusted baseline traffic demand for the three case-study sites.*

6.4. Simulation Modeling Results

6.4.1. Case Study 1: Quadrant Roadway Design

Table 6-1 shows the results of the simulation modeling effort for the Quadrant design. A summary is provided below to better understand the improvements between the scenarios.

Table 6-1 *Comparisons of Traffic Operational Performance for Case Study 1*

Measure	Existing Condition	Alternative Design (Quadrant Roadway)		
	A: Capacity at 60s Delay	B: New Design, Same Volume	C: New Design, Add Volume	D: New Design, Add Lane
Speed Limit (mph)	45	35	35	35
Moving Time (sec)	40	51	51	51
Delay (sec)	60	39	49	49
Travel Time (sec)	100	90 *(-10%)*	100	100
Capacity (vph)	3,600	3,600	5,000 *(+39%)*	5,700 *(+58%)*

Scenario A has a maximum capacity of approximately 3,600 vph at the point where each vehicle experiences 60-seconds of delay at the main intersection. At this point, TransModeler shows that it takes 100 seconds for a vehicle to traverse the system at a speed limit of 45 mph (60 seconds of stop delay plus 40 seconds in motion).

Scenario B introduces the new quadrant roadway design with the same 3,600 vph, but changes the speed limit to 35 mph. The overall travel time is now just 90 seconds per vehicle. The in-motion time is 51 seconds, but the stop delay has dropped from 60 to just 39 seconds. This is a 10% improvement in overall travel time, even though the speed limit is 10 mph slower.

Scenario C increases the amount of traffic until the overall travel time returns to 100 seconds (same as existing). The table shows the design can now handle up to 5,000 vph, which is a 39% increase in capacity, due exclusively to the efficiency of the design (since lanes are similar).

Scenario D adds capacity to the alternative design by increasing the number of lanes that can be had in the existing right-of-way, and then further increases the amount of traffic until the overall travel time gets back to 100 seconds (same as existing). The table shows the design can now handle up to 5,700 vph, which is a 58% increase in capacity.

In summary, the existing design can handle up to 3,600 vph at LOS E, while the new Quadrant design can handle anywhere from 5,000 – 5,700 vph (depending on the right-of-way utilized for vehicles), or a 39%-to-58% increase in capacity, with the same average travel time and slower vehicle speeds.

6.4.2. *Case Study 2: One-Way Split Intersection Design*

Table 6-2 shows the results of the simulation modeling effort for the One-Way Split Intersection design. A summary is provided below to better understand the improvements between the scenarios.

Table 6-2 *Comparisons of Traffic Operational Performance for Case Study 2*

Measure	Existing Condition	Alternative Design (One-way Split Intersection)		
	A: Capacity at 60s	B: New Design, Same Volume	C: New Design, Add Volume	D: New Design, Add Lane
Speed Limit (mph)	45	35	35	35
Moving Time (sec)	40	51	51	51
Delay (sec)	60	9	49	49
Travel Time (sec)	100	60 *(-40%)*	100	100
Capacity (vph)	3,700	3,700*	6,100 *(+65%)*	7,100 *(92%)*

Scenario A has a maximum capacity of approximately 3,700 vph at the point where each vehicle experiences 60-seconds of delay at the main intersection. At this point, TransModeler shows that it takes 100 seconds for a vehicle to traverse the system at a speed limit of 45 mph (60 seconds of stop delay plus 40 seconds in motion).

Scenario B introduces the new One-Way Split Intersection design with the same 3,700 vph, but changes the speed limit to 35 mph. The overall travel time is now just 60 seconds per vehicle. The in-motion time is 51 seconds, but the stop delay has dropped from 60 to just 9 seconds. This is a 40% improvement in overall travel time, even though the speed limit is 10 mph slower.

Scenario C increases the amount of traffic until the overall travel time gets back to 100 seconds (same as existing). The table shows the design can handle up to 6,100 vph, which is a 65% increase in capacity, due exclusively to the efficiency of the design (since lanes are similar).

Scenario D adds capacity to the alternative design by increasing the number of lanes, and then further increases the amount of traffic until the overall travel time gets back to 100 seconds (same as existing). The table shows the design can handle up to 7,100 vph, which is a 92% increase in capacity.

In summary, today's design can handle up to 3,700 vph at LOS E, while the new One-Way Split Intersection configuration can handle anywhere from 6,100 – 7,100 vph (depending on the right-of-way utilized for vehicles), or a 65%-to-92% increase in capacity, with the same average travel time and slower vehicle speeds.

6.4.3. Case Study 3: Combined U-Turn with Two-Quadrant Design

Table 6-3 shows the results of the simulation modeling effort for the U-turn with Quadrants design. A summary is provided below to better understand the improvements between the scenarios.

Table 6-3 *Comparisons of Traffic Operational Performance for Case Study 3*

Measure	Existing Condition	Alternative Design (RCI U-Turn)		
	A: Capacity at 60s	**B: New Design, Same Volume**	**C: New Design, Add Volume**	**D: New Design, Add Lane**
Speed Limit (mph)	45	35	35	35
Moving Time (sec)	40	51	51	51
Delay (sec)	60	39	49	49
Travel Time (sec)	100	90 *(-10%)*	100	100
Capacity (vph)	3800	3800*	5,800 *(+53%)*	6,000 *(+58%)*

Scenario A has a maximum capacity of approximately 3,800 vph at the point where each vehicle experiences 60-seconds of delay at the main intersection. At this point, TransModeler shows that it takes 100 seconds for a vehicle to traverse the system at a speed limit of 45 mph (60 seconds of stop delay plus 40 seconds in motion).

Scenario B introduces the new U-Turn with Two-Quadrant design with the same 3,800 vph, but changes the speed limit to 35 mph. The overall travel time is now just 90 seconds per vehicle. The in-motion time is 51 seconds, but the stop delay has dropped from 60 to just 39 seconds. This is a 10% improvement in overall travel time, even though the speed limit is 10 mph slower.

Scenario C increases the amount of traffic until the overall travel time gets back to 100 seconds (same as existing). The table shows the design can handle up to 5,800 vph, which is a 53% increase in capacity, due exclusively to the efficiency of the design (since lanes are similar).

Scenario D adds capacity to the alternative design by increasing the number of lanes, and then further increases the amount of traffic until the overall travel time gets back to 100 seconds (same as existing). For this case study, we only increase minor street number of lanes. The table shows the design can handle up to 6,000 vph, which is a 58% increase in capacity.

In summary, today's design can handle up to 3,800 vph at LOS E, while the new U-turn plus Quadrant configuration can handle anywhere from 5,800 – 6,000 vph (depending on the right-of-way utilized for vehicles), or a 53%-to-58% increase in capacity, with the same average travel time and slower vehicle speeds.

7. Economics Analysis

7.1. Inequity and Gentrification

In the past, state DOTs have rarely considered how their designs, which are often Stroad-like, have influenced local and regional economics. It is clear that high speed contributes to low density, but it could also be true that decaying conditions on no-frills auto-oriented corridors could also lower already low densities by accelerating a "flight to the fringe" among those with the means of escaping decaying conditions. Thus, if flight to the fringe associated with decaying Stroads is a real phenomenon, then the existence of Stroads could be a strong factor exacerbating inequity by accelerating creation of large swaths of poverty-stricken areas.

However, to the extent that concepts proposed herein would succeed in revitalizing struggling areas, gentrification could become a concern. The Merriam-Webster dictionary defines gentrification as *"a process in which a poor area experiences an influx of middle-class or wealthy people who renovate and rebuild homes and businesses and which often results in an increase in property values and the displacement of earlier, usually poorer residents."*

The poor often rent their homes and businesses. When an area becomes hot for infill and redevelopment, some buildings will be demolished, forcing out renters. When a lot of new development occurs quickly, the cost of rent in the area tends to rise even for older properties, again leading long-time residents to move or into homelessness because they can't afford higher rent. For those who do own a business or a home, they may be manipulated into selling at an unreasonably low price, thereby failing to benefit as much as they should have.

But urban renewal doesn't have to be a bad thing for the poor, provided there are mechanisms to help ensure that the rising tide can lift all boats. The task therefore is to increase the odds that existing residents and businesses can benefit from good jobs, good schools, good parks, and other features associated with renewal.

The Center for American Progress outlines a number of potential solutions, including job training programs, local hire mandates and incentives, right of first refusal, renter protections, rent subsidies, below market purchase opportunities, inclusionary zoning, and creation of a wide range of housing size and quality options, and measures to strengthen community resilience. (*CAP, 2022*). A panel of experts on the topic recommended that when there is a public effort aimed at influencing walkability or urban renewal, planners should ensure low-income stakeholders have a place at the table before the process advances too far, to help identify issues and to find helpful solutions (*Smith, 2014*).

The research team recommends that NCDOT not avoid attempting to influence land uses due to concerns over accusations of promoting gentrification and favoritism. Instead, when it is very clear that a community wants infrastructure that can catalyze walkable development, NCDOT should be aware that forces trending toward gentrification could be unleashed, and thus should explore how to increase the odds that nearby lower income residents and businesses can stay in the area and benefit from the improvements.

7.2. Development Scale Calculator: What does it do? Why is it helpful?

Stroads make it difficult for communities to attract more "taxpayers per square mile" because they hinder walkable infill development. To help address these economic development issues, the research team created a "Development Scale Calculator" in Microsoft Excel, as described in this chapter.

The calculator helps determine how much development a given roadway infrastructure package can support before the market for additional development becomes hindered due to excessive congestion. "Excessive" is defined as key intersections operating at Level of Service E (i.e., 60 seconds of delay per vehicle).

One goal of the calculator is to show how today's Stroad-like designs limit the intensification of land not only because they are "unwalkable," but also because they may not have enough vehicle capacity to support higher levels of urban development even if they were walkable and attractive for development. A second goal is to evaluate new multimodal investment proposals to determine how much walkable development they can support before similar congestion and delay return.

The calculator considers three independent factors that influence the vehicular level of service:

1. **Increased Capacity**: the ability to support more vehicles as a result of Placemaking Alternative Intersections, or anything else that creates new capacity.
2. **Reduced Demand**: enhancements to transit, walking, biking, general connectivity – anything with ability to remove or relocate vehicles from the critical intersection.
3. **Mixed-Use Efficiency**: the nature of what is built affects how many vehicle trips will be generated. Users can propose different Density and Diversity arrangements and see how they are likely to affect the level of service at each critical intersection.

The tool is designed as a sketch-planning tool, meaning the accuracy of results could probably be improved through a suite of more complex analysis tools. However, it is helpful for comparing the general trends of one scenario vs another. It is somewhat challenging to use it in the Excel environment, and may benefit from conversion into a webapp where it could get a broader audience and be easier to use.

7.3. Calculator: Overview of Step-by-Step Analysis Approach

This section shows a few screenshots of the tool along with a high-level explanation of what is happening. It is designed to analyze a study area which has three smaller "intersection areas," each with its own critical signalized intersection. This overview shows only the first intersection, which in this case was the analysis of the four-quadrant design in Greenville. It shows how we concluded that our design supports up to 4-times as much development as at present before congestion returns to LOS E. A more detailed user manual is available as a separate file in the accompanying directory called **Appendix E: Development Scale Calculator**.

This tool exists in an Excel Spreadsheet. Guidance for how to use the tool is in a Word doc, in the same directory as the spreadsheet. Relevant file names are:

- Tool: "NCDOT Development Scale Calculator, V1.5, Oct2023.xlsm"
- How To: "NCDOT Development Scale Calculator, V1.5, Instructions.docx"
- How To: "NCDOT Development Scale Calculator, V1.5, Instructions.pdf"

Trip generation within the tool is based on the 2021 ITE Trip Generation manual (11th edition) for the PM peak hour. The default settings are for five broad uses: single family, multi-family, retail, office, and industrial. Users can get more specific however, with 11 residential definitions, 27 retail, 13 office, and 5 industrial. In addition, the tool adjusts the resulting ITE rates based on expected "internal capture" associated with the scale, density, and diversity of uses. This adjustment factor is based on Dr. Reid Ewing's "MXD Method," which accounts for efficiencies typically associated with mixed-use development (hence MXD). Trip distribution will be described momentarily.

Existing Volume	Scenario	Capacity (vph)	Pass-thru (vph)	Pre-reduct V/C		Post-reduct V/C		Reduced Demand, Area 1								
4,000				Starting VPH	V/C	Reduced VPH	V/C,R	Net. Con.	Int. Capt.	Transit	Walk	Bike	Com-bined	vs Exist	Reduced VPH	Reduced V/C
Int 1: North Quad	Existing	3,700	1,500	4,000	1.08	4,000	1.08	0.0%	10.5%	2.0%	5.7%	1.9%	20.1%	0.0%	4,000	1.08
	Step 1	3,700	1,500	3,700	1.00	3,700	1.00	0.0%	12.0%	2.0%	5.9%	1.9%	21.7%	1.6%	3,700	1.00
	Step 2	5,700	1,500	3,700	0.65	3,700	0.65	0.0%	12.0%	2.0%	5.9%	1.9%	21.7%	1.6%	3,700	0.65
	Step 3	5,700	1,500	5,600	0.98	5,500	0.96	0.0%	11.8%	1.9%	5.9%	1.8%	21.4%	1.3%	5,500	0.96
	Step 4	5,700	1,500	5,600	0.98	4,600	0.81	10.0%	13.4%	3.7%	10.7%	4.3%	42.2%	22.1%	4,600	0.81
	Step 5	5,700	1,500	6,500	1.14	5,300	0.93	10%	13.6%	4%	10.7%	4.4%	42.5%	22.4%	5,300	0.93

Land Use and Trip Generation — Analysis Type: Stepwise (1) or Alternatives (2)? 1

AREA 1: N. Quadrant	Land Use		Unit	PM Peak	Number of Units						Trip Distribution %		
	Description	Type	Type	Trip Rate	Existing	Step 1	Step 2	Step 3	Step 4	Step 5	Int. 1	Int. 2	Int. 3
	Single Family	Residential	DU	0.94	100	100	100	100	100	100	50%	30%	15%
	Multi-Family	Residential	DU	0.51	150	500	500	1,100	1,100	1,400			
	Retail	Retail	KSF	6.59	60	90	90	150	150	200			
	Office	Office	KSF	1.44	260	300	300	600	600	700			
	Industrial	Industrial	KSF	0.34	0	0	0	0	0	0			
	TOTAL			Internal Capture:	10.5%	12.0%	12.0%	11.8%	13.4%	13.6%			
				Pre-Reduction V/C Ratio:	1.08	1.00	0.65	0.98	0.98	1.14			
				Post-Reduction V/C Ratio:	1.08	1.00	0.65	0.96	0.81	0.93			
111	Acres			Floor / Area Ratio (FAR):	0.14	0.23	0.23	0.42	0.42	0.52			

Figure 7-1 Development Scale Calculator, Capacity Analysis Tab & Land Use Tab

Figure 7-1 shows the two primary tabs: "Capacity Analysis" and "Land Use." Focus first on the capacity tab. Here the user inputs the existing peak hour volume (the sum of all approaches) into cell "B5". Next, they input the existing LOS E capacity into cell D6. Note that capacity may be higher or lower than the existing volume, and must be determined by some exterior means, such as Synchro or TransModeler (we used both). To determine how much of the overall capacity is being used by intersection-area development (or potential development), a portion of that capacity must be allocated to pass-through traffic. This can be estimated using a travel demand model or some other means. In this case, we determined in Column T (note the hidden columns) that pass-through needs are about 1500 peak hour vehicles.

Trip Distribution: Since the influence area encircles an intersection, distribution is defined as the percentage of overall trips that will traverse each of the three intersections. Columns N, O, and P on the Land Use tab show that we are assuming 50% of trips generated within the Intersection 1 area will traverse Intersection 1. The reason it is not 100% is because there are other pathways available for getting in and out of the Intersection 1 area.

Note that we estimate 30% of the Intersection 1 land uses will traverse Intersection 2, and 15% will traverse Intersection 3. This volume will then be accounted for when evaluating Intersections 2 and 3 so as not to overstate how much development those areas can handle (since they are affected by the scale of development at Intersection 1). Similarly, a portion of trips generated by development near Intersections 2 and 3 will traverse Intersection 1, which limits how much development can occur at Intersection 1. Since these percentage values can be difficult to estimate, a traffic engineer highly skilled in Traffic Impact Studies can help refine and justify these values.

The analysis then proceeds in six steps (existing conditions, plus five incremental analysis steps):

Step 0: Existing Conditions: *Capacity Tab*: User describes existing volume and existing capacity in the "Existing" row (Row 6). Column AA then shows the existing v/c ratio. AA also shows V/C results of later steps prior to applying demand reduction aspects of the plan. AC and BC are duplicates and show V/C ratios after demand reduction is applied. *Land Use Tab*: User inputs the amount of each type of land use in the "Existing" column (G). This is where the user can change the five default types to add any number of types. Row 20 then shows the share of trips likely to be captured internally (and hence not affecting the intersection) based on the MXD method due to the Density and Diversity of those uses. Low density, all residential or all commercial scenarios will have less internal capture than higher density, mixed-use scenarios.

Step 1: Increased Land Uses, but Existing Capacity: Before increasing capacity, it is helpful to see what would happen to the v/c ratio if additional uses are introduced. Also, due to challenges of Excel-based algorithms, Step 1 is the first opportunity to recognize the reductions in vehicle trips associated with any existing transit, walk/bike enhancements, internal capture, etc. In this case, increasing density will add more trips, but improved diversity of land uses (residential combined with retail and service commercial) also increases internal capture from 10.5% to 12.0% (row 20). The net result is that the v/c ratio goes from 1.08 to 1.00 after these density and diversity of use reductions.

Step 2: New On-Corridor Capacity, with Step 1 Land Use: If your new design creates new capacity, enter that new capacity (as determined externally) as Step 2 (D8). Notice that Column AA v/c ratio improves from 1.00 to 0.65 before accounting for internal capture, due to the major increase in capacity (3,700 to 5,700, as determined by our TransModeler analysis). Notice that both pre-reduction and post-reduction v/c ratios are 0.65. This is because no land use changes nor alternative mode changes have occurred in this step that would reduce demand.

Step 3: Capacity from Step 2, plus even more density: Back on the Land Use tab, the 0.65 v/c ratio, without any increase in reserves for thru-trips, makes it possible to add a lot of new development. Column J shows how the user decided to increase residential units as well as commercial square footage. Behind the scenes, the tool determines the new internal capture rate to be 11.8%, derived from the density and diversity mix, as determined by Dr. Reid Ewing's "Mixed-Use Development," or MXD method *(Ewing, Tian, et. al.)*. Notice on the capacity tab that the aggressive increase in development would cause the post-reduction v/c ratio in column AC and BC (repeated for convenience) to be 0.96 (effectively LOS E). This means the user intentionally selected a scale and mix of uses that drove the v/c ratio close to 1.0. This step represents the maximum amount of development that can be supported at LOS E due to the capacity gains associated with Alternative Intersections, or whatever it was that created new vehicle capacity.

Step 4: Capacity from Step 2, plus Land Use from Step 3, plus Alternative Modes: Back on the Capacity tab, **Figure 7-2** can be seen by clicking the +/- sign above column AU to reveal options for vehicle reduction infrastructure. For convenience these are all called "Alternative Modes," even though some are technically not modes. These represent any factor that can reduce demand at the primary intersection. Factors include:

- Transit Frequency: When transit is frequent, it is practical for more people to rely on.
- Transit Fares: When transit fares are low or even free, more people will leave cars for transit.
- Transit Type: (Bus, BRT, Rail) the more premium the type, the more people are likely to ride.
- Walking / Biking Environment: The better your facilities are, the more you'll attract.
- NEV / LSV (Neighborhood Electric Vehicles, aka Low Speed Vehicles): If you specifically design to attract "tiny cars," this can lower demand for large on-network vehicles.
- Parking: The way parking is handled has an effect on the demand for vehicles in the area
- Street Trees: Connected to walking and biking, but also essential for catalyzing walkable development. The better the trees, the more likely the result can draw down vehicles.
- Network Connectivity: Assumes reduced block sizes, increased connectivity, and new alternative paths resulting in a user-defined estimate of vehicles likely to be diverted.

Existing Volume	Scenario	Demand Reducing Infrastructure - Area 1															Note	
4,000		Term	Transit Freq.		Transit Fare		Transit Type		Bike		Walk / Sidewalk		NEV / LSV		Parking		Street Trees		Net.
			Item	Factor	Item	Factor	Item	Factor	Item	Factor	Item	Factor	Item	Factor	Item	Factor	Item	Factor	Con.
Int 1: North Quad	Existing	Near	30-min	0.75	Typical	1.00	Bus	1.00	Negligible	0.50	Poor	0.75	None	1.00	Min. reqs	1.00	Negligible	0.85	0.0%
	Step 1	Near	30-min	0.75	Typical	1.00	Bus	1.00	Negligible	0.50	Poor	0.75	None	1.00	Min. reqs	1.00	Negligible	0.85	0.0%
	Step 2	Near	30-min	0.75	Typical	1.00	Bus	1.00	Negligible	0.50	Poor	0.75	None	1.00	Min. reqs	1.00	Negligible	0.85	0.0%
	Step 3	Near	30-min	0.75	Typical	1.00	Bus	1.00	Negligible	0.50	Poor	0.75	None	1.00	Min. reqs	1.00	Negligible	0.85	0.0%
	Step 4	Near	15-min	1.00	Free	1.30	Bus	1.00	Cycle Tracks	1.20	Excellent	1.20	Good	1.20	No reqs	1.10	Excellent	1.10	10.0%
	Step 5	Near	15-min	1.00	Free	1.30	Bus	1.00	Cycle Tracks	1.20	Excellent	1.20	Good	1.20	No reqs	1.10	Excellent	1.10	10%

Figure 7-2 *Alternative Mode Factors (Capacity Tab)*

Step 4 is where an analyst can account for these factors. The more of these factors you can claim, (and the higher quality each factor is), the more vehicle demand will go down. The tool accounts for "diminishing returns." For example, consider a case where you have either 10-minute service OR free fares OR premium BRT. Then consider another case you have all of these at the same time. Each, individually, will make a big difference. Combining them all together will be even bigger. But you cannot claim the sum of all factors to achieve a massive benefit. Why not? Because the people attracted by 10-minute frequency are many of the same people who would also be attracted by free fares or by BRT. Thus, a discounting process is used to reduce the odds of double-counting benefits.

Continuing the analysis of Step 4, recall that it has the same vehicle capacity and the same land uses as Step 3, but now it adds in "credits" for additional features that you are now declaring to be part of the design. Cell Z10 on the Capacity Tab (**Figure 7-1**) shows that vehicle demand starts at pre-reduction 5,600 (v/c=0.98, assuming no internal capture nor any reduced demand from the above factors), but then drops to 4,600 vph (v/c=.81) after accounting for demand reduction factors.

Step 5: Land Use Potential at LOS E, after New Capacity and Alt Modes: Since Step 4 shows v/c at 0.81 after accounting for the combined effect of all things that can reduce vehicle demand, it makes sense to now increase the scale of development yet again to the point where the key intersection experiences LOS E, even after accounting for full demand reductions. In this case, the user's final land uses result in V/C = 0.93, (a little short of LOS E, and allows some room for error in calculation, or in the scale of through trips, etc.).

7.4. Additional Summary Results

Figure 7-3 shows the existing conditions (blue), followed by what the area could support based only on vehicular capacity improvements (brown). The green bar shows how much the area can support based on both new capacity AND the ability to reduce vehicles through enhancements to alternative modes, and/or divert vehicles through better connectivity. In this example, the 111 acres around the Greenville Quadrant today support approximately 600 people and 1000 jobs. The new PAI design, combined with other features, could make it possible to support 3,100 residents and 2,600 jobs on this same 111 acres at the point where the average drive time would be similar to today.

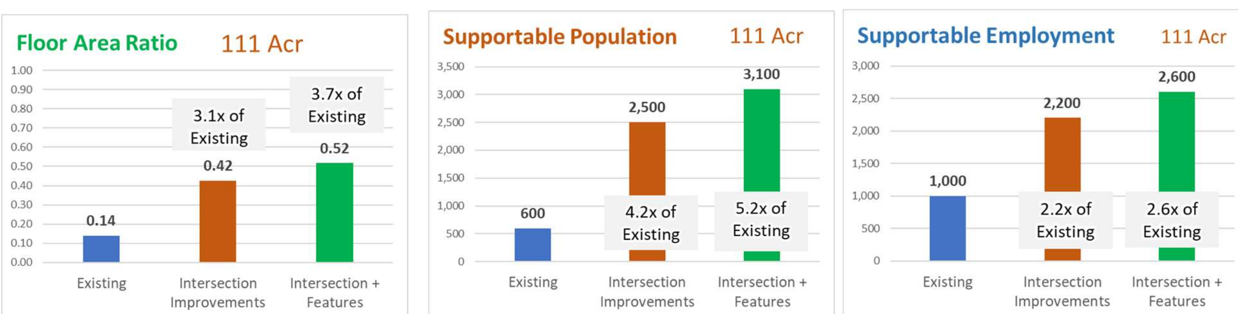


Figure 7-3 *Floor Area Ratio, along with associated Population and Employment, that can be supported.*

Please note this is a sketch planning tool which was applied with a limited budget for the task. Therefore, these claims could be off by a fair amount. Hopefully this is sufficient to demonstrate that it is possible to use PAIs, combined with other features, to create enough accessibility by many modes to support an impressive T4 or T5 urban Activity Center, without also causing a reduction in peak period travel times for drivers.

8. Focus Groups

8.1. Introduction

The team conducted two focus groups over Zoom on February 10th and February 13th, 2023. Participants were made up of professionals and activists who influence development outcomes. They were presented with 3D renderings and analysis of PAIs and other innovative supportive strategies, to get their feedback on the likelihood of these strategies being able to accomplish the goal of transitioning an auto-oriented suburban commercial area into a walkable mixed-use area.

Participant backgrounds included mixed-use developers, real estate appraisers and commercial agents, real estate market analysts, economists, safety/crash researchers, transit experts, transportation planners, land use planners, academic researchers with expertise in new urbanism and real estate, bike/pedestrian professionals (from both agencies and non-profit advocates), and local community representatives. Focus groups helped to obtain information about stakeholders' perceptions, attitudes, and knowledge about place-making strategies and their assessment on how the visual models of proposed intersection strategies might address needs and preferences in the selected partnering communities (aka. Town of Smithfield and City of Greenville, NC). The information gathered from these focus groups is useful for understanding how to retrofit Stroads so that they can attract impressive scales of walkable development. Questions the focus groups can help answer include: How should planning studies be structured for success? What obstacles will hinder the ability to retrofit an area for walkability? What educational efforts and types of materials will be most beneficial in NCDOT's future efforts?

8.2. Focus Group Instrument Development

The focus group discussion guide and questions were developed by the project team members in PowerPoint presentation format. A 34-item participant information questionnaire (pre-focus group) consisting of demographic, transportation, and real estate/development related questions was developed. The questions aimed to understand their general knowledge, attitude, and perceptions in the context of growing suburban communities. Questions focused on their understanding of the market's current and future housing preferences, roads and mobility, commercial corridors and parking, vehicular capacity and mixed-use development, and complete streets. This questionnaire was conducted using an online Qualtrics platform.

In addition to the questionnaire, combination of rating, Likert-scale, and open-ended questions were developed to guide focus group discussions. These questions were used as "live polls" using an online interactive tool (Slido), which is an excellent Q&A and polling platform for live and virtual meetings. The questions aimed to understand the perceptions and opinions about the key design elements included in the 3D-images of the proposed Placemaking Alternative Intersection Strategies demonstrating conceptual scenarios about their potential implementation in actual community settings chosen for this study. Participants provided their insights about parking, slow lanes, before/after scenarios of intersection types, as well as overall impressions on Stroads and complete streets.

After signing a participant consent form, background information was then presented by the project team and separate live polls were administered using the online Slido platform. The participants answered questions anonymously and also provided written and oral responses. The anonymous poll results were also visible to each participant as the responses were received.

8.3. Participants

8.3.1. Participant Recruitment

Participants were recruited by the project team through direct invitations sent to key stakeholders, experts, and agencies identified within and outside of North Carolina. Identified individuals were contacted and asked to participate or provide potential names with similar expertise who could serve as potential focus group participants, as shown in **Table 8-1**. In total, 41 individuals were identified and invited to participate in one of the focus group sessions, with 27 actually participating (15 in the first session, and 12 in the second). A minority of these participants were observers from NCDOT, Smithfield, and Greenville (meaning they did not answer questions nor participate in discussion). Participation in these focus groups was voluntary.

Table 8-1 *Participants and Their Expertise*

Date	Participant Expertise	Number	Focus Group Role
02/10/2023	Bike/Pedestrian Advocates	3	Expert/Private/Non-profit Sector
	Real Estate Appraiser	1	Expert/Private Sector
	Mixed-Use Development	1	Expert/Private Sector
	Real Estate Market Analysis	1	Expert/Private Sector
	Planning	1	Expert/Private Sector
	Transit	1	Expert/Public Sector
	Academic/New Urbanism	1	Expert/Public Sector
	Local Government Representative	4	Observer/Public
	Public Agency (NCDOT)	2	Observer/Public
	TOTAL	**15**	
02/13/2023	Planning	1	Expert/Private Sector
	Land use and Transportation	1	Expert/Private Sector
	Economy	1	Expert/Private Sector
	Real Estate and Architect	1	Expert/Private Sector
	Safety/Crash Research	2	Expert/Public Sector
	Transit	1	Expert/Public Sector
	Academic/Mixed Use Development	1	Expert/Public Sector
	Local Government Representative	3	Observer/Public
	Public Agency (NCDOT)	1	Observer/Public
	TOTAL	**12**	

The groups were arranged based on the availability of the participants, but each session aimed to accommodate diverse expertise backgrounds. Both focus groups lasted approximately 2 ½ hours. Each focus group discussion was facilitated over Zoom, which was recorded and later transcribed. Information collected via Qualtrics and Slido also provided descriptive analysis of the qualitative and quantitative data collected during focus group sessions.

8.3.2. Demographics

Noted earlier, 27 people participated in the focus groups. Of this, 4% had an associate degree, 39% had a bachelor's degree, 42% had a master's degree, and 15% a doctorate degree. The focus group participants ranged in age from 25 to 65 and older (**Table 8-2**). Locations where they live and work included North Carolina (Raleigh, Smithfield, Wilson, Chapel Hill, Greenville, Carrboro, Durham, Charlotte); Colorado, (Denver); Texas (Dallas); South Carolina (Greenville); Kansas (Wichita); New York (New York); and British Columbia (Delta).

Table 8-2 *Participants' Age*

Age Range	Percentage
18-24 years old	0
25-34 years old	11
35-44 years old	23
45-54 years old	31
55-64 years old	23
65and older	8
Prefer Not To Answer	4

8.3.3. Employment and Occupation

81% of the participants were employed in the public or private sector, 15% were self-employed, and 4% retired. The occupation and specialty of participants included:

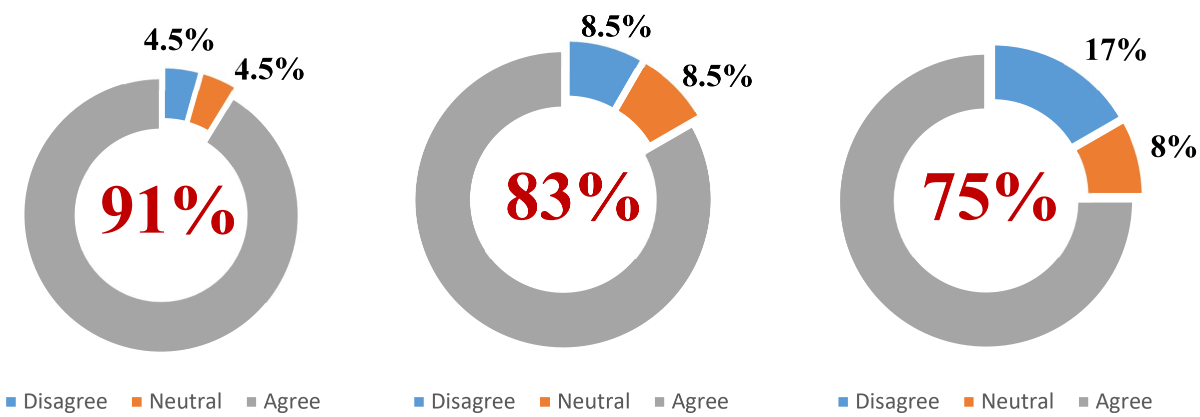
- Non-profit advocates for bike/pedestrians and road safety
- Traffic engineers
- Transportation planners and consultants
- City planners and land use experts
- University researchers with an emphasis on pedestrian safety, speed management, health, equity, and climate resilience in transportation
- City engineers
- Urban economist
- Developer, mixed-use and shopping centers
- University Professors with expertise in development, architecture, and urban design
- Urban designer with an expertise in mixed-use and infrastructure development
- Real-estate economics specialist in commercial revitalization
- Downtown development administration
- Transit planner and manager

8.4. Findings

8.4.1. Pre-Focus Group Questionnaire Results

The participants completed a pre-focus group questionnaire to understand the general knowledge, attitude, and perceptions related to topical areas of current and future housing preferences, roads and mobility, commercial corridors and parking, vehicular capacity and mixed-use development, and complete streets in the context of growing suburban communities. Note that while participants are experts in some aspects of mobility or development, they are not all experts relative to each question. Thus, responses may vary relative to those with true expertise relative to the question.

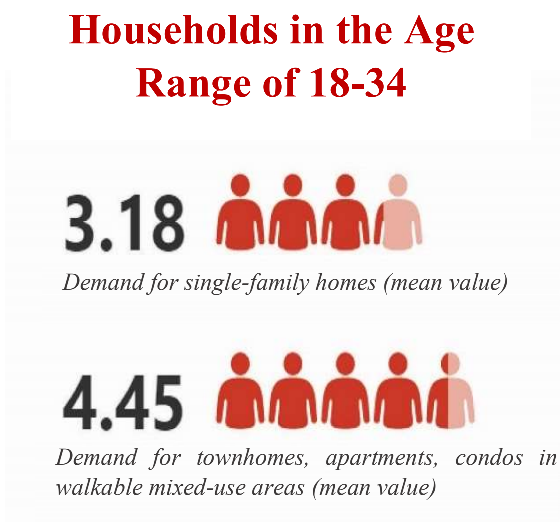
When participants were asked about their opinions of the ***current and future housing preferences in growing suburban and urban communities***, 91% of respondents agreed that the cost of housing is an increasing problem (**Figure** **7-1** A). The majority (83%) also agreed that more commercial areas will need to be rezoned to encourage creation of more affordable townhomes, apartments, and condos in walkable mixed-use areas (**Figure** **7-1** B). Most participants (75%) also indicated that there is strong demand for attractive high-density areas that nearby residents will welcome rather than oppose (**Figure** **7-1** C).

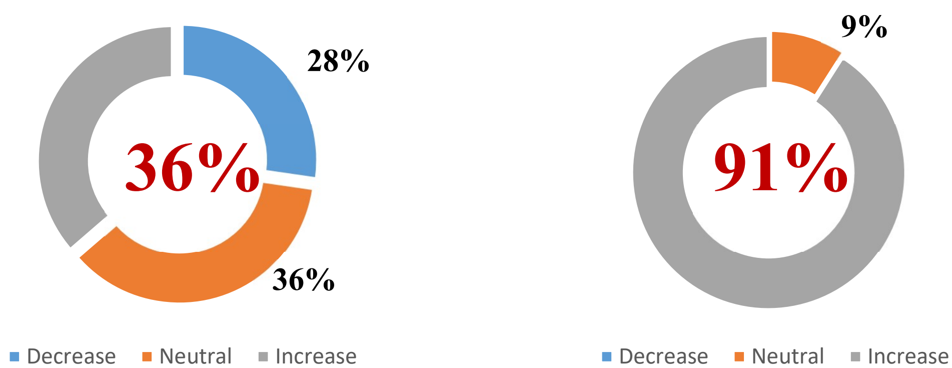


A B C

Figure 8-1 Housing preferences in growing suburban/urban communities.

For households **in the age range of 18-34 years of age**, 36% of participants believe that the ***demand for single-family homes separated from commercial areas*** will increase in the future. Another 36% of respondents believe this demand will stay the same as at present, and 28% think that demand for single family homes will decrease (potentially in favor of mixed-use environments) (**Figure 8-2** A). When asked specifically about future demand for townhomes, apartments, and condos located in walkable mixed-use areas (relative to today's demand), 91% of respondents were convinced the demand will increase, while 9% were neutral (**Figure 8-2** B).





A B

Figure 8-2 Demand for housing types among households in the age range of 18-34

In the near future, for households **in the age range of 35-54**, 61% of participants believe that the ***demand for single-family homes separated from commercial areas*** will increase in the future. 30% of respondents believe this demand will stay the same as at present, and 9% think that demand for single family homes will decrease for this age group, in favor of mixed-use environments (**Figure 8-3**A). When asked specifically about future demand for townhomes, apartments, and condos located in walkable mixed-use areas (relative to today's demand), 86% were convinced demand will increase, while 14% were neutral (**Figure 8-3** B).

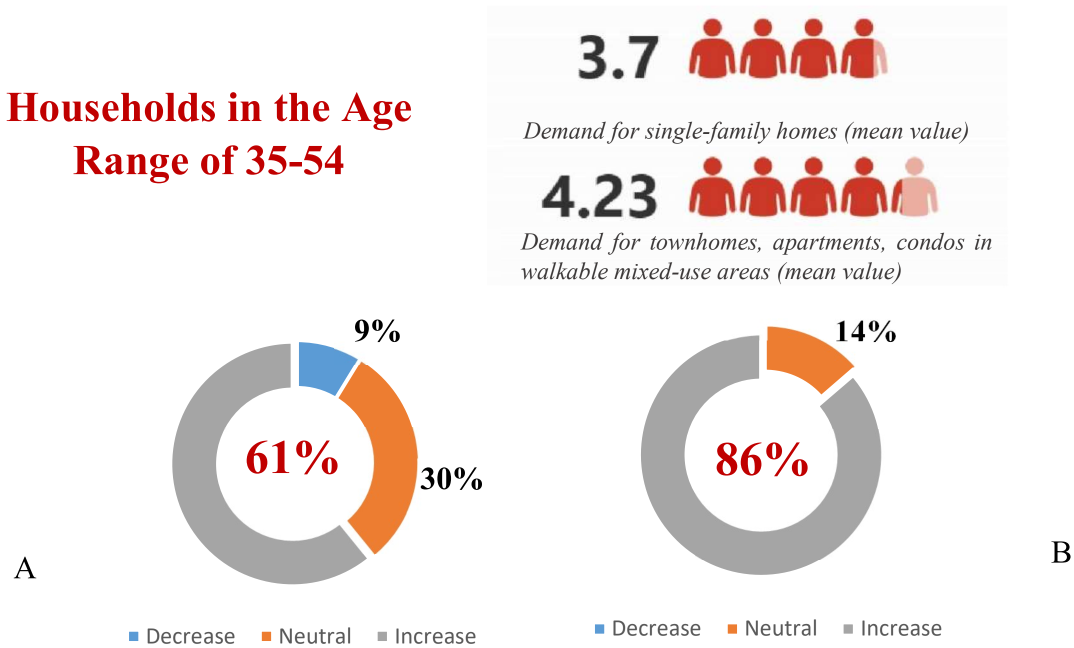


Figure 8-3 Demand for housing types among households in the age range of 35-54

In the near future, for households **in the age range of 55 and above**, 44% of participants believe that the ***demand for single-family homes separated from commercial areas*** will increase in the future, 17% of respondents believe this demand will stay the same as at present, and 39% think that demand for single family homes will decrease for this age group, in favor of mixed-use environments (**Figure** 7-4 A).

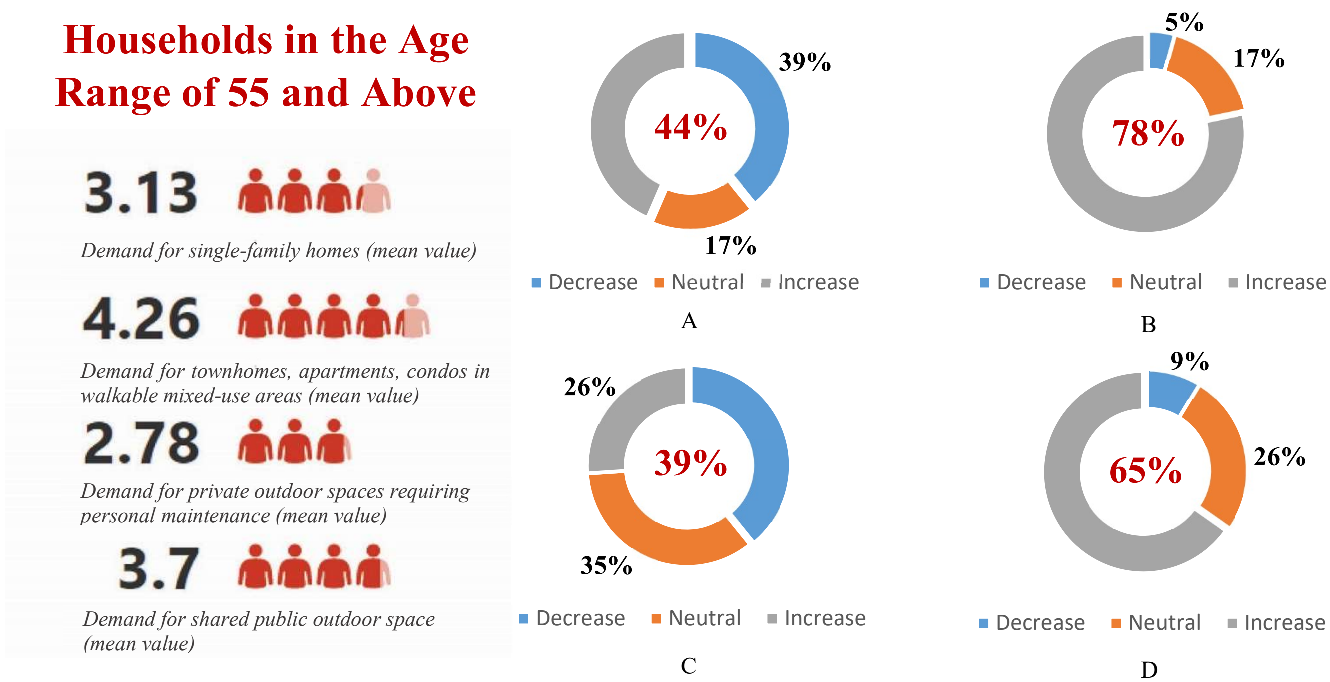


Figure 8-4 Demand for housing types among households in the age range of 55 and above

When asked specifically about future demand for townhomes, apartments, and condos located in walkable mixed-use areas (relative to today's demand), 78% were convinced demand will increase, while 17% were neutral, and 5% thought it would decrease (**Figure 7-4** B). Last, 39% believe that most households in this age range will not want private outdoor spaces that require personal responsibility for maintenance and 65% believe there will be strong demand for living in areas with shared outdoor spaces maintained professionally (**Figure 7-4** C and D).

When participants were asked about their opinions of the ***current and/or future transportation preferences in growing suburban and urban communities***, 96% of respondents agreed that demand for alternative modes of transportation in addition to driving will continue to increase substantially (**Figure 8-5** A). Not surprising, 83% consider typical suburban highways to be too fast, unsafe, and unappealing for walkable development to take root (**Figure 8-5** B). The majority of respondents (96%) agree that well-maintained street trees and streetscapes are critical for catalyzing walkability and livability in mixed-use areas (**Figure 8-5** C). Last, 88% also believe that reducing maximum traffic speeds is essential for catalyzing walkable areas (**Figure 8-5** D).

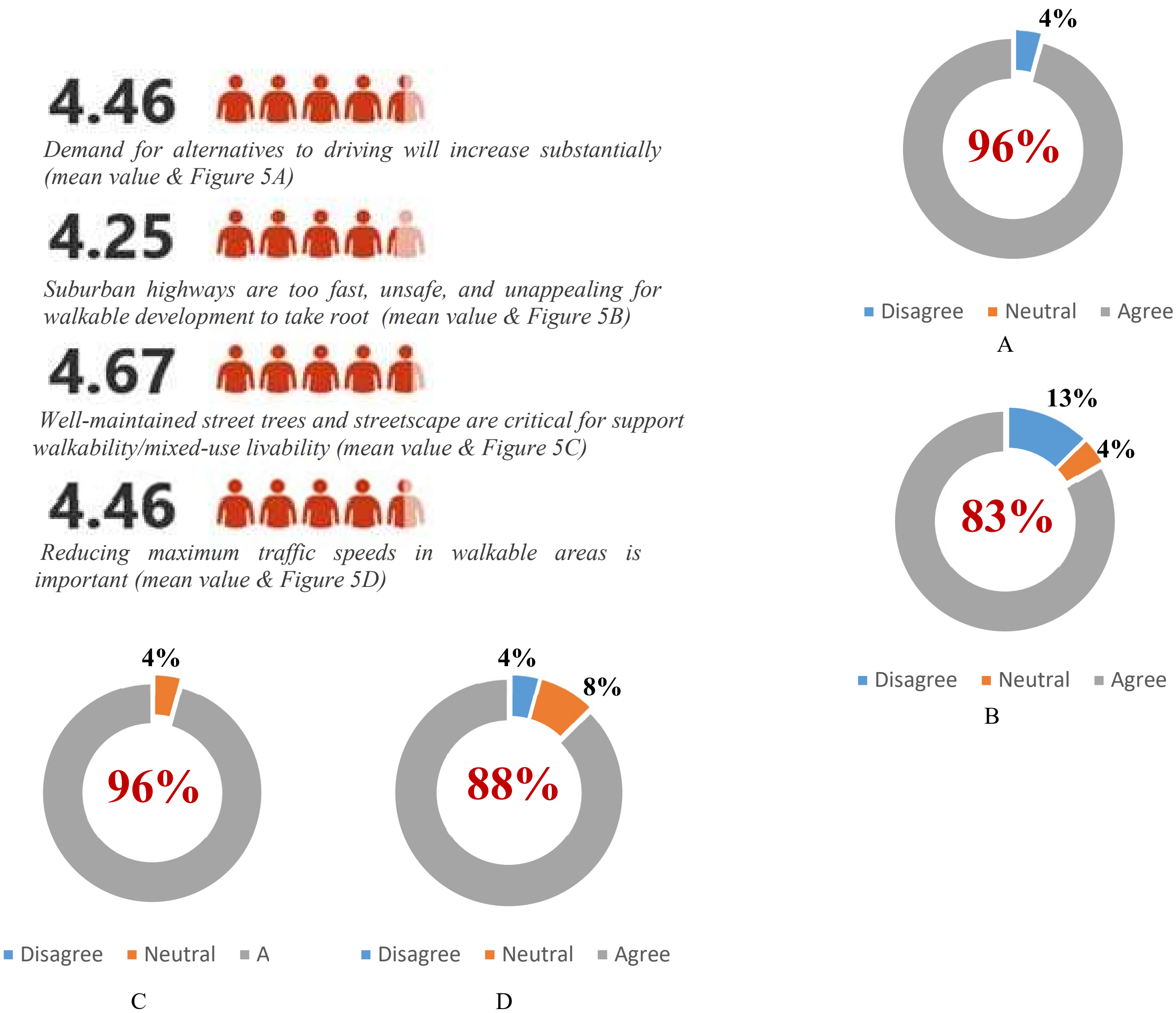


***Figure 8-5** Transportation preferences in growing suburban/urban communities*

Participants recognize that there are behavioral changes happening due to evolving e-commerce, remote/hybrid working, and other evolving business models, which are affecting the future of real estate in suburban and urban communities (**Figure 8-6**). The majority (46%) of respondents believe that existing commercial areas will not be affected much from changing commercial

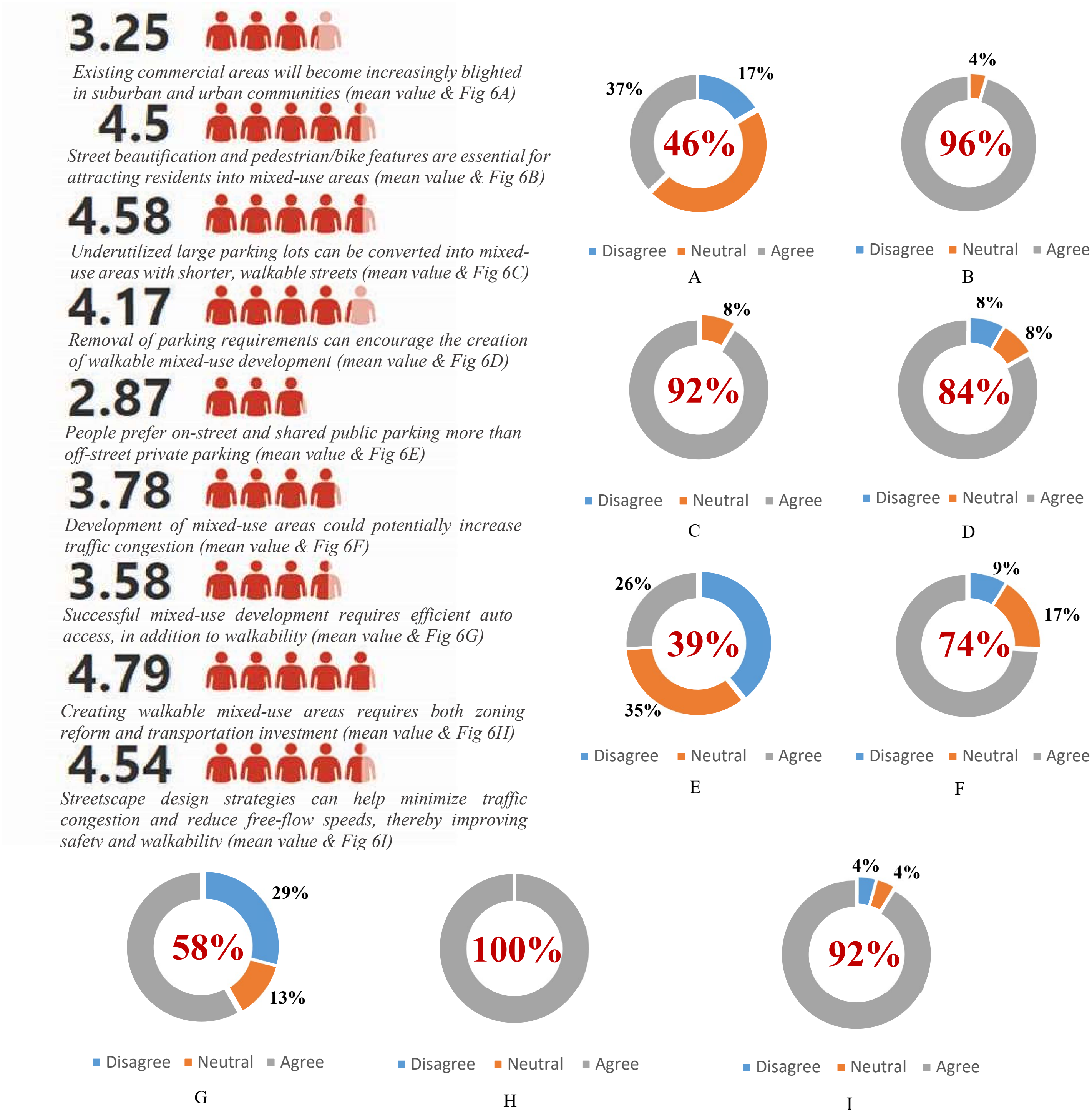


Figure 8-6 *Focus group opinions on parking in growing suburban communities.*

behaviors and trends; however, 37% believe that existing commercial areas will become increasingly blighted in suburban and urban communities (A). The overwhelming majority (96%) of respondents agree that beautification of streets and inclusion of pedestrian/bike features are essential for attracting residents into commercial-dominated areas (B). When asked about underutilized parking lots, 92% agree that these areas provide an opportunity to convert excess parking lots into mixed-use activity centers including commercial/retail, residential units, and walkable streets (C). When questioned further on parking, 84% believe that removal of minimum parking requirements can encourage the creation of walkable mixed-use development and streets (D).

However, 39% believe that off-street parking will still be preferred by consumers compared to on-street and shared public parking and 35% indicated no significant opinion on parking preferences (E). There is strong agreement among respondents (74%) that additional density could contribute to increased traffic congestion, despite higher usage of alternative modes (F). Further, 58% believe that successful mixed-use development requires efficient auto access, in addition to walkability, while 29% do not think uncongested auto-access is essential for mixed-use areas to grow (G). All participants (100%) agree that creating walkable mixed-use areas requires both zoning reform and transportation investment at the same time (H). Lastly, 92% agree that streetscape design strategies to reduce free-flow speeds are essential for improving safety and walkability (G).

Next, participants were asked about their opinions of city council acceptance of higher densification using mixed-use development. Respondents thought that city councils will be reluctant (38%) to permit additional mixed-use development in congested areas, while 33% believe city councils will approve development regardless of congestion. The majority (58%) also agree that developers will be interested in constructing additional mixed-use development in congested areas, as 25% think that they may be reluctant.

Participants were provided the following pictures in **Figure 8-7** of a Stroad and Complete Street and asked to select ***the top five benefits of converting "Stroads" into "Complete Streets" in growing suburban and urban communities.*** Twelve options were provided to choose from. Responses indicated that achieving multi-modal mobility in addition to driving, livability, safety, and overall quality of life, as well as catalyzing mixed-use development were listed, as shown in **Figure 8-7**.

However, the experts indicated that there are barriers that make it difficult to implement "Complete Streets" in growing suburban and urban communities (**Figure 8-8**). The top five barriers were: 1) opinion differences among stakeholders about priorities and needs in communities; 2) cost of constructing and maintaining complete streets; 3) resistance from traffic engineers and/or emergency services due to perceived challenges such streets may provide; 4) overall public opposition; and 5) organizational cultures particularly in local governments. Lack of expertise in designing, constructing, and maintaining such streets was also listed among challenges for implementing complete streets.

Stroad Example

Complete Street Example

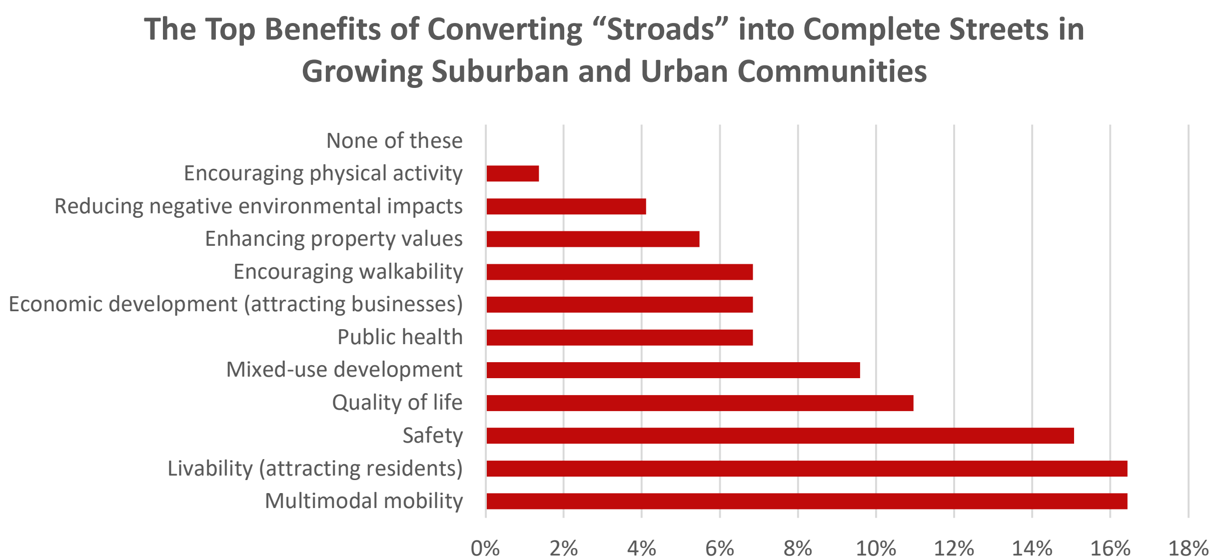


Figure 8-7 *Focus Groups: Top Benefits of Converting "Stroads" into Complete Streets*

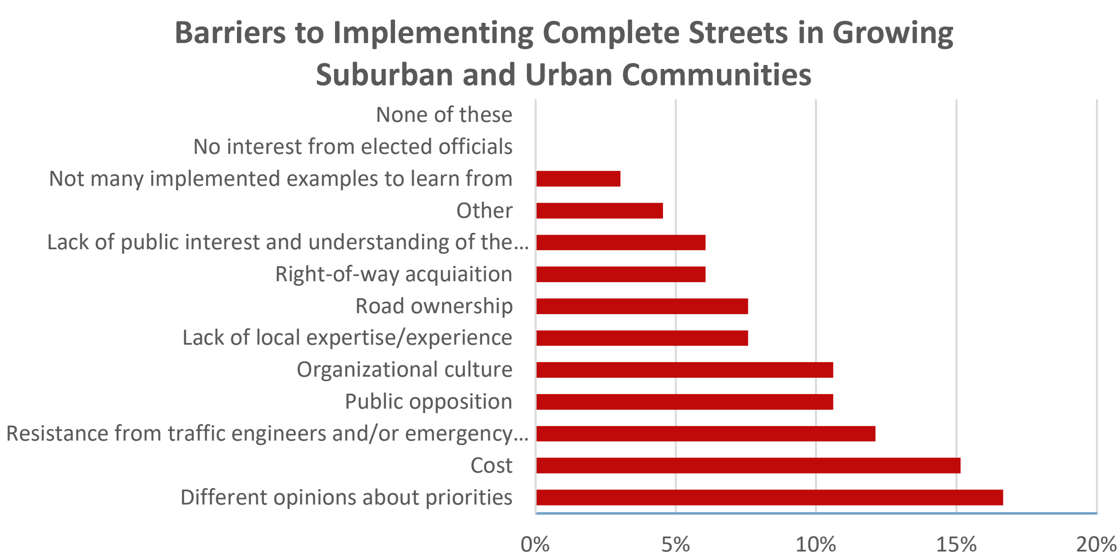


Figure 8-8 *Focus Groups: Barriers That Make It Difficult to Implement Complete Streets*

8.4.2. Focus Group Discussion Results

Slow Lanes

In the first focus group, 90% considered slow lanes to be an attractive feature of an aspiring mixed-use activity center. They saw value in accommodating golf-cart sized electric vehicles, particularly in the context of affordability challenges and rising numbers of elderly citizens in suburban communities. In the second focus group, 50% of the participants were neutral on whether this feature would be helpful in attracting mixed-use development, while 40% thought it would be attractive.

Figure 8-9 Before / After depicting "slow lanes" (teal color)

In the meantime, 70% of the first focus group agreed that designing for tiny, "neighborhood only" four-wheel electric vehicles could help reduce parking needs, which in turn can create more space for buildings in the long run. In the second group, 40% neutral and 40% agreed that they would be popular enough to reduce the amount of land consumed by parking substantially.

In the first focus group, 30% were neutral about bikes and golf-cart sized electric vehicles each sharing these slow lanes (where bikes would define the maximum speed). 50% said it would be "okay" or "definitely okay" to share a slow lane. The second focus group was more negative: 60% were not supportive or only moderately supportive. Only 40% thought that sharing would be okay for the biking community.

When the first focus group participants were asked to reflect on the idea of having standard vehicles also share the "slow lane" for parking access, 50% were not supportive and thought that this will not be okay with the biking community, even if there would be speed humps or some other assurance that the vehicles will not travel faster than "bike speed." 30% were neutral about this idea and only 25% were supportive. However, 80% of the second focus group participants were strongly not supportive of having standard vehicles sharing the slow lane with bikes even if it is for parking access.

The participants highlighted some further concerns, as well as opportunities to consider. The following are representative responses:

"The bottom slide shows a much denser streetscape, which screams for more types of safe mobility. However, as a person who often rides a bike, I am not excited about the many conflict points with parking. I prefer that the parking go in the back."

"Slow lanes need color concrete demarcation or tactile strip - you want to make sure that it's not unsafe for bicyclists."

"Don't allow too many things to use the slow lane - parking, cycling and car movements – There may need to be a dedicated bike track. Be careful not to do too much, because you've got parking, transit, cycling and automobiles all in the same place. Don't give up on this idea though because it may be the best thing in certain circumstances."

Some also raised concern on management of speeds in the slow lane making sure that *"the fast large vehicles will be kept out of the slow lane".* Some also considered it to be an *"interesting concept" further suggesting that "there are several technical issues that would need to be resolved (as much as possible): (1) how to clearly delineate the spaces with significant speed differential; (2) how to legally designate speed limits; (3) and deal with the many conflict points between angle parking and thru lanes; the continuous median would probably push more trips on side street network."*

One participant also commented on the scale of mixed use that may be triggered by Complete Streets. "*It seems possible that single story commercial could transition to 3-4-story mixed-used buildings for two or three blocks. But the rest of the corridor is still going to be more single-use commercial in nature.* Some also saw the opportunities for slow lanes to provide *"a space for autonomous micro transit options in the future."*

***It is important to note** that these focus groups included a large number of bicycle advocates, and they were generally very negative about mixing bikes with golf-cart-sized vehicles and with standard vehicles accessing adjacent parking. They were more positive about golf-cart-sized vehicles, provided they "act like bikes" in terms of speed. However, it will require further conversations with bicycle advocating the pros and cons of a slow lane with adjacent parking, in the way that was presented in scenarios.*

Parking

In the first focus group, 45% agreed that converting private parking between the road and existing buildings to on-street parking will help catalyze walkable development, with 27% neutral and the other 27% thought it would be difficult to achieve. In the second focus group, 67% were in complete agreement that this would be good, while 22% were neutral and 11% disagreed.

Focus groups were asked if they thought property owners could be convinced to donate their outermost private parking into public parking, on the promise that it would still be a similar amount of parking, would relieve them of maintenance, and it would help elevate the value of their property. In the first group, 64% did not believe that most property owners could be easily convinced to donate the right-of-way, even if the overall amount of parking is similar and if it proves necessary for the success of a desired complete streets. In the second group, 55% believed that most property owners will be unwilling to make such a donation without compensation.

However, it is important to note that focus groups response to this question may indicate that they either did not fully comprehend the potential benefits to property owners, or they may believe it will be challenging to educate property owners in a way that will motivate them to consider the conversion of auto-oriented private parking into pedestrian-oriented on-street parking.

Figure 8-10 *A Business Improvement District could help fund maintenance of trees and other features.*

Next, focus groups were asked to comment on the following statement: "Do you believe that most property owners could be convinced to pay into a business improvement district (BID) for trees and other streetscape, if a market analysis suggest the increase in property value and business receipts will exceed the cost of maintenance fees." In the first group, 63% thought it may be very difficult to convince businesses to pay into a BID even with a strong case that their benefits would likely exceed their costs. However, the second focus group thought the opposite: 66% believe that the property owners probably would contribute to a BID if they saw a compelling case that benefits would exceed costs, and 22% were neutral.

When discussing parking, participants highlighted some concerns, as well as opportunities to consider in terms of safety, traffic movement, and placement of parking on/off streets. The following are representative responses:

"Your street section here is so wide, and you've got cars pulling in and out of it to park. It's almost like that parking wants to go behind the buildings and just be removed all together from the street." Another participant was also concerned that "*Diagonal parking creates more congestion than it would solve…There is a lot of diagonal parking in these situations shown. Unless you're really in a slow setting, like below 20 miles per hour kind of setting, this would really tend to create congestion as opposed to solving it. I'm not a big fan of diagonal parking."*

One participant raised concerns with bike conflict points in association with parking on street, suggesting a dedicated bus/bike lane instead of a slow lane and on-street parking. *"I would prefer that the lane near the curb be a bus and bike lane."*

Some also raised concern about how parking off-site may impact economic activity already happening on existing sites. "*In the top image there is a lot of economic activity going on. It's just* *not walkable. Hopefully, it's improving economic activity as demonstrated below because people want to go there."*

One participant also stated that developers will not easily give up parking on site without a strong case for doing so. They indicated that retail wants cars and traffic volume. "*On giving up space…Developers will not give up space and donate a row of parking. I strongly believe that won't happen. To give up this kind of space is like giving up basically dollars out of their pocket. And most of them aren't down with complete streets unless they can really see things from an economic perspective. They're looking at this on the retail side. Traffic, and particularly automotive traffic, is considered good for them. They want people to get to their place with a car. This is still in their mindset. Metered parking has been shown on the academic side, to be a good thing for retail, because it spins people out. However, most business owners see that we need free parking because it allows people to come to downtown or shopping areas. They don't see the turnover. So even something as simple as that is hard for them to grasp on a regular scale."*

Overall feedback received about parking *may suggest that "extreme makeover" conversions, which include converting private to public parking, will be challenging in areas where auto-oriented businesses are doing well. Such efforts will likely be much easier in struggling locations.*

Stroad versus Complete Streets

Figure 8-11 *Typical Stroad*

The majority responded that they are familiar with "Stroads" such as this, as they drive on them occasionally or frequently.

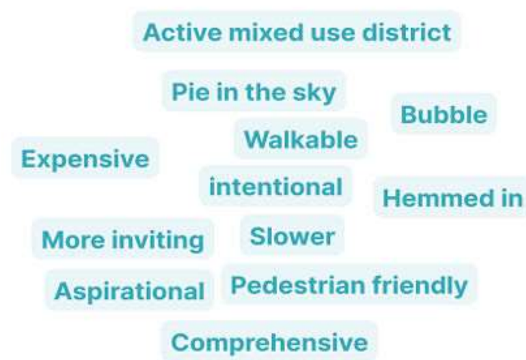
When participants were asked to describe **Figure 8-11** representing a typical suburban "Stroad," the most common word from the first focus group was "*unsafe*." Others said "dangerous, unwelcoming, car-oriented, dated, etc."

The most common phrases from the second group were "*fast, hostile*, and *auto centric*." Some also said "bland, unwalkable, risky, etc."

Figure 8-12 Stroad converted into Complete Street

When participants were asked to describe **Figure 8-11**, converting a Stroad into a Complete Street, first focus group said things like "*friendly, inviting, green, destination, attractive, vibrant, etc*." However, some also said negative things such as *"inefficient space use, conflicts, and river of asphalt."*

The second focus group described this scenario as "*walkable, active mixed-use district, comprehensive, slower, inviting, aspirational, etc*." Some also said negative things such as *"bubble, pie in the sky, expensive to implement."*



Participants said Stroads become worse over time "*by congestion as traffic increases to reach newer developments further out*." They also indicated that unless Stroads change, there will be "*gradual disinvestment, continued vehicular-pedestrian fatalities and injuries, and continued car-dependency.*" "*Car dependency will continue, impacting health and accessibility for neighborhoods.*" "*Noise pollution and traffic will exacerbate, causing a deterioration in quality of life.*" Another participant expressed that "*Financially infeasible maintenance will lead to gradual degradation.*" One participant pointed out that "*there will be decay and devaluation of property values. There will be increasing numbers of people moving to these locations with few options for affordable housing. Transit will follow as a necessity but will not be able to provide good safe access."* However, some also cautioned that *"it will all depend greatly on the overall demand in particular areas. Design alone will not drive growth"* but overall *"Human scale development will struggle.*"

The majority agreed that a Stroad is cheaper per mile, but more expensive per capita, because there are too few taxpayers to help support it. Participants were asked "If properties are rezoned to encourage mixed-use residential, but Stroads remain largely unchanged, how will the market react?" Many stated that "*The market may be slow to react unless the roadway is improved, or plans must at least be in place towards investing in its improvement in the near future.*" Additionally, some indicated that "*High-growth regions will see redevelopment and those redevelopments will be hampered by existing zoning regulations (hefty setbacks, excessive parking requirements), etc.*" A few of the participants also mentioned that *"It depends on the location. This is not one size fits all.*" "*They will continue to build because land is cheap and undeveloped land is cheaper.*" And "*This stroad would simply draw motorized traffic from other parts of the network and serve a through function.*" Some also cautioned that "*You won't get the mixed use you desire because the market won't reject the auto-centricity.*"

The majority responded "yes" when asked, "Will the Complete Street result in slower vehicular traffic?" Many stated that "*Complete Streets will spur walkable mixed-use development*" and "*This will attract large numbers of retiring seniors for when they cannot or should not drive*". Some agreed that if the new Complete Street traverses a wealthy area, it could introduce affordable housing in a way the adjacent neighborhoods can accept, however, some also disagreed with this statement. Many also agreed that if the new street traverses a blighted and struggling area, it could be a means of stabilizing the area.

Finally, when participants were asked "Assuming an ideal location where the market definitely would respond, what could prevent this transition from happening?" the top responses included: "*Traffic engineers will not agree to it*." "*NIMBY: The devil you know is better than the devil you don't." "Business and property owners will demand compensation.*" "*Failure to explain pros and cons well enough.*" "*Too difficult to raise enough money.*" They also indicated that in order to have buy-in from developers and give up space for parking, there needs to be some sort of bonus allocation for height, density, or other elements. This can help with their profitability in their parcel design or project design. But most thought that this comes down to the local level and local zoning decisions that must be made in a case-by-case basis.

8.4.3. Alternative Intersection Types

a) Quadrant Intersections

When the first focus group was asked to rate the Quadrant Intersection depicted in **Figure 8-13** as in terms of **safety**, 57% considered it as "safe" for pedestrians, drivers, and cyclists. 29% were neutral, and only 14% thought they are unsafe. 44% of the second focus group thought Quadrants provide safe conditions and 33% were neutral. 22% thought Quadrants were somewhat unsafe.

Figure 8-13 *Before / After Quadrant Intersection*

When asked about **walkability**, 43% of the first group considered Quadrants walkable. 43% were neutral. 14% considered it not walkable. The second focus group was more divided. 44% considered it walkable, but 44% also considered it not particularly walkable.

In terms of **traffic flow**, 72% of the first focus group understood easily why Quadrants were efficient, while 14% were neutral about it. 44% of the second group considered Quadrant Intersections to be efficient, and another 44% were neutral about it.

When thinking about **comfort and convenience**, 43% of the first group agreed with this for pedestrians, drivers, and cyclists. Another 43% were neutral about it. In the second focus group 56% were neutral about Quadrants.

When thinking about **improved connectivity**, 43% in the first group agreed, while 29% expressed that they don't achieve connectivity that well. 29% were neutral. In the second group, 44% were neutral and 33% thought that Quadrants do not provide adequate connections to surroundings. However, some of the participants cautioned that there is need for a robust connecting street network for Quadrants to work. Establishing a well-connected side street network is essential rather than providing connectivity for the frontage streets only. Both parallel streets and short crossroads should be connected.

In terms of accessibility, the Quadrants were also considered to provide equitable access to uses in the area. The majority of both focus group sessions also considered Quadrant Intersections to provide an appealing look and sense of place.

They indicated that *"You've got to look at the street network as well. You can't just go ask somebody to give up right-of-way and compensate them for it, unless the public, the policymakers, the county commissions, or the Council Members are also convinced that there's going to be a systemic fiscal benefit."* In addition, it was expressed that "*Quadrant intersections, will require* *systemic understanding of the fiscal implications, both from the private sector and the tax base and the policymakers."* Some also considered that the Quadrants may take away some public space.

Some of the participants thought that the purpose of the Quadrants is to "*remove the left turn out of an intersection, so there's less delay at that intersection. Therefore, you can have higher volume traffic and potentially move people through at a more consistent pace."* They also cautioned that *"if the quadrant intersections are being built and provide the opportunity for rezoning for the areas around it, these could be really valuable lands opening up opportunities for mixed use development. But you would have to be very careful as new development comes in to make sure that you are prioritizing pedestrians, slowing people down at that intersection, as you make sure that there you have slow turning movements. I would be really focused on the future development of being a walkable and safe corridor or intersection."*

b) U-Turn Intersections

Figure 8-14 *Before (top) / After (bottom) views of Placemaking U-Turns*

Focus groups were shown images in **Figure 8-14** and **Figure 8-15**, and provided explanations of how the designs work along with pros and cons as understood by the research team. When the first focus group was asked to rate the proposed U-turn Intersection design in terms of **safety**, 38% expected it to be safer than before for drivers, cyclists, and pedestrians. 50% were neutral, and 12% thought it might be less safe.

Figure 8-15 Before / After showing intersection windmill U-Turns

In the second group, 66% expected it to be safer than before for drivers, cyclists, and pedestrians. 34% were neutral, and no one thought it might be less safe.

Some cautioned that the two-stage crossing (i.e., pedestrian refuge in the middle) could result in less pedestrian compliance, because many may feel safe enough to jaywalk.

When asked about **walkability**, 50% in the first group were neutral, while 25% considered it more walkable and 25% thought it was less walkable. There was a more equal distribution among responses in the second group where more walkable, neutral, and less walkable each got 33%.

In both sessions, most agreed that this system would have a **traffic calming** effect, but also would be less congested due to the 2-phase signals. They agreed this type of intersection can provide **comfortable conditions** for pedestrians, cyclists, and drivers. In terms of **connectivity** the majority thought U-Turns would provide good connectivity and access to surroundings. Most also considered these intersections would provide an appealing look and support the **sense of place**.

c) One-Way Split Intersections

Figure 8-16 Before (top) / After (bottom) views of Placemaking One-Way Split Intersections

Focus groups were shown images in **Figure 8-16** and **Figure 8-17**, and provided explanations of how the designs work along with pros and cons as understood by the research team. When both focus groups were asked to rate the proposed One-Way Intersection design in terms of **safety**, 60% considered the after condition much safer, while 20% were neutral and another 20% thought it might be less safe. Regarding **walkability**, 60% considered the after condition much better. These intersections were also perceived as neither comfortable nor uncomfortable in terms of providing convenience for car drivers, bike riders, and pedestrians.

In terms of **connectivity** the majority believe One-Way Splits <u>will</u> provide good connections and access to surroundings. They also considered these intersections to provide an appealing look and support the **sense of place** of the areas that they are part of.

Figure 8-17 *More before / after views of one-ways*

One participant highlighted some concerns on slow lanes and bike/pedestrian safety related to the One-Way Splits. "*The slow lanes in this scheme give me a little bit of concern for safety and travel time as a transit planner, which is my background. Put transit and everything else into slow lanes while we're moving traffic through the downtown area in the 2 lanes. I see buses being stopped, and then bikers starting out into those lanes. And then there is parking on the other side. I don't know if it's the best solution."* The participants also expressed that we need to consider "what is it that psychologically causes drivers to be slower while passing through these types of zones. They cautioned that three lanes, in addition to a slow lane, can create some real problems. They suggested we "design" for the desired speed, and not just accept the "posted speed".

8.5. Focus Group Summary

The focus groups presented an opportunity to understand the ways community stakeholders and various types of experts' view PAIs and design strategies. Although these groups were not representative of all stakeholder types, the opinions obtained provide a foundation for the development of future tools that may lead to better acceptance of proposed innovative intersection strategies among broader stakeholders. The information obtained in the focus groups is critical to the development of further conversations and potential implementations by providing insight into those concepts that are not well understood. More importantly, it gives an awareness of the issues related to mobility, transportation, as well as land use and development in rapidly growing suburban communities.

Overall, these focus groups were well received by the participants. Many participants indicated their appreciation of having the opportunity to learn more about the proposed PAIs and design strategies. They also were glad to vocalize their opinions on this subject. A few people said that they would like to stay engaged and help out in any aspect of this initiative. During the focus group discussions, many participants stated that they liked the focus group format as an effective way to learn and interact with others. The participants also said they liked the focus group format and the use of interactive tools, such as Slido, because it requires their involvement and enable everyone to join conversations in oral or anonymous polling format.

These findings indicate that there is a willingness by various expertise groups and our community partners to become involved in this initiative. This enthusiasm should be embraced, and active participation by wider community stakeholders should be encouraged. The community's involvement is critical to the success of this initiative for positive impact. More importantly, they can provide insight on the perceived barriers that keep communities from having innovative placemaking and intersection solutions being implemented.

9. Summary of Research Findings

9.1. Summary of Research Efforts

The Problem of Stroads and the Need for Placemaking: This report first offers an overview of the problems that are often associated with auto-oriented development. It describes land use "Transects" and how the design of arterials and local networks influences land use. It defines an increasingly common term "Stroad" as a street/road hybrid. "Streets" are slow and people-friendly (e.g., "Main Street"), while roads are fast with minimal side-friction. Stroads try to do both but do neither very well. Many Stroads clearly play a role in the ensuing blight that reduces land values and activity density over time.

Demonstration of Placemaking Alternative Intersections: With a clear understanding of the problems to be solved, the report then offers an overview of the three "Placemaking Alternative Intersection" families (PAIs). A key aspect of this effort was to generate graphics depicting how these designs could be adapted for use in walkable environments. For this task, we elected to utilize real-world locations that could benefit from these ideas. We found dozens of sites across the state with impressive potential and settled on sites in Greenville and Smithfield for graphical renderings and further analysis. We contacted each community and gained their permission to serve as "guinea pigs" for our ideas, with a caveat that our ideas would not be vetted through any public process as part of this research effort. They would get "free ideas" that they could vet later if they found them promising. In trade, NCDOT would have their permission to use the resulting graphics and analysis for other communities that are hoping to create walkable mixed-use environments.

Additional Strategies, and the Development Scale Calculator: In developing concepts for each site, we quickly realized that while PAIs offer an excellent foundation for Placemaking, there are many other factors such as block size, alternative mode features, parking policies, form-based zoning, stakeholder sentiment, level of blight, and market absorption rate to consider when attempting to determine the extent to which a site is a good candidate for a Placemaking investment strategy. Thus, a section of this report expounds on these supporting topics. We also created a "Development Scale Calculator" to help determine the economic development potential of the overall investment strategy. The report concludes with graphics of each study area, along with appendices highlighting the location of graphics, animations, presentations, and other resources developed for the effort.

Win-Win for Everyone: In terms of traffic operations, this research found that alternative intersection designs outperform the conventional design in the following four aspects: 1) alternative designs reduce average travel time, which makes for happy drivers; 2) alternative designs increase roadway capacity, which leads to happy local transportation management authorities; 3) alternative designs can accommodate more development, which creates happy local businesses and land developers; and, last but not least, 4) alternative designs create safer and more accessible facilities for bicyclists and pedestrians when used correctly, which is better for everyone.

9.2. How to Determine Good Locations for Placemaking Alternative Intersections

Since the concept of Placemaking Alternative Intersections is new, it will be critical for NCDOT's first applications to be successful. If the first few locations are not ideal, the public may be skeptical of implementing them later at places where they would be very ideal.

1. **Opportunity for Placemaking Alternative Intersections**: In an ICE-style review of the area, what kinds of designs appear reasonably possible to achieve? Can PAI's score be higher than other options, especially when factoring in community objectives?
2. **Community Excitement**: Is this a community that is actively inviting NCDOT to help them foster a placemaking environment? Has the community considered actions such as eliminating minimum parking requirements, and allowing form-based mixed-use zoning?
3. **Market Studies**: If you build it, what will the market do? Will it offset enough greenfield infrastructure and reduce overall VMT and congestion enough to make it worthwhile?
4. **Equity**: Economically depressed neighborhoods are often more willing to "try anything," where well-off areas are more likely to subscribe to "if it isn't broken, don't fix it." While depressed areas may be willing, they also often do not know how to get involved, or they lack clout when they do get involved. Spend extra time looking for opportunities in these locations, and consider elevating the ranking in underprivileged areas, all else being equal.

9.3. Website with Research Summaries and Before/After Sliders

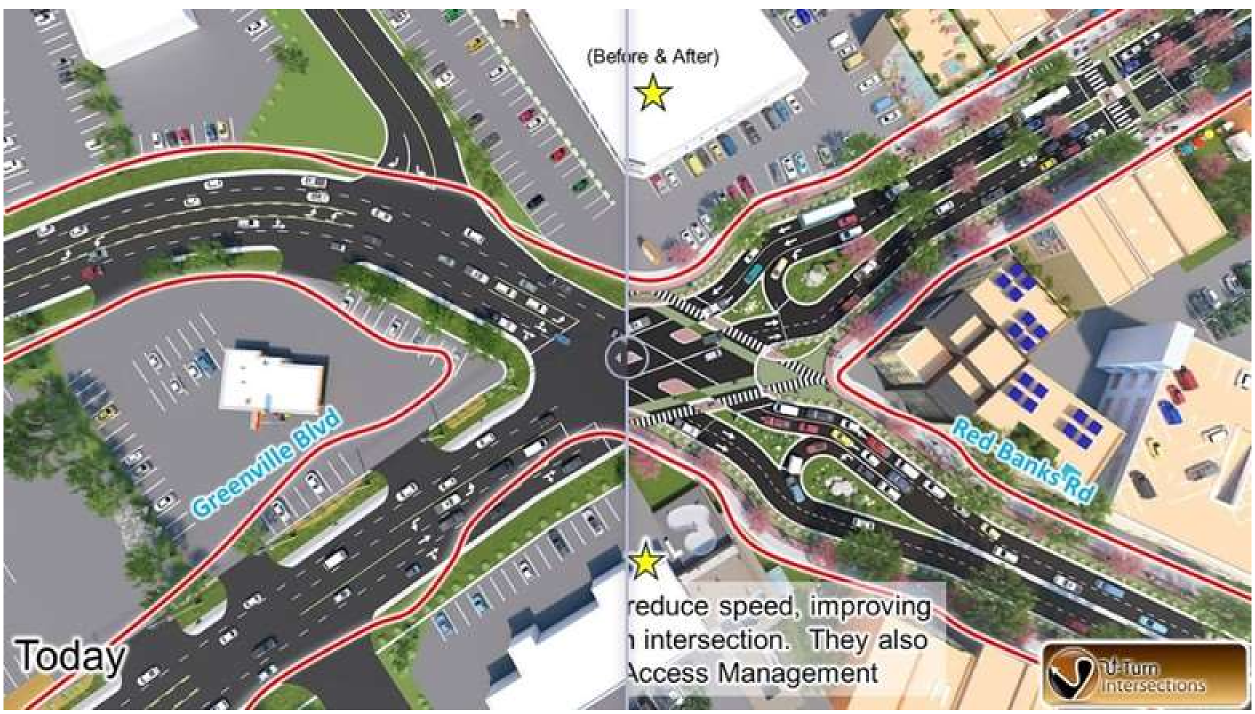


Figure 9-1 Example of before/after sliders, courtesy of Urban Innovators.

Go to urbaninnovators.com/pr-ncdot-ai-research, or UrbanInnovators.com and find "Projects."

10.Future Research and Implementation Needs

Based on our focus groups, expert consensus is that the ideas presented herein are highly likely to catalyze walkable mixed-use development within the suburbs. If accurate, this could be among the greatest “bang for buck” topics for positively influencing climate change, equity, safety, and household affordability. Agencies are increasingly being asked to “do more with less,” which in this case can mean reducing the overall cost of infrastructure per capita.

While it is likely that the concepts presented herein will be expensive on a per-mile basis, they could easily reduce costs on a per-capita basis. In truth, that is the better measure of affordability – more expensive per mile, but far fewer miles needed due to higher supportable density.

Here are a series of research objectives and implementation strategies that can help move these designs toward mass adoption.

10.1. Research Need: Probable Costs and Return on Investment

In this research effort, the team was tasked to create graphical renderings depicting how Alternative Intersections can be adapted for walkable urban environments, and to determine other features that may be necessary to help catalyze such environments. Consider a “Phase 2” element exploring how much it would likely cost to create such environments and evaluate the extent to which the designs will offer overall cost savings relative to more typical options.

For example, it is easy to present a small-area placemaking infrastructure package to an engineering design team and secure a planning-level estimate of the likely cost for creating that environment. But to evaluate the return on that investment (ROI) requires also determining the development capacity and absorption rate that would be unleashed by the design. Thus, this task would include real estate market studies to identify a likely rate of absorption. Knowing the rate of absorption helps reveal the rate at which lower-density greenfield development is NOT occurring, (since each residential unit in a walkable environment represents a unit and associated infrastructure that was not built in a more auto-oriented environment).

At a certain year, the additional cost of off-site sprawl-related infrastructure will surpass the initial savings associated with on-site bare-bones designs. Any continued on-site absorption thereafter will contribute to net cost savings, or per-capita cost savings, for the region.

Unlike Phase 1, where generic design concepts can be applied to any location (and were applied to sites in Greenville and Smithfield), market absorption rates are *all about* “location, location, location.” This means the team would need to select locations with a “high probability” of creating an impressive ROI, then evaluate those locations to confirm the probable range of the ROI. This will help reveal the “fiscal wisdom” of applying designs broadly across the state: If ROI is extremely high, then many locations will be likely to create a very good ROI. If ROI is relatively small or even negative, then the research might not be justified from a long-term cost-savings perspective. It would have to then be justified from other measures such as equity, safety, community building, etc.

10.2. Research Need: Potential for Value Capture & Public-Private Partnerships

This research need focuses on how to catalyze walkable development using PAIs. "Catalyze" fundamentally means, "Creating conditions where there is significant probability that developers will create walkable development because of the profit potential." Thus, profit potential means there could be opportunities for innovative financing through value-capture mechanisms. This task could explore how to construct value capture mechanisms, how much money could be raised, and if there are opportunities for public-private partnerships to break through obstacles. This is done is some states such as Georgia where improvements are made on roads through incremental tax funding and even straight capital investments with nearby businesses for upgrades.

10.3. Implementation: Webinars, Workshops, Seminars

The factor that most hinders valuable research from implementation is the lack of awareness of the research and its benefits. NCDOT should consider sponsoring knowledge dissemination efforts for MPOs, Cities, Consultants, NCDOT Staff, etc. via topic-specific webinars, and at industry gatherings such as NCSITE, NCAMPO, etc. Maybe even open these NC-based webinars to a national audience. Workshops would first describe the general ideas and show how they have been applied at Greenville and Smithfield. Then participants could select sites in their own jurisdiction and attempt to create sketch applications – a mini-ICE evaluation. Participants could critique each other's sites to see if they spot more opportunities, and the research team could do the same.

10.4. Implementation: Modified Prioritization Criteria

NCDOT's "SPOT" funding formula program is reportedly among the best in the nation. However, the process currently emphasizes congestion relief, safety, and a few other factors above community building. They also do not account for indirect, long-term benefits of higher density mixed-use development such as public health, reduced sprawl, and associated cost savings. The research team recommends an effort to revisit project prioritization formulas so that additional performance metrics can be accounted for. Such a revisit could include a significant number of interviews and focus groups to discover what stakeholders like about the current program and where they think there is room for improvement.

10.5. Implementation: Planning Studies in Greenville

Last year, the research team applied for a grant from the National Science Foundation to conduct a 12-month effort aimed at engaging stakeholders in Greenville for a deeper-dive evaluation of the options presented herein to see if they could win support. While our "Stage 1" proposal was awarded $50,000 as 1-of-50 to compete for 1-of-20 $1-million grants, our "Stage 2" proposal was not selected. Nevertheless, Greenville was and still is excited to explore these ideas as potential solutions at the sites we identified, or at other sites such as near the ECU Medical Center. Consider working with Greenville to advance these ideas there through grants with partners such as FHWA.

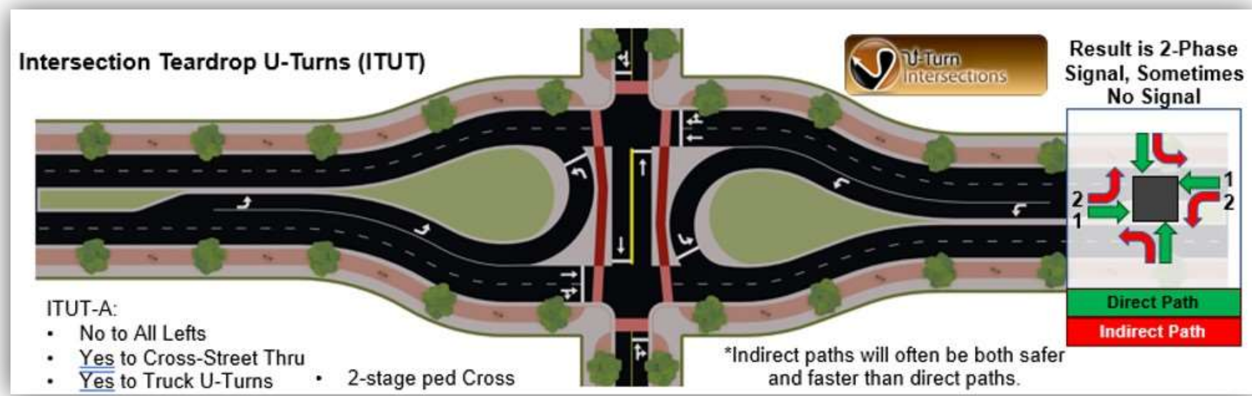
10.6. Implementation: Incorporate into RFPs for Planning Efforts

NCDOT should consider coordinating with their own planning staff, and with MPOs and cities, to modify how RFPs for corridor studies and small area studies are issued. Studies and transportation master plans that involve communities seeking to create walkable development should specifically explore options presented in this research.

10.7. Implementation: Convert Development Scale Tool into a Webapp

The Excel tool predicts how much development an area can support before key intersections become overloaded. This is a powerful feature, but cumbersome and obscure in Excel. A Webapp will make it easy to use and accessible across the state and the country.

10.8. Implementation: Additions to Top-View Library



The research team developed a wide range of variants for Quadrants, U-Turns, and One-Ways in the style shown above. This is meant to give planners, traffic engineers, and designers ideas they may not have thought of before. The library at present does not include Continuous Flow Intersections, Continuous Green-T's, and a few other designs, focusing on how to help these fit into a more urban context. This effort would intentionally exclude freeway interchanges, as there are plenty of design examples for these. This will help NCDOT have a more comprehensive library of options to help demonstrate how all designs can be more compatible with walkability than they historically have been.

10.9. Thank You, NCDOT and Others!

The NCSU, ITRE, and Urban Innovators Team enjoyed advancing this important effort. Thank you to those at NCDOT, Greenville, Smithfield, and focus group members who helped create an excellent outcome for this effort.

11.References

Abbiasov, Timur, et. al. The 15-Minute City Quantified Using Mobility Data, *National Bureau of Economic Research*, December 2022

Anderson, G., Searfoss, L., Cox, A., Schilling, E., Seskin, S., & Zimmerman, C. Safer streets, stronger economies: Complete streets project outcomes from across the United State. *ITE Journal*, 85(6), 2015, 29–36.

Babalik-Sutcliffe, E. Urban form and sustainable transport: Lessons from the Ankara case. *International Journal of Sustainable Transportation*, 7(5), 2013, pp.416–430. https://doi.org/10.1080/15568318.2012.676152

Blackburn, L., Dunn, M., Martinson, R., et al. Improving Intersections for Pedestrians and Bicyclists Informational Guide. Report No. FHWA-SA-22-017, Washington, D.C., 2022.

Boone, J.L. and J.E. Hummer, "Unconventional Design and Operation Strategies for Over-Saturated Major Suburban Arterials," FHWA/NC-94/009, Final Report, North Carolina Department of Transportation, Raleigh, April 1995.

Buehler, R., & Pucher, J. Demand for public transport in Germany and the USA: An analysis of rider characteristics. *Transport Reviews*, 32(5), 2012, pp.541–567. https://doi.org/10.1080/01441647.2012.707695

Center for American Progress, Combatting Effects of Gentrification and Lack of Affordable Housing, https://www.americanprogress.org/article/localized-anti-displacement-policies/, 2022

Dehghanmongabadi A., Hoşkara, S. An integrated framework for planning successful complete streets: Determinative variables and main steps, *International Journal of Sustainable Transportation*, 2020, DOI: 10.1080/15568318.2020.1858373

Duany, Andres, Elizabeth Plater-Zyberk, Jeff Speck. Suburban Nation: The Rise of Sprawl and the Decline of the American Dream. North Point Press. 2000, Pp.430

Duncan, C., Brown, M., Stein, N., et al. A. *Right-Sizing Transportation Investments: A Guidebook for Planning and Programming*. NCHRP Research Report 917, National Cooperative Highway Research Program, Transportation Research Board, Washington, D.C., 2019.

Ewing, Reid; Guang Tian, et. al., Traffic generated by mixed-use developments—A follow-up 31-region study; *Transportation Research Part D: Transport and Environment,* Volume 78, January, 2020

Fitzpatrick, K., Wooldridge, M.D., Blaschke, J.D. *Urban Intersection Design Guide: Volume 1 – Guidelines*. Report No. FHWA/TX-05/0-4365-P2 Vol.1, Texas Department of Transportation, Austin, TX, 2005.

Gossling, S. Urban transport transitions: Copenhagen, City of Cyclists. *Journal of Transport Geography*, 33, 2013, pp.196–206. https://doi. org/10.1016/j.jtrangeo.2013.10.013

Hickman, R., Hall, P., & Banister, D. Planning more for sustainable mobility. *Journal of Transport Geography*, 33, 2013, pp.210–219. https://doi.org/10.1016/j.jtrangeo.2013.07.004

Hughes, W., Jagannathan, R., Sengupta, D., Humman, J. *Alternative Intersections/Interchanges: Informational Report (AIIR)*. Report No. FHWA-HRT-09-060, U.S. Department of Transportation, Washington, D.C., 2010.

Hummer, J. E. Unconventional Left-Turn Alternatives for Urban and Suburban Arterials, Part 1. *ITE Journal*, Vol. 68, No. 9, 1998a, pp. 26–29.

Hummer, J. E. Unconventional Left-Turn Alternatives for Urban and Suburban Arterials, Part 2. *ITE Journal*, Vol. 68, No. 9, 1998b, pp. 101–106.

Hummer, J.E., Reid, J.D. *Unconventional Left-Turn Alternatives for Urban and Suburban Arterials: An Update*. TRB Circular E-C019: Urban Street Symposium, 2000, pp.1-17.

Hummer, J., B. Ray, A. Daleiden, P. Jenior, and J. Knudsen. Restricted Crossing U-Turn Informational Guide. Publication No. FHWA-SA-14-070, Federal Highway Administration, Washington, D.C., 2014.

MacLeod, K. E., Sanders, R. L., Griffin, A., Cooper, J. F., & Ragland, D. R. Latent analysis of complete streets and traffic safety along an urban corridor. *Journal of Transport & Health*, 8, 2018, pp.15–29. https://doi.org/10.1016/j.jth.2017.05.001

Prillwitz, J., & Barr, S. Moving towards sustainability? Mobility styles, attitudes and individual travel behaviour. *Journal of Transport Geography*, 19(6), 2011, pp.1590–1600. https://doi.org/10.1016/j.jtrangeo.2011. 06.011

Reid, J.D., and Hummer, J.E. Analyzing System Travel Time in Arterial Corridors with Unconventional Designs Using Microscopic Simulation. *Transportation Research Record*, No. 1678, 1999, pp. 208-215.

Reid, J.D. Using Quadrant Roadways to Improve Arterial Intersection Operations. *ITE Journal*, Vol.70(6), 2000, pp.34-36, 43-45.

Reid, J.D., Hummer, J.E. Travel Time Comparisons Between Seven Unconventional Arterial Intersection Designs. *Transportation Research Record*, No.1751, 2001, pp.56-66.

Reid, J., L. Sutherland, B. Ray, A. Daleiden, P. Jenior, and J. Knudsen. Median U-Turn Informational Guide. Publication No. FHWA-SA-14-069, Federal Highway Administration, Washington, D.C., 2014.

Reid, J.D., Hummer, J. Quadrant Roadway Intersection Informational Guide. Publication No. FHWA-SA-19-029, Federal Highway Administration, Washington, D.C., 2019.

Rodegerdts, L. Bansen, J., Tiesler, C., et al. Roundabouts: An Informational Guide Second Edition. NCHRP Report 672, Transportation Research Board, Washington, D.C., 2010.

Rutkowski, M. & Hemme, D. Designing Complete Streets for Towns and Suburbs, Not Just for Big Cities. 2021. Retrieved from https://www.stantec.com/en/ideas/topic/mobility/designing-complete-streets-for-towns-and-suburbs-not-just-for-big-cities

Seskin, S., & Gordon-Koven, L. (2013). The best complete streets policies of 2012. https://www.smartgrowthamerica.org/app/legacy/documents/ cs-2012-policy-analysis.pdf

Shin, B.Y. Special Provisions for Left Turns at Signalized Intersections to Increase Capacity and Safety. *Journal of Advanced Transportation*, Vol.31(1), 1997, pp.95-109.

Shumaker, M.L., Hummer, J.E., Huntsinger, L.F. Barriers to implementation of unconventional intersection designs: A survey of transportation professionals. *Public Works Management and Policy*, Vol.18(3), 2012, pp.244-262.

Smith, S., https://nextcity.org/urbanist-news/gentrification-solutions-affordable-housing-ideas, 2014

Steyn, H., Z. Bugg, B. Ray, A. Daleiden, P. Jenior, and J. Knudsen. Displaced Left Turn Intersection Informational Guide. Publication No. FHWA-SA-14-068, Federal Highway Administration, Washington, D.C., 2014.

Stephens, A.N., Beanland, V., Candappa, N., et al. A driving simulator evaluation of potential speed reductions using two innovative designs for signalised urban intersections. *Accident Analysis and Prevention*, Vol.98, 2017, pp.25-36.

Strong Towns. https://www.strongtowns.org/ (Accessed: June 15, 2023)

Steg, L. Sustainable transportation: A psychological perspective. IATSS Research, 31(2), 2007, pp.58–66. https://doi.org/10.1016/S0386- 1112(14)60223-5

Urban3, *Cost of Service Analysis*, https://www.urbanthree.com/services/cost-of-service-analysis/

Vandegrift, D., & Zanoni, N. An economic analysis of complete streets policies. *Landscape and Urban Planning*, 171, 2018, pp.88–97. https:// doi.org/10.1016/j.landurbplan.2017.11.004

VDOT. *Innovative Intersections and Interchanges*. Virginia Department of Transportation, 2023. Available: https://www.virginiadot.org/innovativeintersections/

Yu, C.-Y., Xu, M., Towne, S. D., & Iman, S. Assessing the economic benefits and resilience of complete streets in Orlando, FL: A natural experimental design approach. *Journal of Transport & Health*, 8, 2018, pp.169–178. https://doi.org/10.1016/j.jth. 2017.11.005

Zavestoski, S., & Agyeman, J. Incomplete Streets. London, 2015.

Appendix A, PowerPoint and Key Graphics

This is the primary appendix associated with this project. Most of the graphics created for this effort will be found here.

Name: "NCDOT_PAI_research_BestSlides_Pt1_Rationale.pptx"

- The above file has a large number of slides that can be used to help demonstrate the rationale for Placemaking Alternative Intersections.

Name: "NCDOT_PAI_research_BestSlides_Pt2_Renders.pptx"

- The above file contains 3d renderings of the Placemaking Alternative Intersection concepts created for this effort. There are many before / after depictions.

Below are other supporting files and directories.

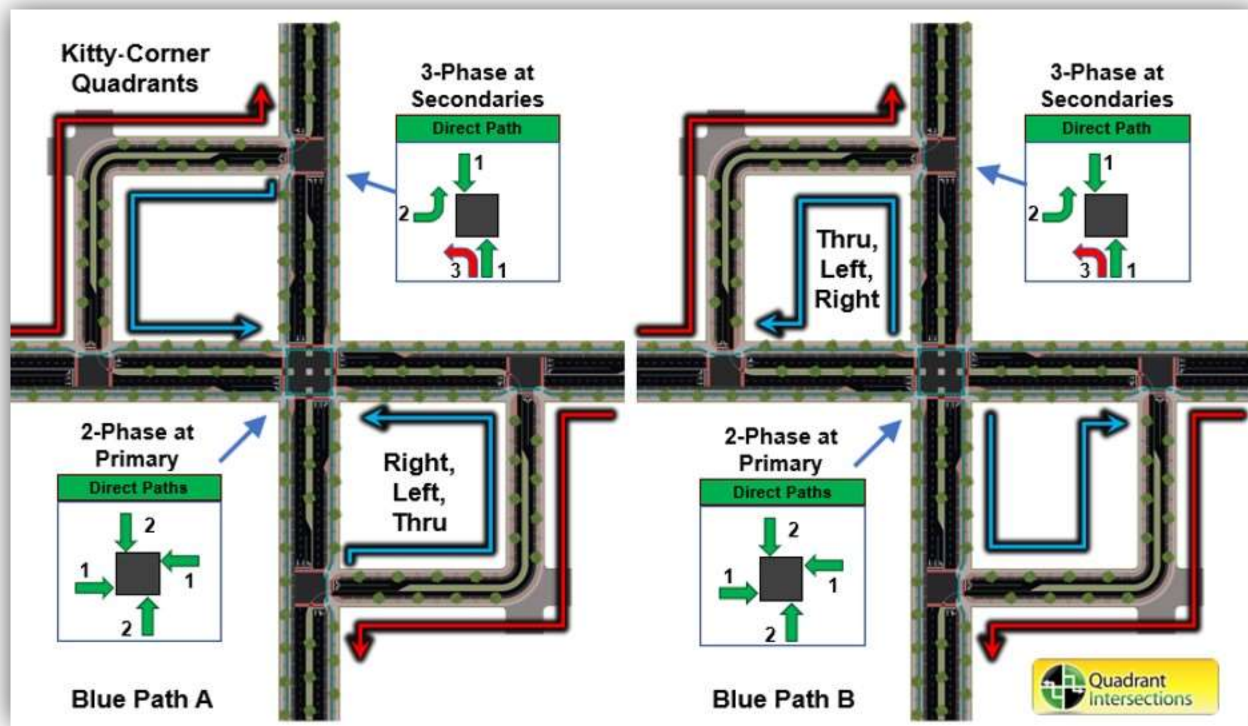
- Name: "NCDOT_PAI_research_NCAMPO.pptx" (prepared for NCAMPO conference)
- Name: "Cross-Sections, Greenville.pptx"
- Name: "Cross-Sections, Smithfield.pptx"
- Name: "Cross-Sections, Bowties and Teardrops.pptx"
- Directory: "BestGraphicsFromPowerPoints" (Many jpg files that are usually screen captures of slides in the PowerPoint presentations).
- Directory: "Animations" (Contains .mp4 files depicting fly-through animations of a few designs).

Appendix B: Top-View Drawings of Placemaking Alternative Intersections

Source file is a landscape view PowerPoint file, converted to pdf, containing graphics of the style below.

- Name: "NCDOT, PAI, Diagrams_TopView.pptx"
- Name: "NCDOT, PAI, Diagrams_TopView.pdf"
- Directory PNG: Images with transparent backgrounds which can be used in Google Earth to create "Lego Set" sketch planning ideas.

Example from PowerPoint / PDF



Example application of .png images.

Appendix C: Potential Locations Across North Carolina

This appendix contains mainly stick-figure concept sketches derived from Google Earth, showing a few of the locations we discovered through a quick overview of potential locations for more in-depth research. The team ultimately settled on sites in Greenville and Smithfield, but these were also candidate sites.

Source file is a Word doc tech memo from Urban Innovators, converted to pdf.

- Name: "NCDOT, PAI, Quadrant and One-Way Potential Locations.docx"
- Name: "NCDOT, PAI, Quadrant and One-Way Potential Locations.pdf"

Appendix D: Addressing Negativity Toward One-Way Streets

Source file is a Word doc technical memorandum from Urban Innovators, converted to pdf.

- Name: "NCDOT, PAI, Addressing Negativity Toward One-Way Streets.docx"
- Name: "NCDOT, PAI, Addressing Negativity Toward One-Way Streets.pdf"

Appendix E: Development Scale Calculator

This tool exists in an Excel Spreadsheet. Guidance for how to use the tool is in a Word doc, in the same directory as the spreadsheet. This how-to guidance is not repeated as an appendix in this final report.

- Tool: "NCDOT Development Scale Calculator, V1.5, Oct2023.xlsm"
- Tool: "Greenville_NewBern_SqFt_WaffleChart_Analysis.xlsx"
- How To: "NCDOT Development Scale Calculator, V1.5, Instructions.docx"
- How To: "NCDOT Development Scale Calculator, V1.5, Instructions.pdf"

Appendix F: Focus Group Slides

Focus group slides are provided for reference.

- "Focus Group Invitation.pdf"
- "Innovative_Interesection_FocusGroup_2-10-23.pdf

Appendix G: Traffic Simulation Tools

The tools exist in TransModeler and Synchro files:

- Synchro drawing for existing conditions: “Synchro Drawing_Smithfield.pptx”, “Synchro Drawing_Greenville.pptx”
- Synchro model: “Synchro Model_Existing”
- Synchro model: “Synchro Model_Proposed”
- TransModeler model: “Greenville QR_Baseline”
- TransModeler model: “Greenville QR_Proposed”
- TransModeler model: “Greenville Oneway_Baseline”
- TransModeler model: “Greenville Oneway_Proposed”
- TransModeler model: “Greenville Bowtie_Baseline”
- TransModeler model: “Greenville Bowtie_Proposed”