Urban Applications of Innovative Intersection Designs

Sponsored by North Carolina Department of Transportation (NCDOT)

1. Executive Summary

Problem: How to convert auto-oriented corridors into safe, walkable "Places"?
In North Carolina and across the United States, communities are increasingly frustrated with the deterioration of their auto-oriented suburban commercial areas. Both housing and transportation have become unaffordable. Elderly citizens who can no longer drive safely are increasing in number. People are anxious to foster walkable mixed-use environments at urban-level densities where they can get more exercise, and their lives will be more affordable.

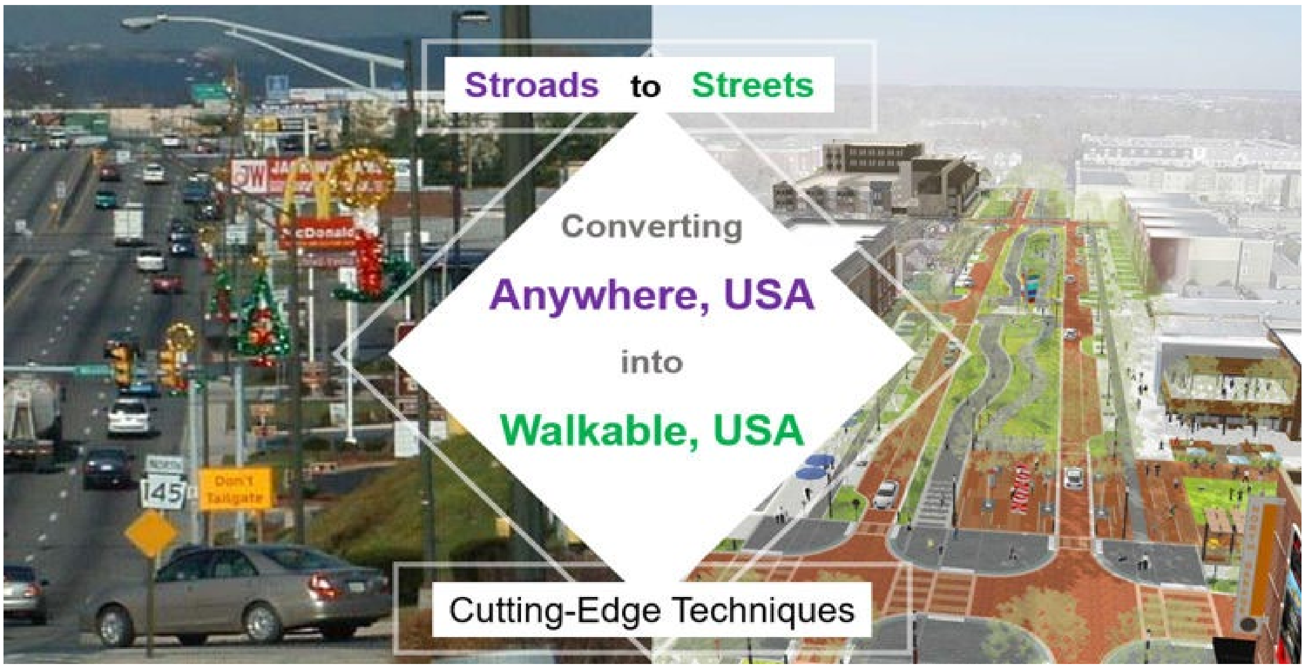


Figure 1 Converting auto-oriented corridors into walkable boulevards is a nationwide challenge.

However, such commercial areas often have 5-7-lane arterials with 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 high volumes of long-distance traffic, while at the same time creating conditions that can help communities achieve their walkable development goals.

Research Team: NCDOT recognizes the need for managing high volumes of traffic in urban-friendly ways, so they sponsored this research effort to develop graphics and insights regarding how "Placemaking Alternative Intersections" can help. North Carolina State University served as the lead research entity. Chris Cunningham from NCSU's Institute for Transportation Research and Education (ITRE) served as the lead Principal Investigator. Co-PIs were Celen Pasalar from NCSU's department of urban design, and Mike Brown of Urban Innovators. These were all supported by many excellent assistants, primarily Guangchuan Yang, Yanhua Lu, and Brijesh Kukadiya.

“Stroads” define the suburbs, but “Complete Streets” are increasingly desired.

Suburban commercial highways are increasingly referred to as “Stroads” – a street/road hybrid. *(Strong Towns, 2023).* A “street” is a walkable corridor where residents and businesses interact (i.e., “Main Street”). A “road” is for vehicles moving quickly from Origin to Destination at speeds of 40 mph or higher. Communities want walkability, but engineers lack the tools for delivering both impressive walkability and adequate mobility at the same time, even if given ample funding and a mandate.

Figure 2 *Streets, Roads, and "Stroads": The Futon of Transportation*

This research gives both engineers and planners the tools they need to shake hands, instead of always wrestling for the upper hand!

Figure 3 *If we can’t find effective ways to satisfy engineers, placemaking is likely to lose!*

Placemaking Alternative Intersections (PAIs)

Figure 4 compares a four-phase signal to each of the placemaking intersections, which all have just three or two phases. 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 like a circuit breaker: when too many "switches" are turned on, the overload trips the breaker, creating "Level of Service F". The placemaking designs studied in this effort each handle lefts in alternative ways. The result reduces the number of phases at a single intersection, which increases overall green time for everyone.

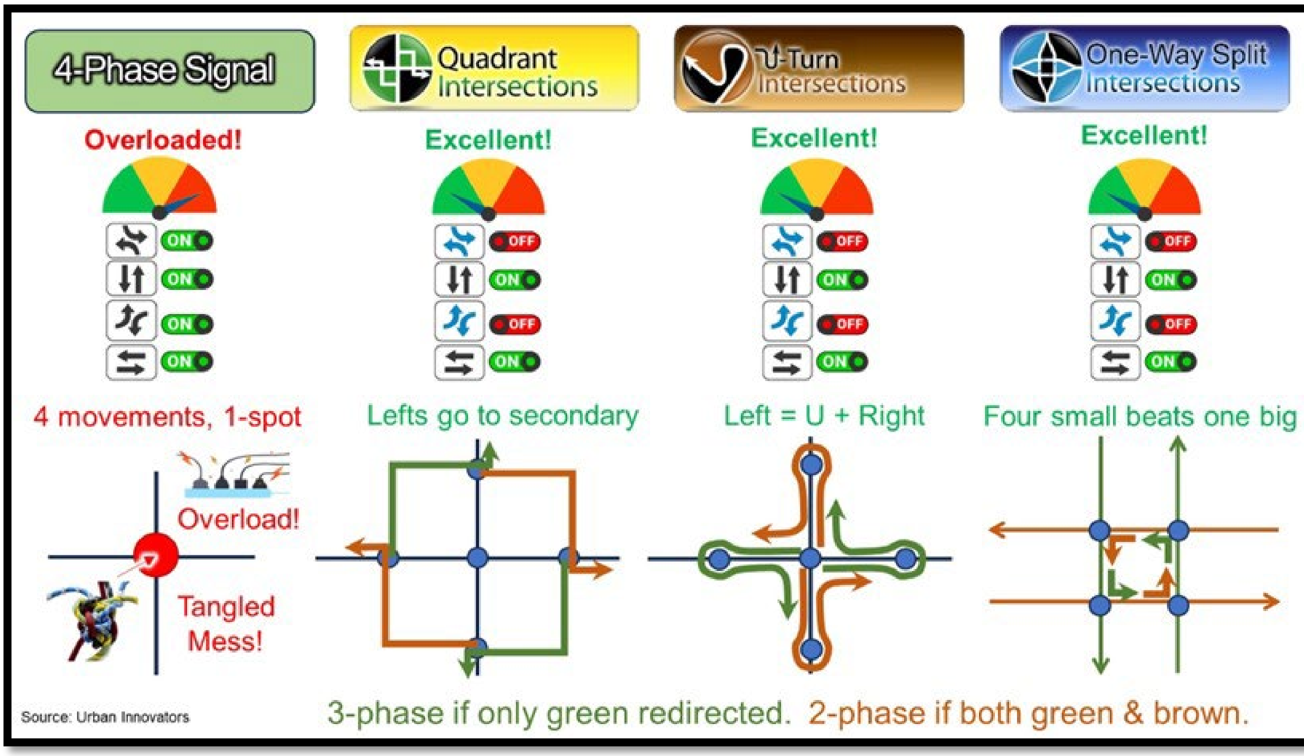
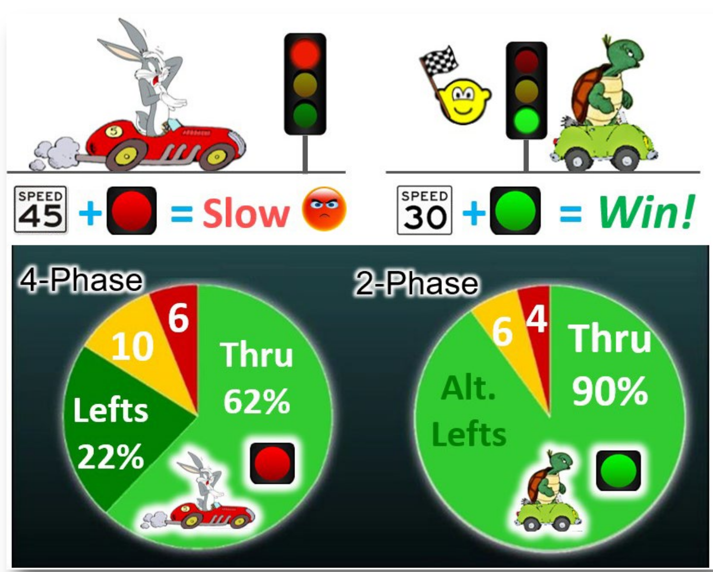


Figure 4 Four-phase signals tie traffic in knots. The others untangle the mess and create great "Places."

Drive Slow… Travel Fast!



With more green time, it is easy to introduce traffic calming and safer speed limits without making drive times any longer – key to political viability! It's just like the tortoise and hare – "fast" is rather slow if you must stop a lot.

With pedestrian-compatible speeds, more connectivity, and many other pedestrian-oriented features that these designs facilitate, it becomes possible to transition auto-oriented commercial areas into walkable mixed-use!

Opening a New Frontier: Improvements for Traffic AND Walkability

The blue curve illustrates how today's "Stroads" often serve traffic perhaps as a 5 on a scale of 1 to 10. These tend to 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 before traffic performance suffers significantly.

This research demonstrates how Placemaking Alternative Intersections make it possible to reach the green curve, where both traffic and walkability experts can shake hands instead of wrestling.

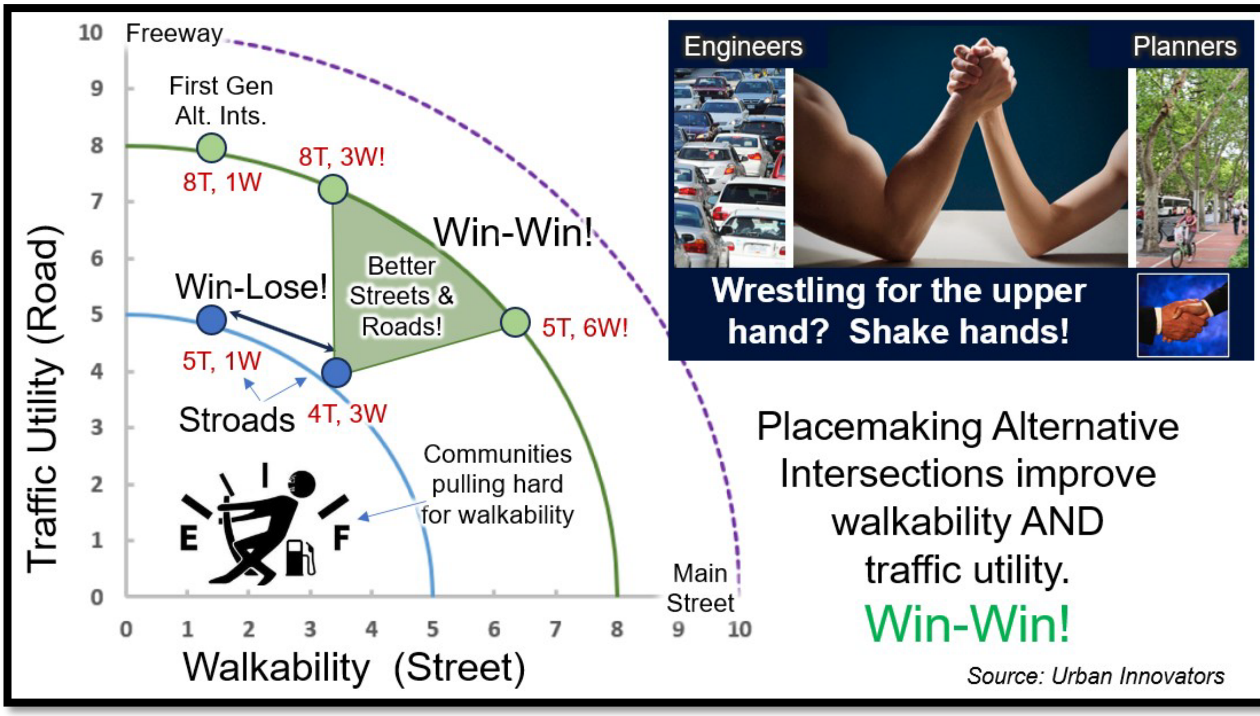


Figure 5 PAIs open a new frontier of Win-Win for both traffic and walkability.

Why Does It Matters? Our cities tend to be fiscally "in the red," meaning that on a lifecycle basis, we have more infrastructure than we can afford to maintain. **Figure 6** features analysis from Strong Towns and Urban3, where higher-density mixed-use areas generally contribute more to the tax base than they cost to maintain (blue), while lower-density development consumes more than they contribute (red). Their research has found that most American suburbs have a lot more red than blue, meaning that cities are finding it increasingly difficult to "just fill potholes."

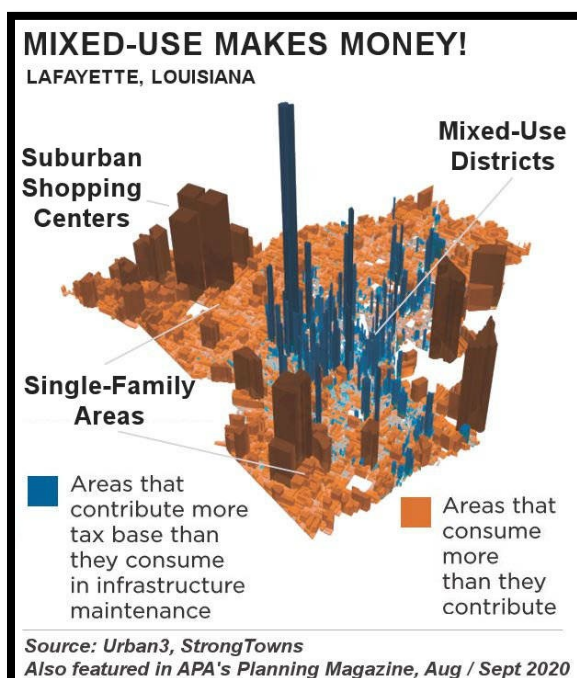


Figure 6 Low-income, high-density areas often subsidize lower density, wealthier areas.

Stuck in Third Gear (T3)

Suburban areas need stable or increasing value, or they risk decaying. The "transect" below shows how once an area is fully suburban (T3), it often wants to start creating pockets of T4 and T5 urbanism to stay economically vibrant and to have affordable, walkable "Places" for nearby residents.

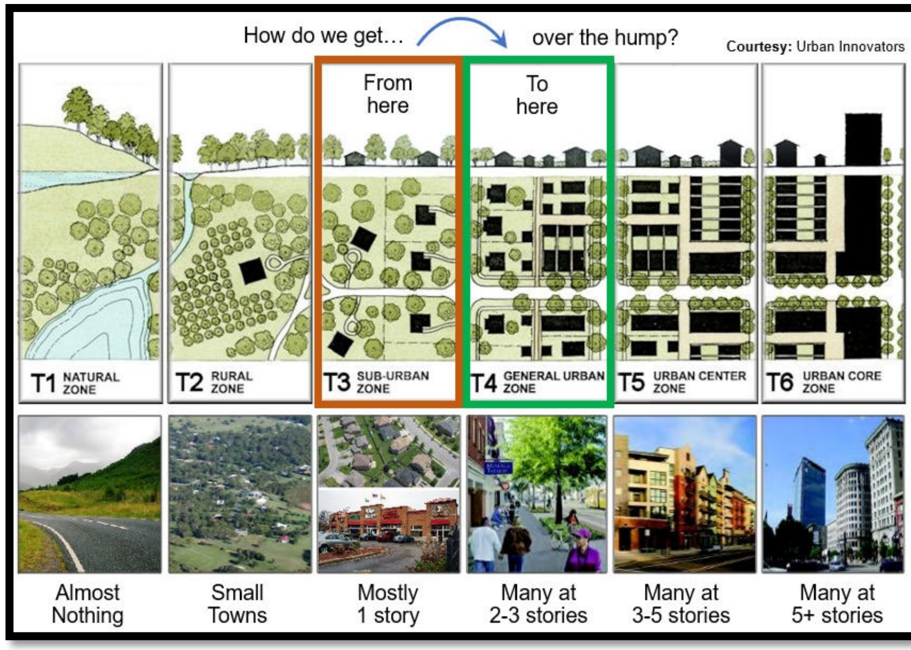


Figure 7 *Transects or Context Zones: Land gets stuck in T3.*

But there are major hindrances to walkability – namely auto-oriented Stroads that are difficult to reinvent as walkable Complete Street boulevards. Even with plenty of money and a mandate, engineers don't know how to handle high levels of traffic in walk-friendly ways – they squeeze in a bike lane and find a few spots for trees, then call it "Complete". It's the best they can do.

As the shine wears off and Greyfields emerge, we need to find ways to still serve traffic (that has nowhere else it can go), but also catalyze walkable Places – creating booming "goldfields" again. Ironically, this means we may need to *increase* vehicular capacity even as we *lower* speed limits. Why? Because walkable development in the suburbs will still generate a lot of vehicle trips!

How to Turn Greyfields into Goldfields

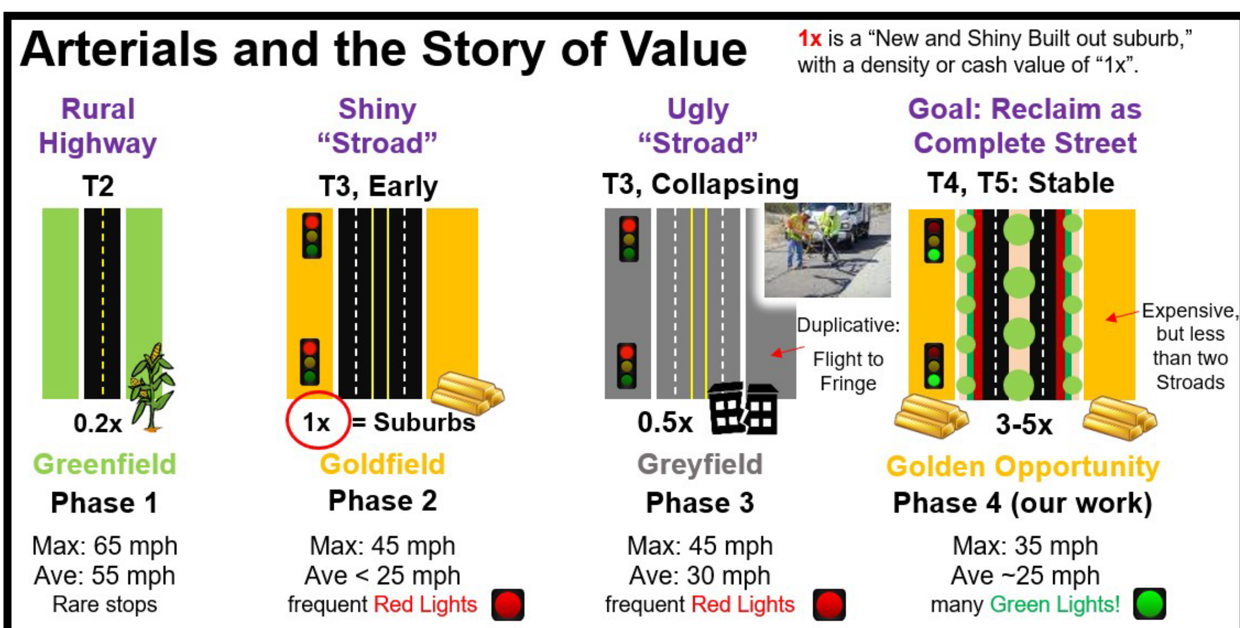


Figure 8 *Arterials and the story of nearby real estate value* *Source: Urban Innovators*

Referring to **Figure 8** above, an arterial highway starts small through rural land (Ph1). When it is widened, it is designed for high speeds, because people are used to that. But then a "goldfield" boom occurs. Business clamors to be there – it's where the "eyeballs" are (Ph2). Stoplights are added for safety, and the result is rather slow due to so many red lights! As cheap buildings and no-frills auto-oriented roadways start to decay, businesses and residents of means "flee to the fringe" (Ph3).

The result is duplicative infrastructure. Yes, Stroads are "cheaper per mile," but you build so many miles, catalyze so much sprawl, and motivate so much flight, that the accumulated infrastructure per square mile soon enough exceeds what the residents per square mile can afford to maintain!

Figure 9 shows how auto-oriented commercial areas tend to reach peak value quickly but then decline steadily in value over time as residents and businesses of means abandon the decaying area.

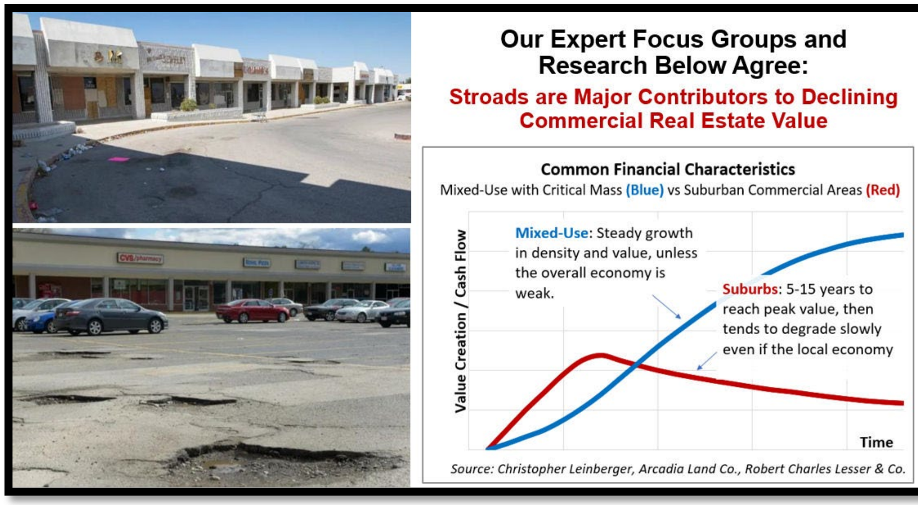


Figure 9 Auto-oriented commercial areas peak then lose value. Mixed-use only grows.

This happens in part because the Stroads in these areas repel redevelopment investment. On the other hand, mixed-use areas tend to increase in value over time in part because their tree-lined streets are very walkable, livable, and multimodal accessible, which catalyzes ongoing investment. This research demonstrates how to make Stroads more walkable and livable, while at the same time delivering similar travel times to even higher levels of traffic.

Cheaper is More Expensive!

When straining to keep up with growth and congestion, it is tempting to dismiss investment in aesthetics and placemaking as too expensive – "a luxury we can't afford." As shown in **Figure 10**, the top Stroad is certainly cheaper per mile, but it also catalyzes low density to grow up around it, meaning more miles are required.

Figure 10 Which system is more affordable?

Although the "Complete Street" is expensive up front, it is far more affordable than the alternative over time because it attracts much more activity!

So, when someone says, "We can't afford to build it!" Just respond, "We can't afford not to!"

Graphical Concepts: Idealized Retrofits

Focus Groups asked us to show an auto-oriented Stroad intersection, and then show how that same area would look immediately after the Alternative Intersection project. Then finally shows how it could look after the market has had enough years to react to the walkable infrastructure. Below is how a one-way split intersection can be created by carving a short pathway through parking lots. Two small commercial buildings would be impacted, but the reduced congestion, improved safety, and walkable activity center may be worth it.

The main report has similar depictions for a "Kitty-Corner Quadrant" and for a "Bowtie" (a form of U-turn design).

Before / After sliders of these graphics are also available at UrbanInnovators.com under "Projects, North Carolina".

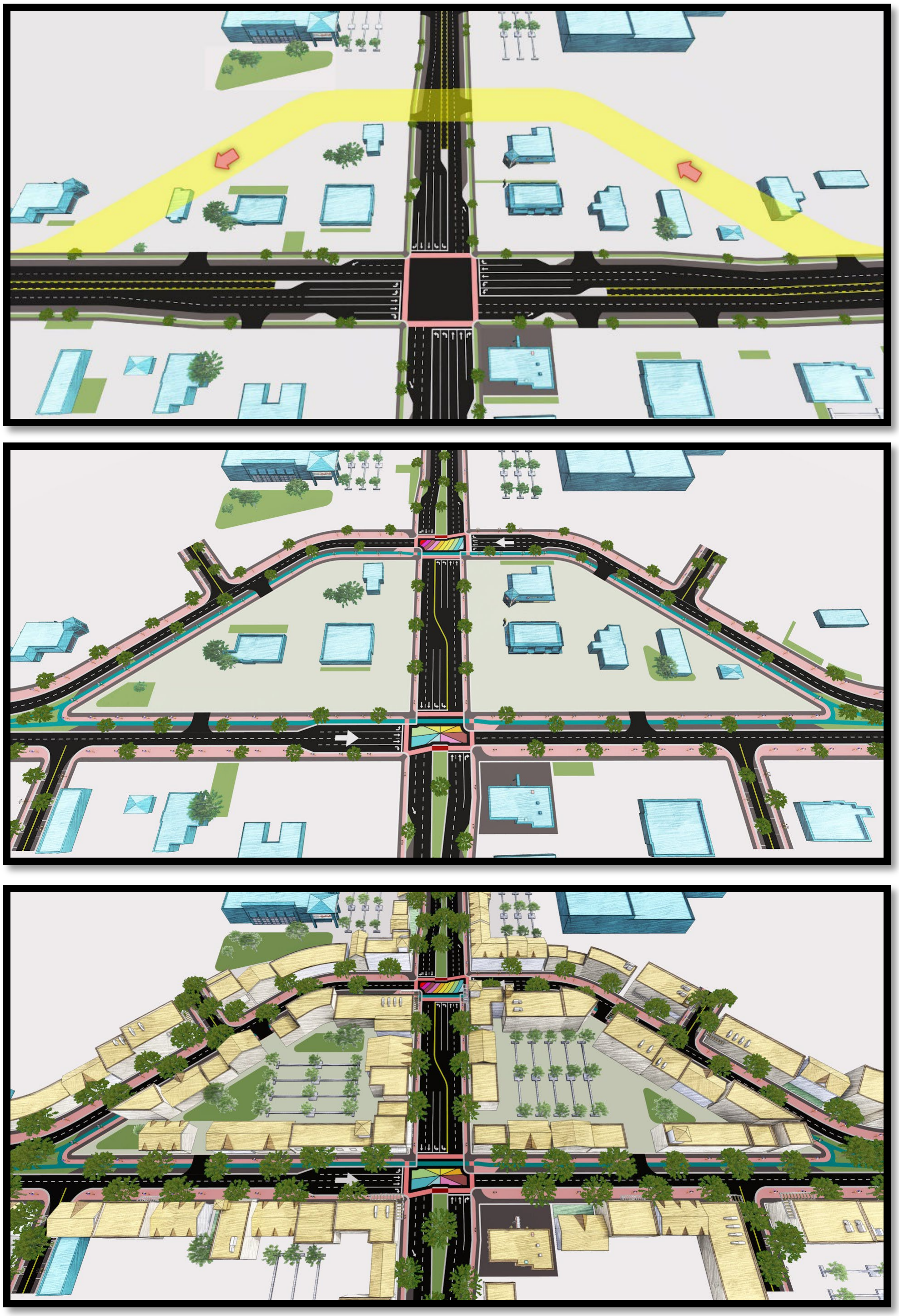


Figure 11 Transitioning from Stroad to Walkable Neighborhood Using a Short One-Way Split

Graphical Concepts from Greenville and Smithfield, NC

Rather than hypothetical locations, the team elected to study real-world locations. Sites in Greenville and Smithfield were selected because all three of the PAIs of interest (Quadrants, U-Turns, and One-Ways), could be developed within proximity of each other. The team reached out to planning staff in each community and gained their permission to explore ideas, provided that any graphics be explained as "research only" so as not to imply that the concepts have been publicly vetted.

This research has produced an extensive library of graphics and associated analysis centered around sites in these communities. The next several pages are a small sample of the types of graphics discussed in the larger report and available in the appendices.

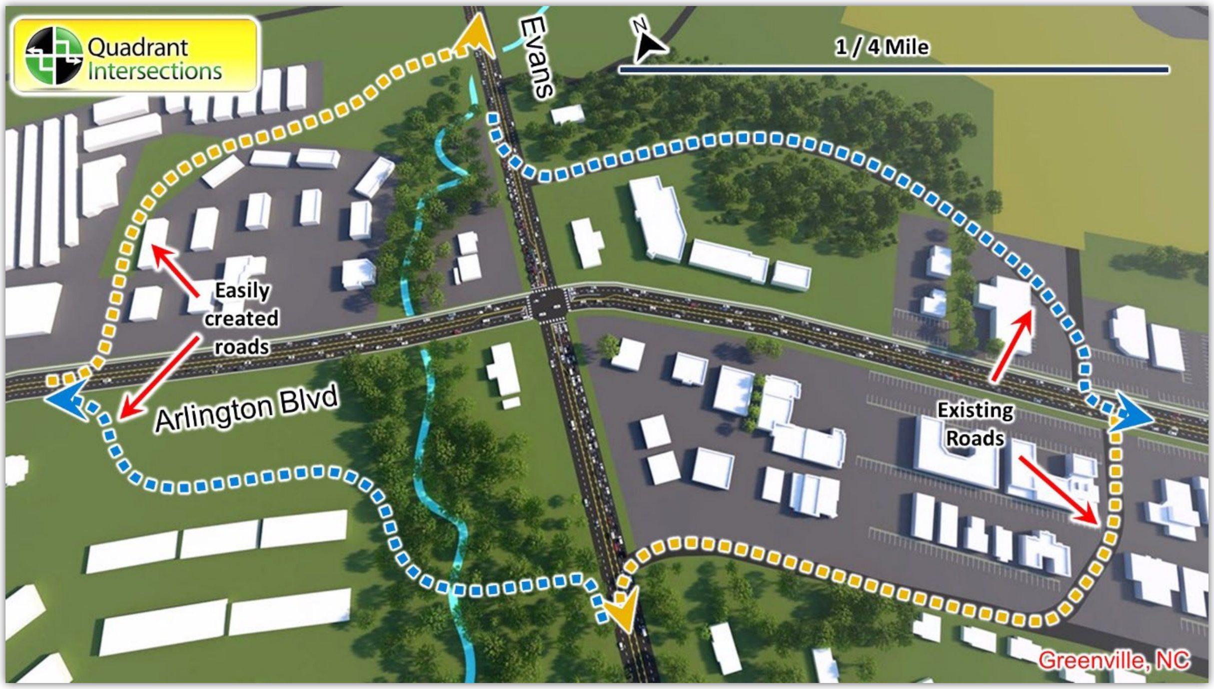


Figure 12 Four Quadrant concept for Arlington Blvd and Evans Street in Greenville

“Slow Lanes” for All Vehicles vs. Bike-Only Lanes

Stroads often have private parking in front of buildings, but walkability is much better if buildings front of the sidewalk, and any parking would be public (either parallel or angle). In our experiments with Greenville and Smithfield, we converted private parking into on-street public parking.

Our first idea was to access this parking with a “slow lane” which would also accommodate bikes, with speed humps to guarantee larger vehicles were bike compatible (10-15 mph). Bike advocates in our focus groups were split on this idea. They prefer exclusive space with less friction. The scenes below show both angle parking with a slow lane and parallel parking with a protected bike-only lane. Graphics are available for both cases, though we are emphasizing the more traditional concepts.

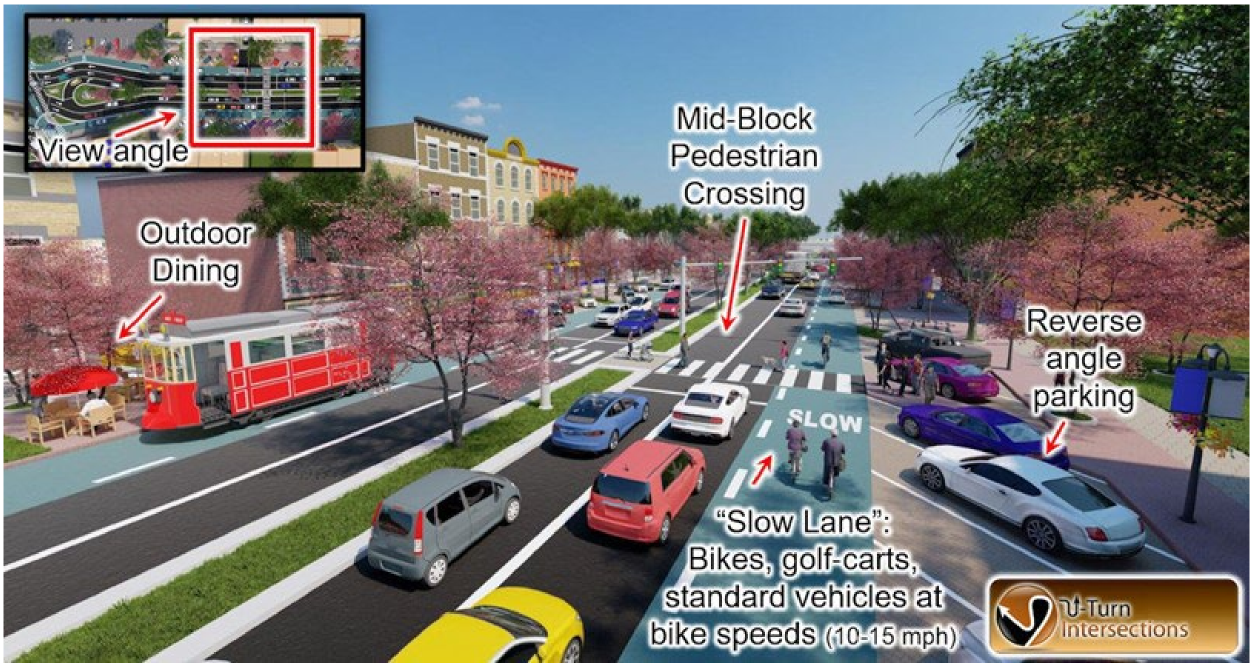


Figure 13 Scenes depicting multimodal "slow lanes” vs protected bike lane.

Synchronization Makes One-Way Speeds Easier to Reduce Than on Two-Ways

These graphics depict hypothetical speeds to demonstrate the benefits of perfect signal coordination, which is possible with one-way streets but not possible with two-ways. In the "before" two-way, speed limits are often set at 30-35 mph. But drivers frequently elect to 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 is likely to obey the limit even if it is intentionally set at just 25 mph for walkability. They obey because they quickly discover the signals on each block are set to turn green at 25 mph, so anything above 25 makes them arrive at the next signal just a little too early. Drivers can't discern synchronization in a two-way system, and thus they cannot be motivated to obey the speed limit for this reason. This is one of the key benefits of one-ways. On top of that, there is a lot more space for other uses!

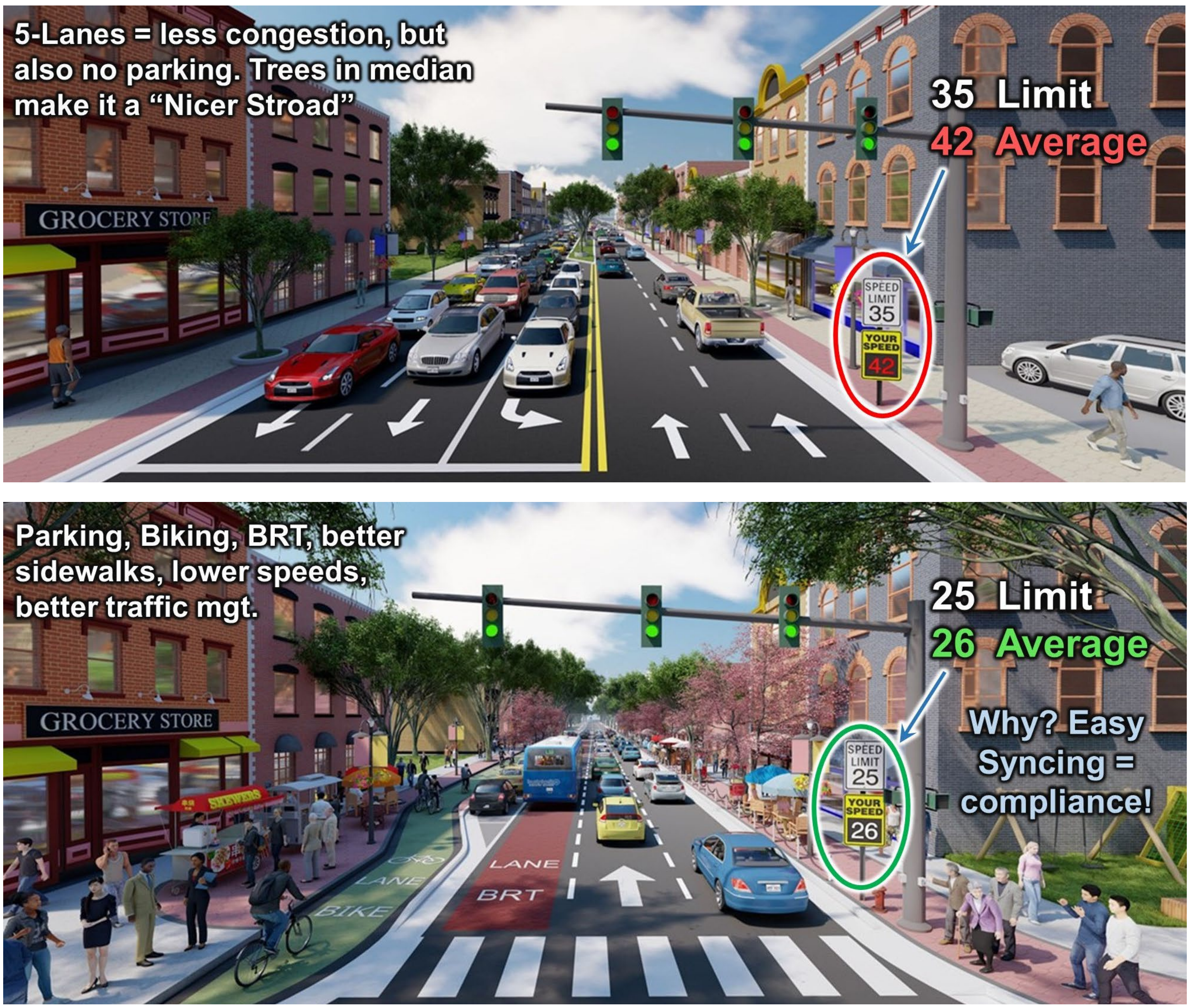


Figure 14 *Converting a two-way Stroad to one-way Complete Street on a historic "Main Street" (or any street where possible)*

Addressing One-Way Negativity: This research demonstrates that one-way streets are excellent replacements for two-way Stroads with 5-7-lane cross sections. However, there is a lot of negativities toward one-way streets among many planners. This is addressed in **Appendix D**.

Top View Diagrams: In addition to site-specific diagrams in Greenville and Smithfield, the team also developed top-view idealized diagrams depicting many types of Quadrants, U-Turns, and One-Way systems. A few samples are depicted here. They have transparent backgrounds so they can be used in Google Earth to create "quick concepts" such as this. These are available as part of a PowerPoint presentation and as PNG files in **Appendix B**.

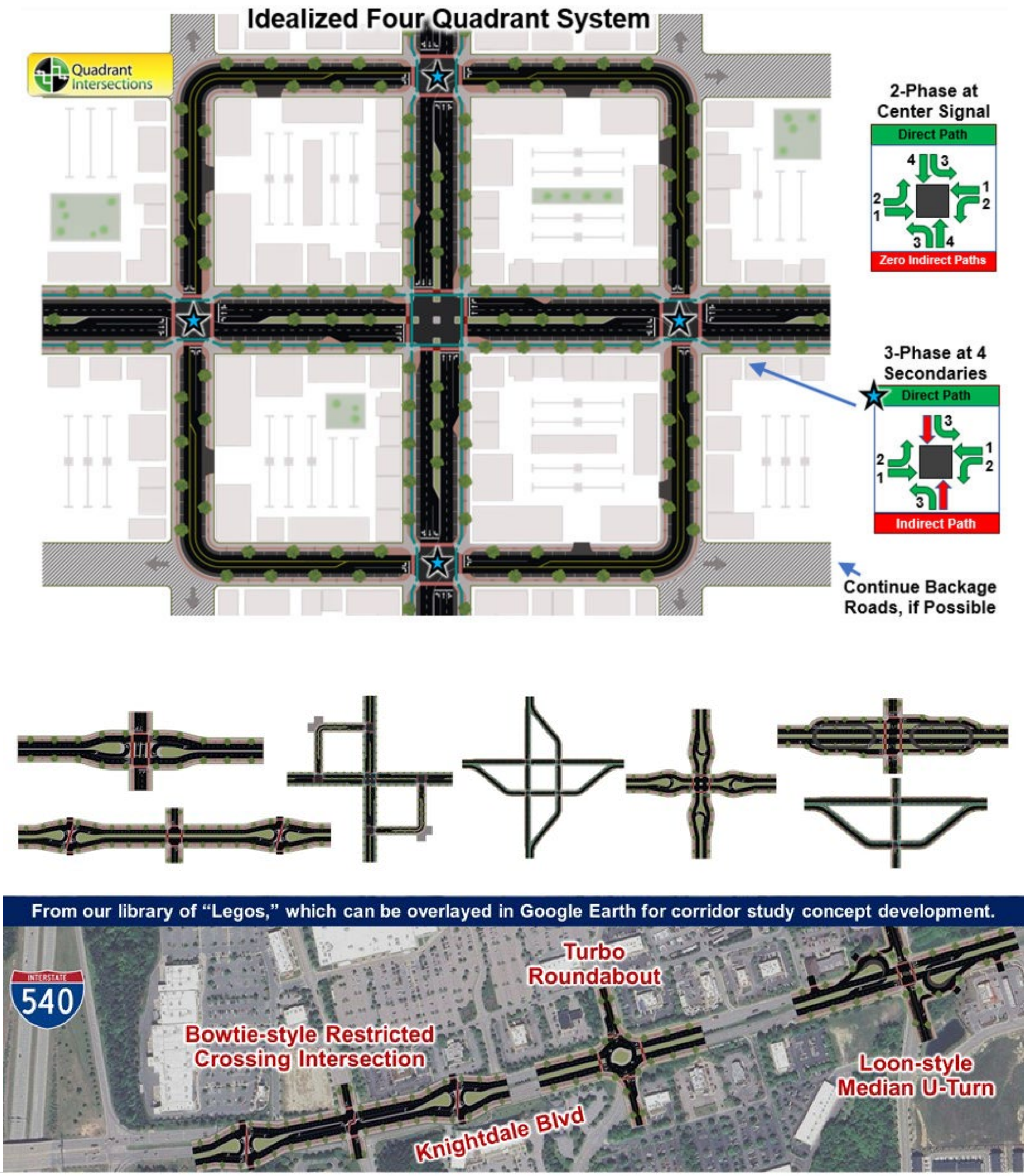


Figure 15 Examples from dozens of Top View diagrams available in Appendix B

Traffic Operational Analysis

Traffic engineers often evaluate before and after conditions for singular intersections using a Level of Service methodology. Common software platforms for such analysis include Synchro and TransModeler (both used here). Because Alternative Intersections often involve spreading volume across more than one intersection, we could not evaluate before/after a delay at a single intersection. Instead, the team evaluated the average "time in the system," including both in-motion time and stop-delay time, ensuring that both before and after systems have the same entry and exit locations.

Using the table below as an example, the analysis progressed as follows:

1. **Capacity Before**: What is the peak hour capacity of the base-case intersection, in terms of total vehicles served at Level of Service E (the point where the average vehicle spends 60 seconds stopped at the intersection)? In the table, the "before" case for the Quadrant Roadway system has a capacity of 3,600 vph (column A).

2. **Time-in-System Before**: What is the average time-in-system at that point? (60 seconds stopped, plus additional time in motion at the posted speed limit to enter and exit the system). Column A shows time-in-motion is 40 seconds at a 45-mph speed limit, for a total of 100 seconds in the system.

3. **Time-in-System After**: Assuming the new design, attempting to mimic the same number of lanes and turning lanes, determine the new time-in-system to serve the same base-case volume. Note that the new design often includes multiple signalized intersections and a lower speed limit. Column B demonstrates that despite new signals and slower speed limit, forcing you to "drive slower," you also "travel faster" due to less stop delay at any given signal.

4. **Capacity After**: Where Column B shows it is possible to serve 3,600 vph with 90 seconds of overall travel time, Column C shows 5,000 vph, or a 39% increase in overall capacity, when volumes are increased until the time-in-system is back up to the original 100 seconds.

5. **New Study Area Capacity**: Column C evaluates the new design being careful not to add new lanes, ensuring an "apples to apples" comparison. However, to prepare the area to support significantly higher development, the team did add new lanes when the right-of-way was available. Column D shows a 58% overall increase in capacity associated with the new design, fitted to the available right-of-way and future development potential.

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%)*

There is no uniform industry standard for comparing multi-intersection systems. We believe this "Time in System" approach, pioneered in this research, is a major step forward for creating apples-to-apples comparison between very different systems.

Development Scale Calculator

When evaluating candidate sites for walkable activity centers, a key question is "Given our new PAI-generated vehicle capacity, how much walkable development can the area support before the key intersections serving the area become excessively congested again?" To help answer this question, the team created an Excel-based "Development Scale Calculator." To run it, the user inputs both the before and after traffic capacity of key intersections, as determined through a stepwise microsimulation process described in the previous section.

The user then tells the tool how many housing units and commercial square feet are in the study area both today and in the future. The tool then estimates the number of vehicle trips likely to traverse the key intersections, discounting for trips reduced due to alternative mode improvements, connectivity improvements, and shorter trip lengths associated with higher density and land use diversity. The user increases the amount of residential and commercial until the key intersection reaches maximum capacity under the new infrastructure package, and this tells you how much development the new design can support.

Below is an output from the tool. It shows that the maximum population and employment that the 111 acres around this intersection can support today is about 600 residents and 1000 jobs (blue bars), with the rest of the capacity dedicated to pass-through traffic. However, after the new Quadrant design is installed, along with better bus service, bike lanes, etc., the area can now support up to 3,100 residents and 2,600 jobs (green bars), which is a 3.7x increase in overall Floor Area Ratio.

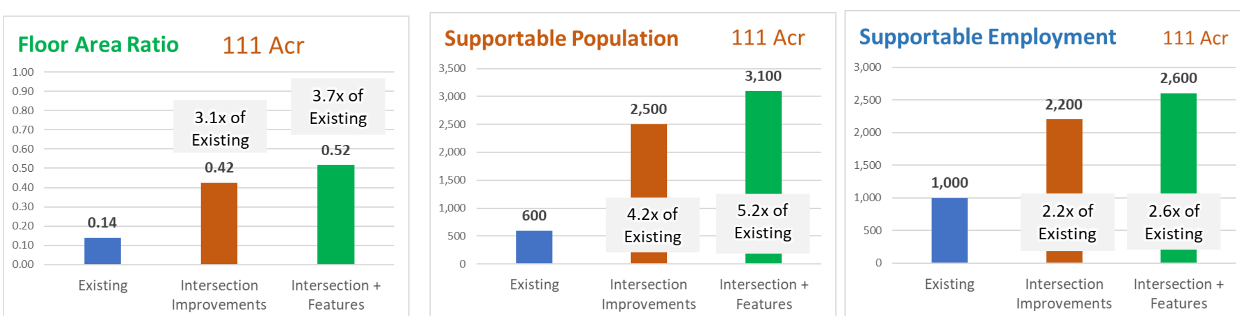


Figure 16 *Floor Area Ratio, along with associated Population and Employment, that can be supported.*

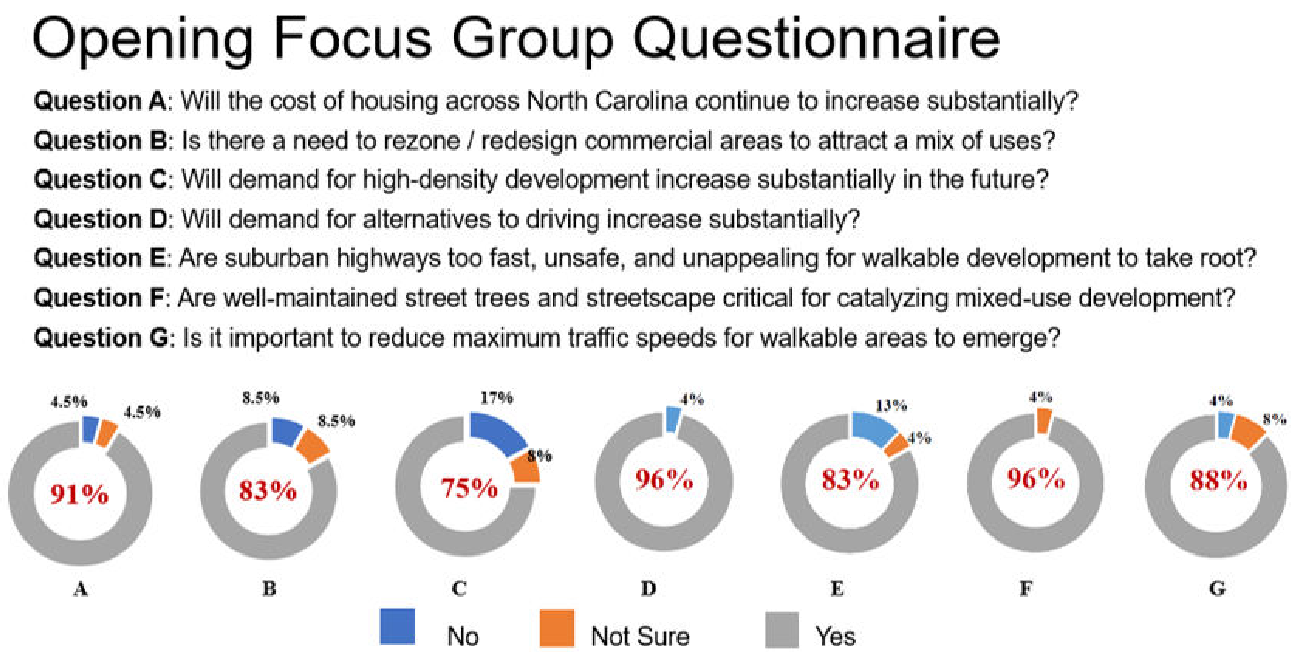
Caution: The calculator helps to estimate the maximum amount of development that could be supported without creating a serious congestion problem. However, this does not mean the market would have sufficient interest at that location to create that much development anytime soon. Determining market demand would require a separate market analysis from real estate professionals to gain confidence that "if you build it, they will come."

This calculator, along with instructions for using it, is available in **Appendix E**. The tool is extremely useful, but also cumbersome and obscure in Excel. The research team recommends that NCDOT consider upgrading this to a Web app at some point.

Two Focus Groups of Experts

The research focuses on how to retrofit Stroad-like suburban commercial areas to attract more urban-scale mixed-use development. In that context, it was important to show our rendering concepts to professionals such as mixed-use developers, real estate agents, bicycle advocates, and academic researchers. We did this and asked them to weigh in on how well the market would respond to the concepts.

The feedback from these professionals was positive in nearly every regard. There was hesitancy, especially among bicycle advocates, for the concept of "slow lanes" that would mix bikes and standard automobiles traveling at "bike speed" while seeking parking, but otherwise, there was a lot of confidence that these designs could work. By maintaining high vehicular access, but also including features such as uniform street trees, transit improvements, speed reductions, and enhancements to nearby connectivity, they agree there will be many cases across the state where such investments will increase adjacent property values, catalyze walkable development, and prove cheaper in the long run than no-frills Stroads.



They also noted a strong need to coordinate the infrastructure improvements with changes in zoning, such as form-based zoning codes that encourage mixed uses and higher densities. They also recommended changes in policy such as the elimination of minimum parking requirements, as a mechanism to help ensure a high return on investment. When cities are willing to do that, and a market study suggests strong interests, then it would make a lot of sense for NCDOT to prioritize Complete Street investments.

They also noted that auto-oriented locations that have become run-down and are now suffering economic hardship would probably be a lot more likely to welcome early demonstration projects than newer places may be indifferent or even hostile to a demonstration project (i.e., if it isn't broken, don't fix it). See the Focus Group section in the main report.

Future Research and Implementation Needs

The focus groups of experts agree that this research can have a powerful and positive influence on land uses for the benefit of climate change, equity, safety, and household affordability. They believe it can also reduce the long-term per capita cost of infrastructure. With this much potential, it is critical that this research advances into common practice first in North Carolina, and then across the nation. The final report thereby closes with the following recommendations for additional research and near-term advancement.

Return on Investment Research: How much will these designs and their supporting elements cost? Which items offer more ROI than others? Though these designs are "expensive per mile," would they attract so much activity density that they would need far fewer miles than the default auto-oriented alternatives, thereby proving to be "cheaper per capita?" Answering this question can help make a case that NCDOT's SPOT prioritization process should account for such ROI.

Safety Evaluation: Create Crash Modification Factors (CMFs) for the Quadrants, U-Turns, and One-Ways envisioned for urban environments. For areas that can attract and support 3-5x scales of development, it seems possible there could be more crashes per mile because there is more density per mile. If so, this could create an illusion that they are unsafe even if there are fewer crashes per capita (because there are fewer overall intersections and miles of roadway).

Value Capture and PPPs: If these designs succeed at catalyzing walkable development, that means impressive value has been created. It means developers will make a profit in the wake of PAI investment. How can this value be captured to help pay for the necessary features? Are there ways that the private sector can be engaged to help remove obstacles?

Webinars and Workshops: The factor that most hinders valuable research from implementation is the lack of awareness. In addition to any final reporting webinars associated with closing out this research, NCDOT should consider sponsoring additional knowledge dissemination for MPOs, Cities, Consultants, NCDOT Staff, etc. via topic-specific webinars, and at industry gatherings.

Modernize Prioritization Criteria: In addition to traditional metrics such as reduced congestion and safety, funding formulas should account for indirect, long-term benefits of higher-density mixed-use development such as equity, climate change, public health, household affordability, and cost savings associated with reduced sprawl.

Incorporate into RFPs for Planning Efforts: Studies and transportation master plans that involve communities seeking to create walkable development should specifically explore options presented in this research.

Convert Development Scale Tool into a Web app: The Excel tool predicts how much development an area can support before key intersections become overloaded. A Web app will make it easier to use and accessible across the state and the country.

Website with Research Summaries, Before/After Sliders

Content very similar to this executive summary is available on the website below. In addition, there are several "before/after" sliders that make it easy to understand the specific changes that help convert Stroads into Walkable Boulevards.

urbaninnovators.com/pr-ncdot-ai-research

Or just go to UrbanInnovators.com and find "Projects," then "NCDOT"