

NORTH CAROLINA

Department of Transportation

Rural Roundabouts and Rural All Way Stop Control (AWSC) in North Carolina

Carrie Simpson, NCDOT Safety Evaluation Engineer

December 7, 2023

Connecting people, products and places safely and efficiently with customer focus, accountability and environmental sensitivity to enhance the economy and vitality of North Carolina

North Carolina's Highway System

Nearly

80,000

**Miles
of Road**

More Than

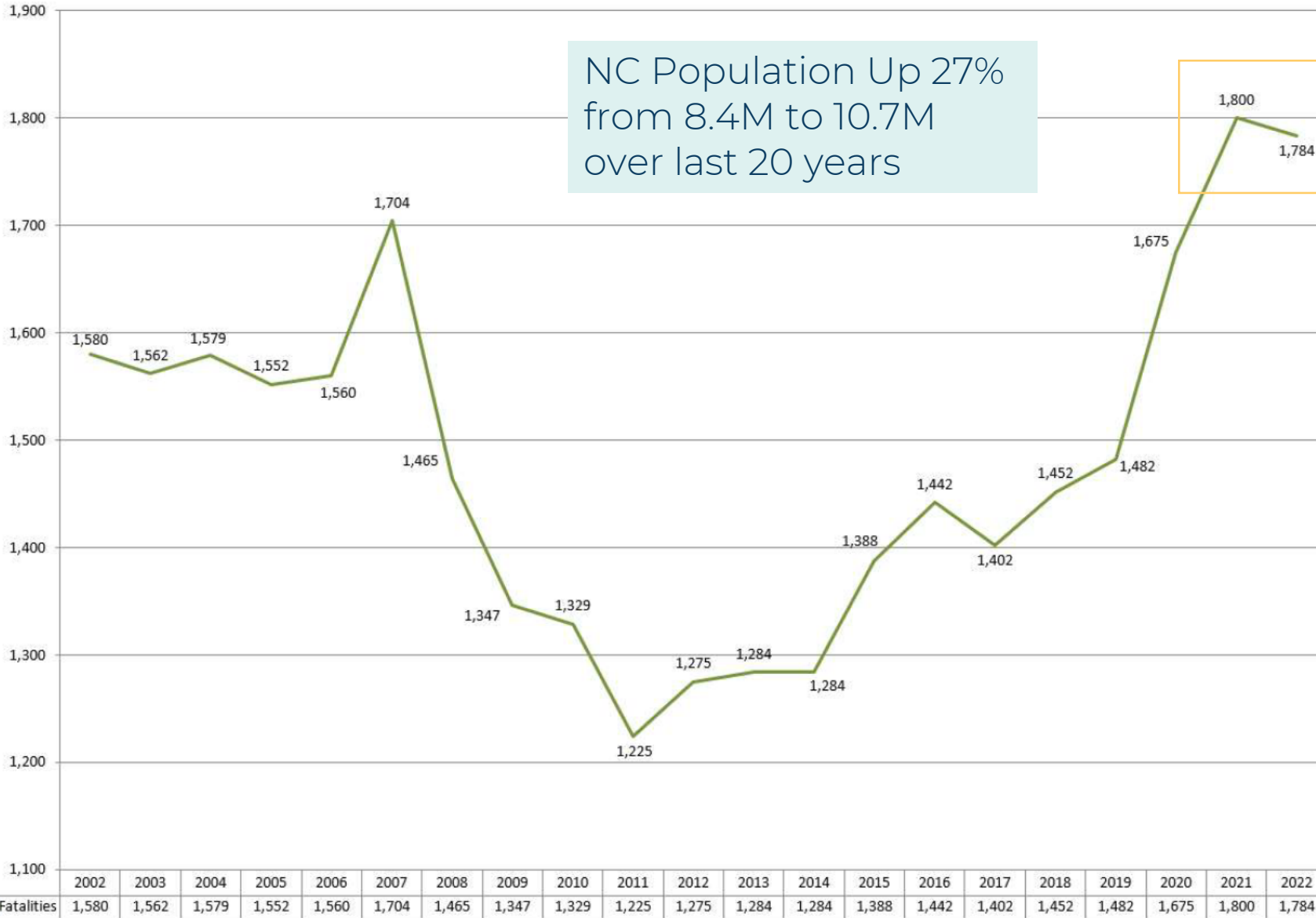
13,500

Bridges

The Division of Highways supports the delivery of statewide transportation projects and is responsible for nearly 80,000 miles of road in North Carolina, making it the nation's second largest state-maintained highway system.

Fatalities
North Carolina Fatality Trends Since 2002

NC Population Up 27%
from 8.4M to 10.7M
over last 20 years



Time to Next Fatality
or Serious Injury in NC

Roadway Departure
2.6 Hours

Intersection
4.0 Hours

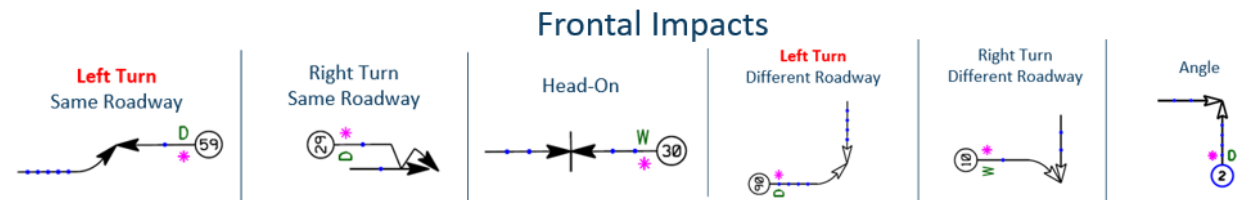
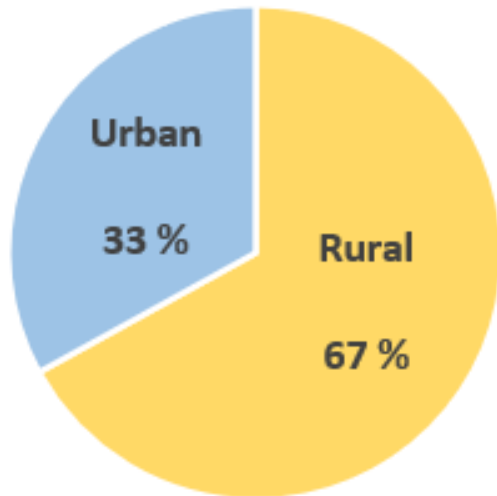
Pedestrian & Bike
13.4 Hours

North Carolina Intersection Crash Trends

Over 15,000 Frontal Impact Crashes Annually at Rural NC Intersections, Including Over 300 Fatalities and Over 1,100 Serious Injuries* *2019 stats



Frontal Impact – Fatal and Serious Injuries



Safest Feasible Intersection Design (SaFID)

Uses *Safety & Mobility* Data to provide guidance on best design based on intersection cross-section and volumes.

For 2 Lane @ 2 Lane intersections:

- AWSC is SaFID where major & minor streets carry <7,500 vpd. Pushing AWSC feasibility above that....
- Above that, full-size one-lane roundabout (up to ~15,000 vpd)....
- Then a traffic signal above one-lane roundabout capacity.

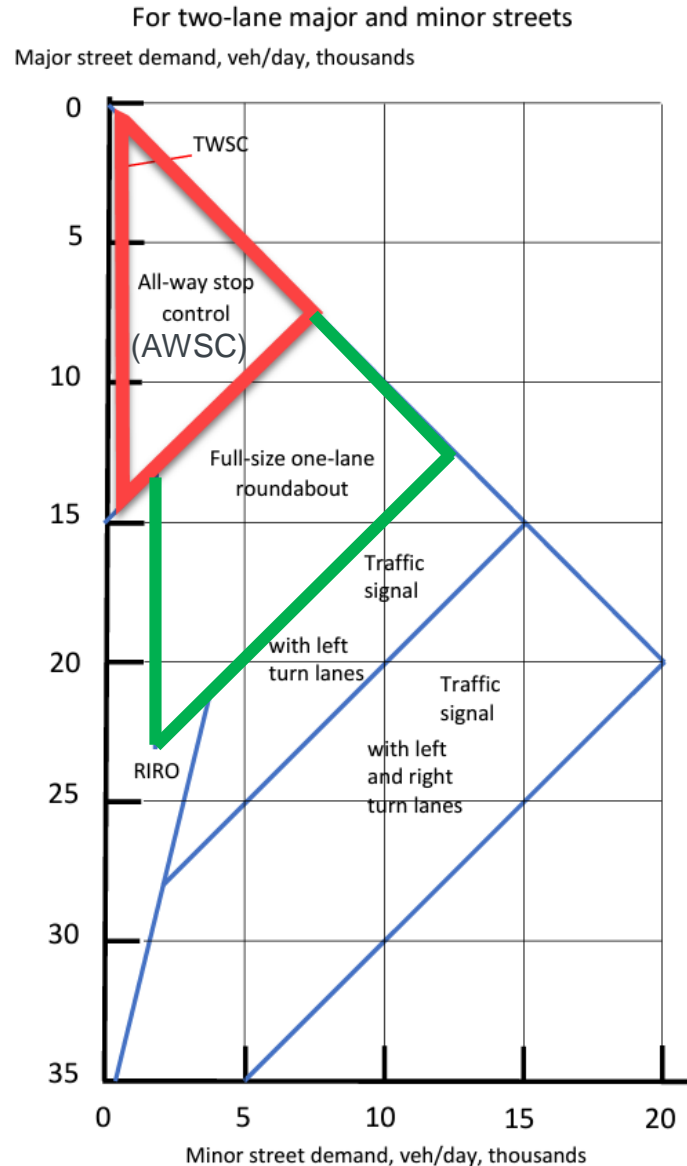


Figure 2. SaFID chart for two-lane major and minor streets.

First Published May 2020 ITE Journal
Dr. Joseph Hummer



https://connect.ncdot.gov/resources/safety/Teppi/TEPPL%20All%20Documents%20Library/C62_Guidance.pdf

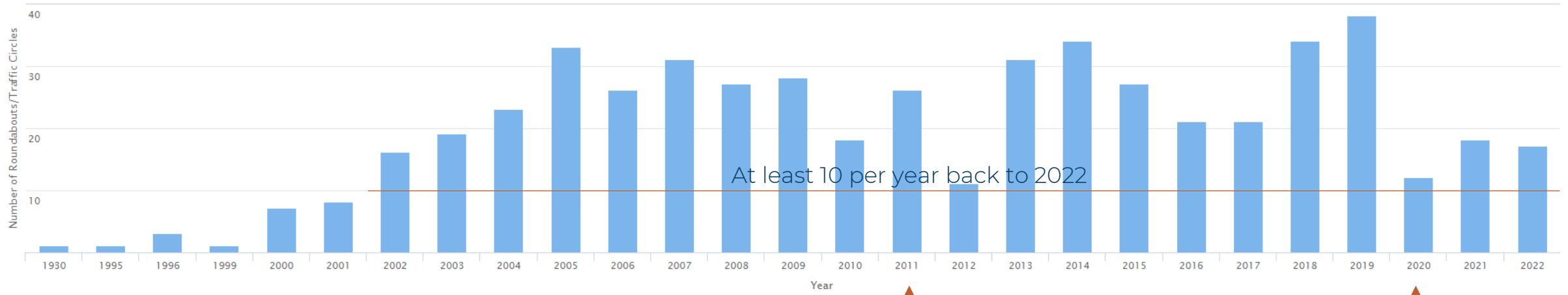
https://www.ite.org/ITEORG/assets/File/ITEJ%20Published/2020/ITE_ITE_May2020.pdf

Roundabouts in NC

Over 600 Roundabouts in North Carolina

One of 7 states with > 600

NC Roundabout Timeline



At least 10 per year back to 2022

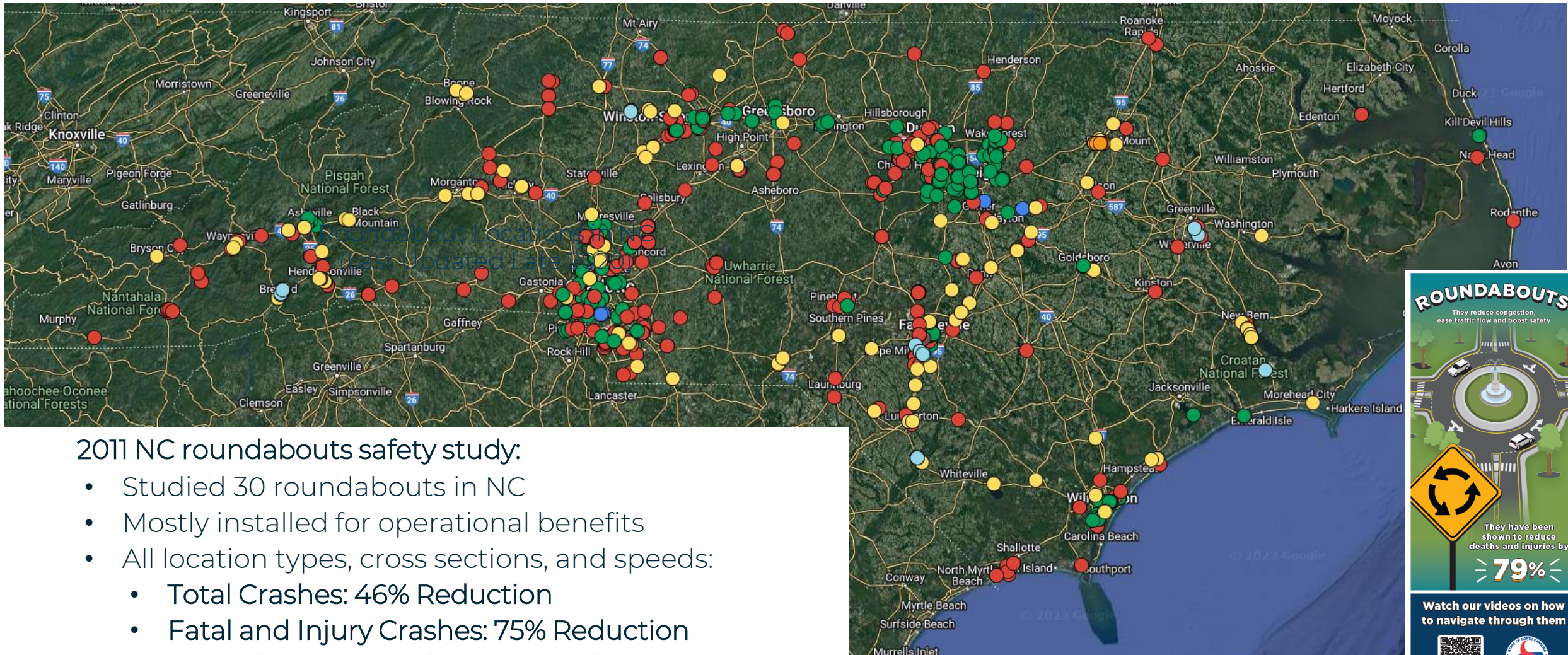
First safety study of roundabouts in NC

Rural roundabouts safety study in NC

© 2023 - Kittelson & Associates, Inc.

Source: Kittelson Roundabouts Database

Roundabouts in NC



2011 NC roundabouts safety study:

- Studied 30 roundabouts in NC
- Mostly installed for operational benefits
- All location types, cross sections, and speeds:
 - Total Crashes: 46% Reduction
 - Fatal and Injury Crashes: 75% Reduction
 - Frontal Impact Crashes: 76% Reduction

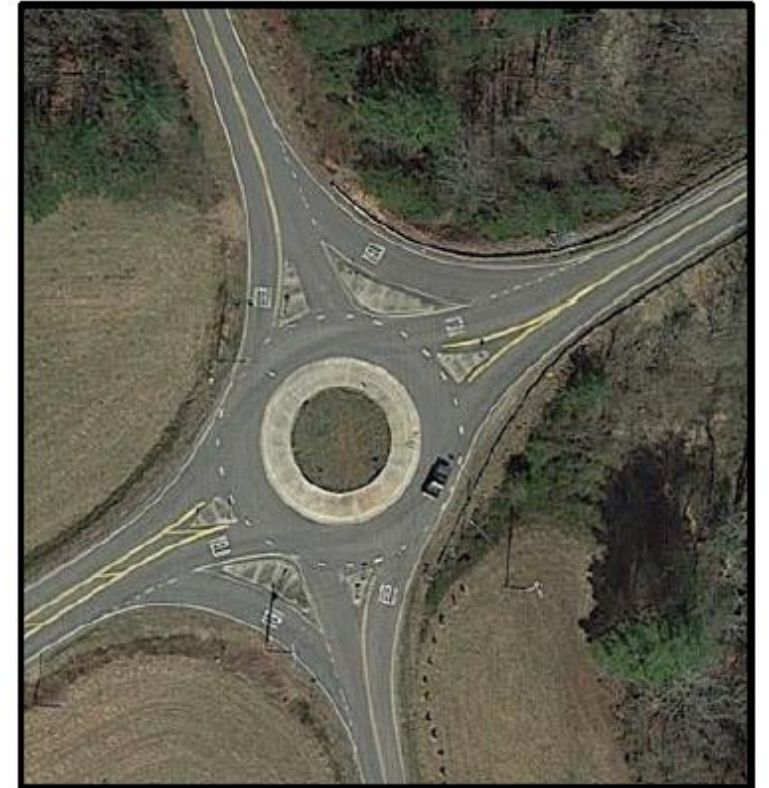
* All Statistically significant at 95% Confidence Interval

NC Rural Roundabout Evaluation

2020 – Daniell Bagley – NCDOT Safety Evaluation Group

- Studied 13 intersections that were converted to Roundabouts (EB)
 - All sites installed between 2006 and 2016
 - All sites converted from 2-way stop control
 - All sites were 2-Lane @ 2-Lane intersections with at least 1 leg with an approaching speed of 55 mph
 - All sites had inscribed circle diameters between 100' and 160'
 - Average Major Road AADT of 6,000 vpd.
Average Minor Road AADT of 3,600 vpd.

Note: 2006 – 2016 timeframe... pre SaFID...
some in the SaFID range for AWSC



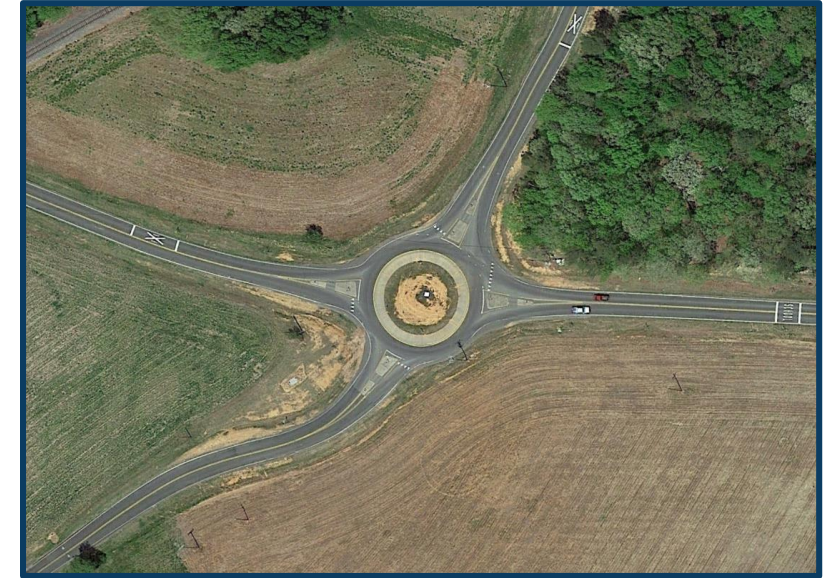
NC Rural Roundabout Evaluation

Overall Results

- Total Crashes: **41% Reduction**
- Fatal and Injury Crashes: **78% Reduction**
- Frontal Impact Crashes: **62% Reduction**

Other Key Takeaways

- Similar results to 2011 roundabout evaluation
- Similar evaluation results between the four 3-leg roundabouts vs. the nine 4-leg roundabouts
- More rural RAB installed/planned since study



NCDOT Rural Roundabout Evaluation



Half with intersection lighting (in at least one quadrant)

Some differences in signing/markings beyond base signage:

- Half with 'keep right' signs on median approaches – left photo
- Couple with pavement arrows - middle photo
- Half with posted advisory speeds (on at least one approach) – right photo
- Typically, not a “step down” of speed limits on approach.... Use advisory speed

Modular Minis – The Future?

<90' Inscribed Circle Diameter, Traversable Center Island



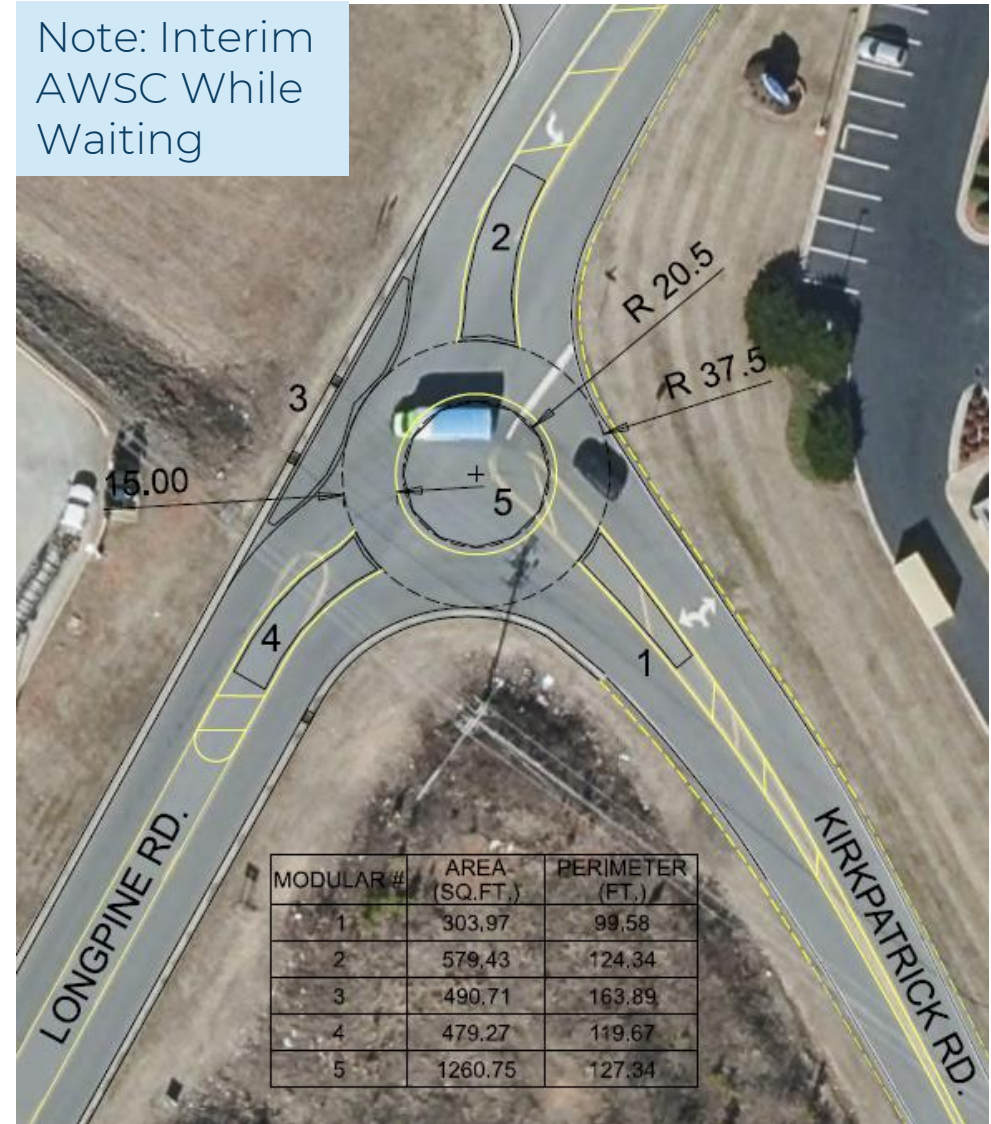
35 mph approaches

CONSTRUCTION TIME ~ 1 MONTH

Day 1 = Traffic in circular roundabout pattern

Day 5 = Roundabout installation substantially complete

Day 30 = Final signs and pavement markings complete



COST = \$185,000

FUNDED 2022 → CONSTRUCTED 2023

Comparison of Roundabouts, Traffic Signals, and AWSC



AVERAGE TIME TO COMPLETION:

> 3 YEARS*

1-2 YEARS

< 1 YEAR

AVERAGE COST:

> \$1-3 M*

\$200,000

\$30,000

EXPECTED FATAL AND SEVERE INJURY CRASH REDUCTION:

> 90%

~ 50%

> 90%

*Full Size, One-Lane Roundabout (>90' inscribed circle diameter)

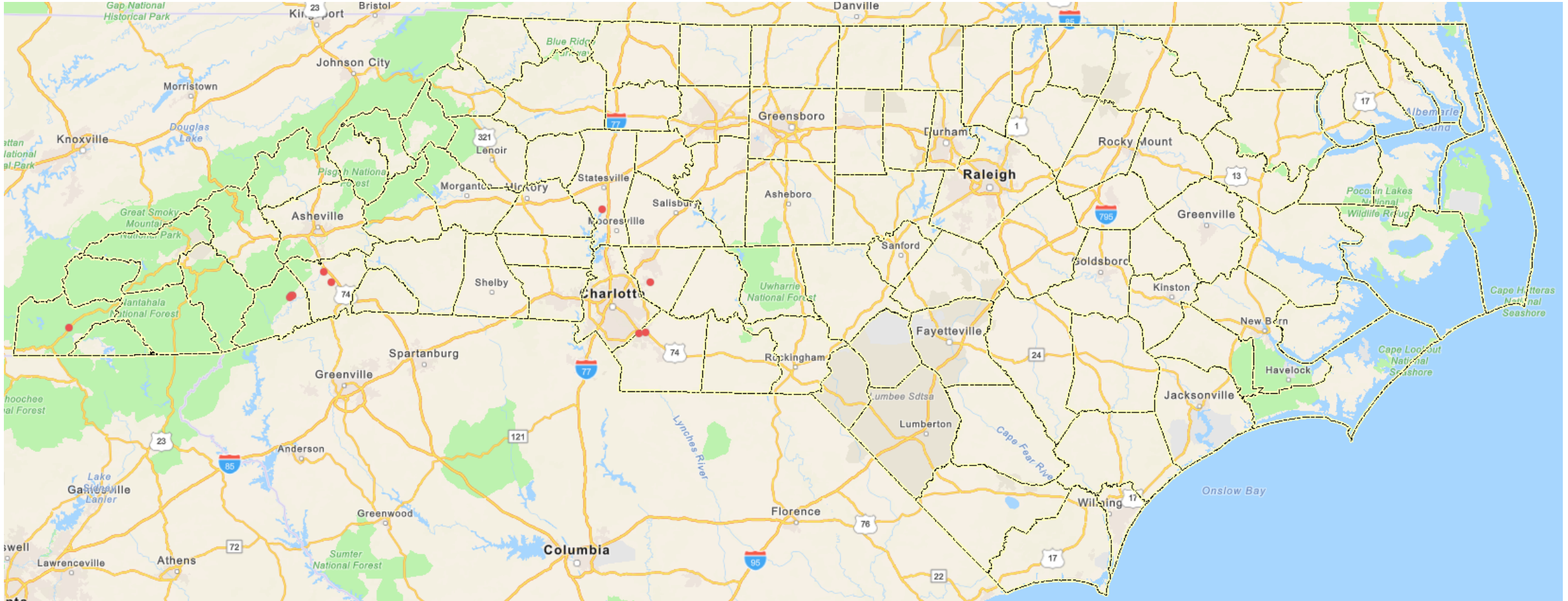
In its SaFID niche, AWSC is strong:
 Time
 Cost
 Safety
 (& Mobility NOT degraded)

North Carolina



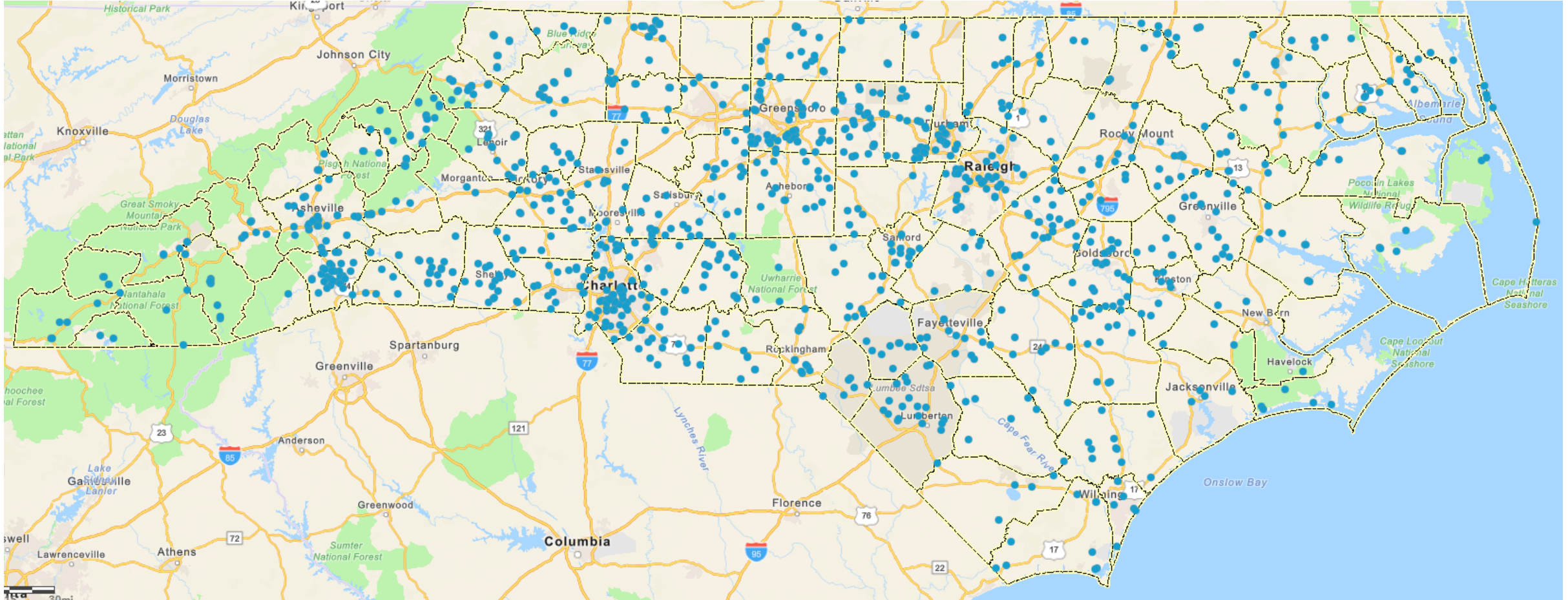
59,000 State Maintained, Rural, 2-Lane @ 2-Lane, Minor Road Stop Control Intersections

North Carolina



Safety Projects we could fund annually @ \$2-3 Million per project

North Carolina



Safety Projects we could fund annually @ \$30,000 per project

DECISION TO MOVE TO MORE LOW-COST & PROVEN TREATMENTS SYSTEMICALLY

Between 2020-22, NCDOT allocated > \$10 Million to RURAL AWSC

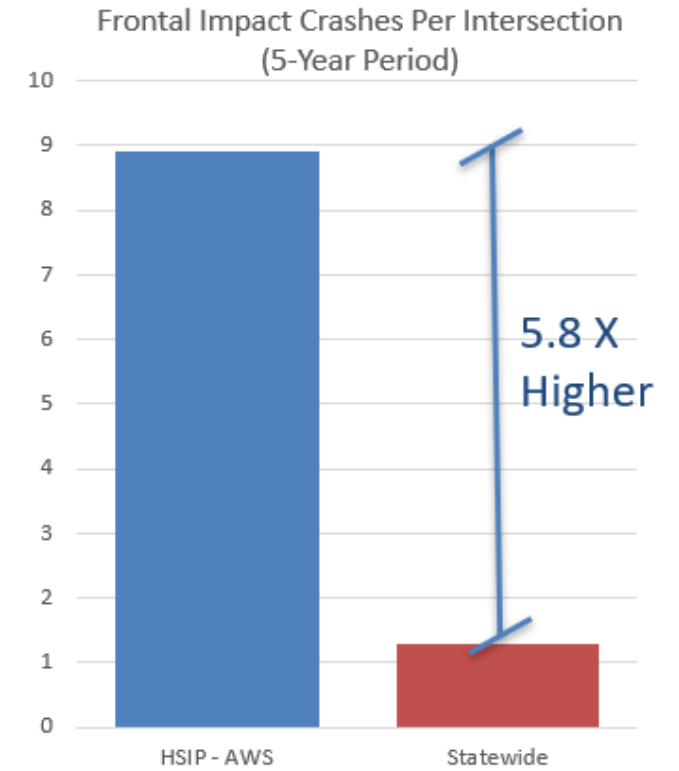


ALL WAY STOP: SR 1603 (Old Carriage Road) at SR 1604 (Hunter Hill Road), Nash County, North Carolina

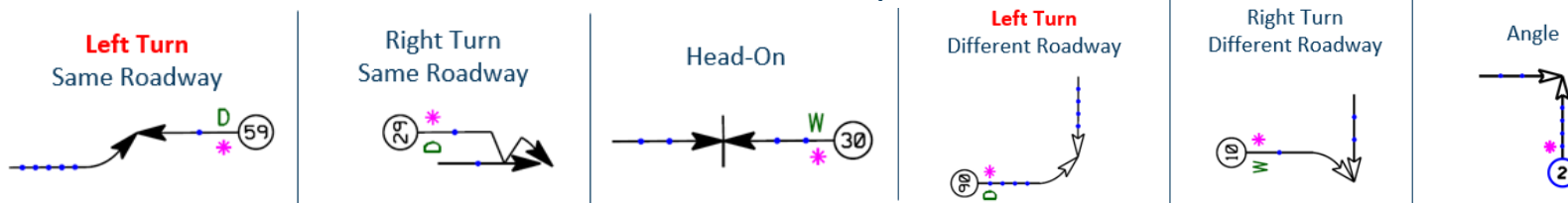
NCDOT HSIP Warranting Criteria for AWSC

Highway Safety Improvement Program (HSIP) flags sites meeting certain criteria:

- ✓ Intersection of 2-lane roadways
- ✓ AADT under 7,500 vehicles per day on all approaches
- ✓ At least 6 frontal impact crashes in 5-years
- ✓ Outside Urban Boundaries (Most 45 – 55 mph)

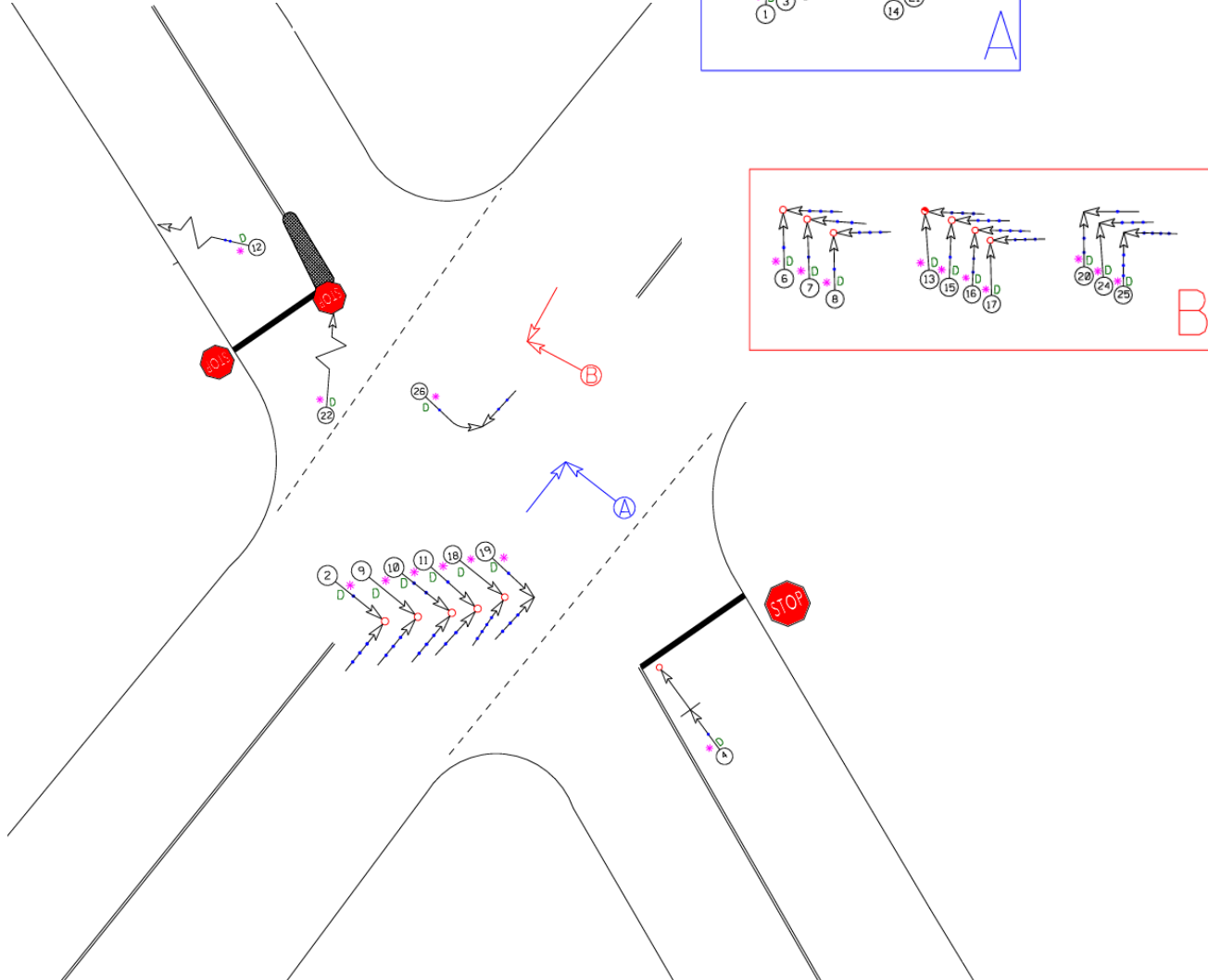


Frontal Impacts



Identified hundreds of intersections

10 Year Crash History ("Before")



Why Not Just Enhanced Signing?



Why Not Actuated Flashers?

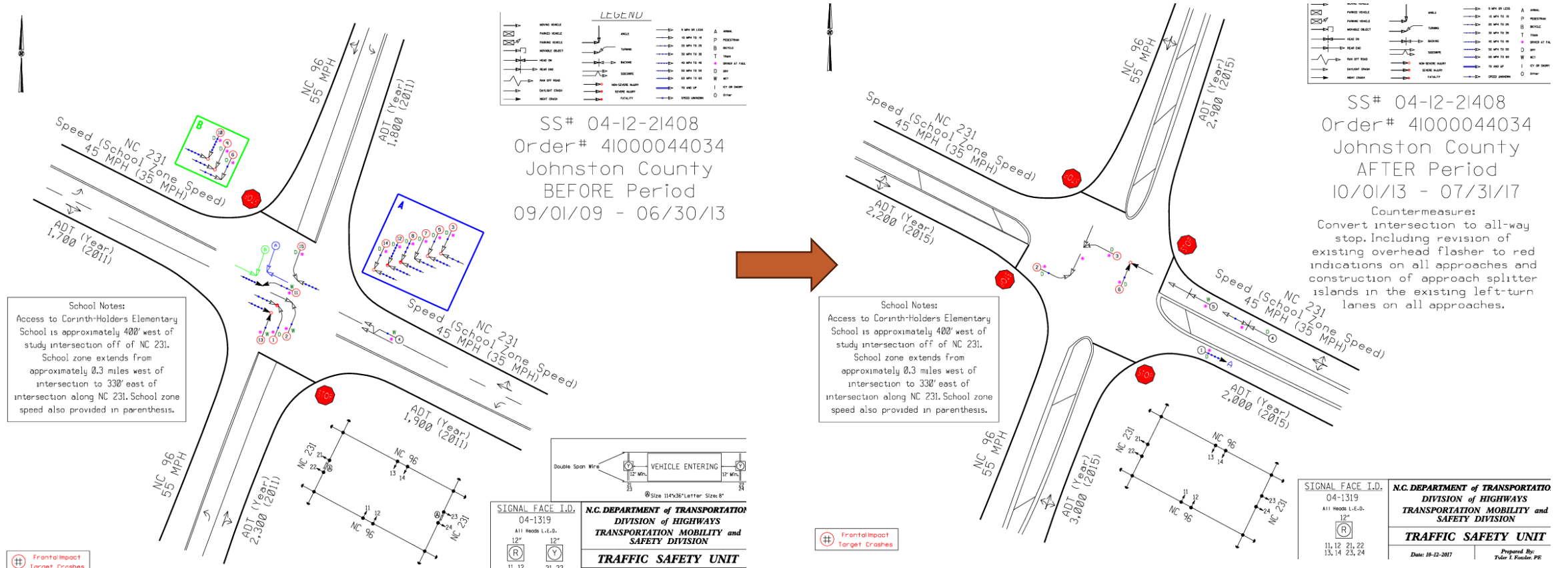


Why Not Actuated Flashers?



Why Not Actuated Flashers?

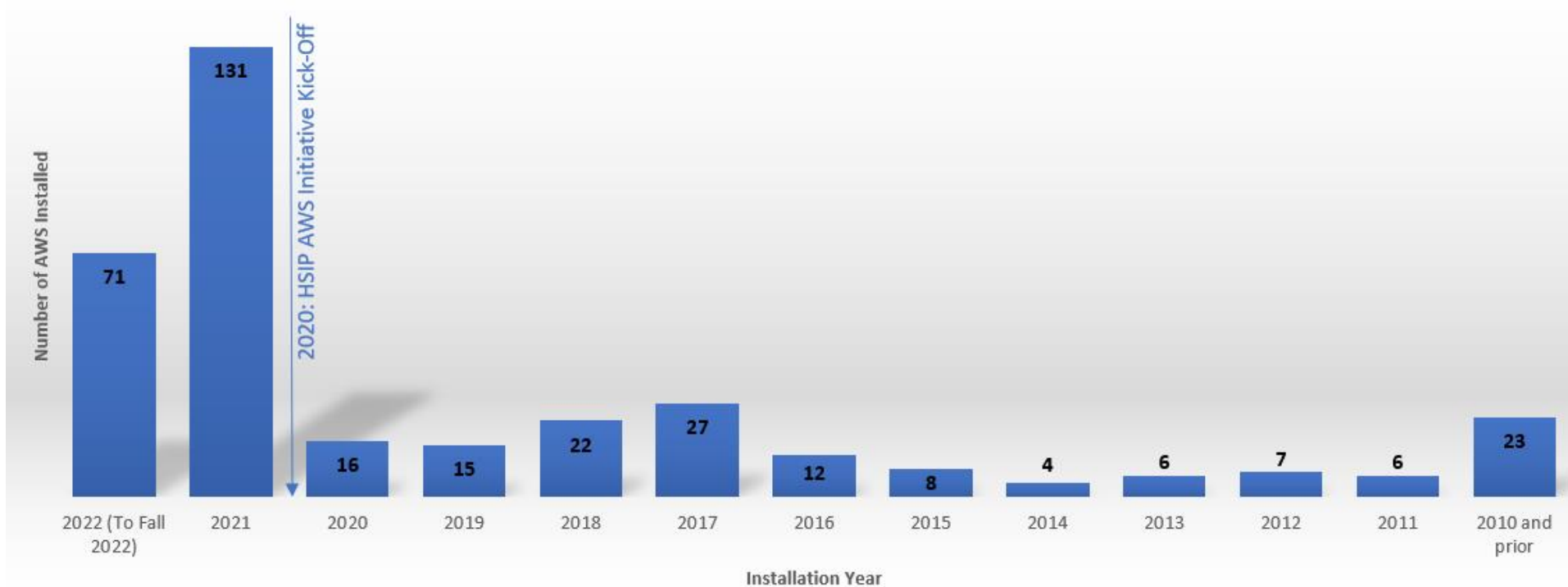
With AWSC => 60% Reduction in Total Crashes, 79% Reduction in Frontal Impact Crashes, 89% Reduction in Injury Crashes



AWSC Safety Evaluation

Evaluated 348 rural intersections converted from minor road stop control to AWSC thru HSIP

All Way Stops in North Carolina: Evaluated Sites



- These are just sites installed through late 2022. More are underway....
- As of early 2023, ~450 AWSC funded as safety projects in North Carolina.

AWSC Safety Evaluation

Overall Results from 348 Intersections Indicate Significant Crash Reductions with AWS:

- Total crashes per year: **55% Reduction**
- Frontal Impact crashes per year: **65% Reduction**

Overwhelming Effectiveness Across AWS Sites:

- 84% of intersections saw reductions in total crashes
- 89% of intersections saw reductions in frontal impact crashes


Remember... High Speed Roundabouts saw:

- Total Crashes – 41% Reduction
- Frontal Impact Crashes – 62% Reduction

AWSC Safety Evaluation

Overall Results from 348 Intersections Indicate Significant Crash Reductions with AWS:

Injury Crashes Significantly Reduced with AWS:

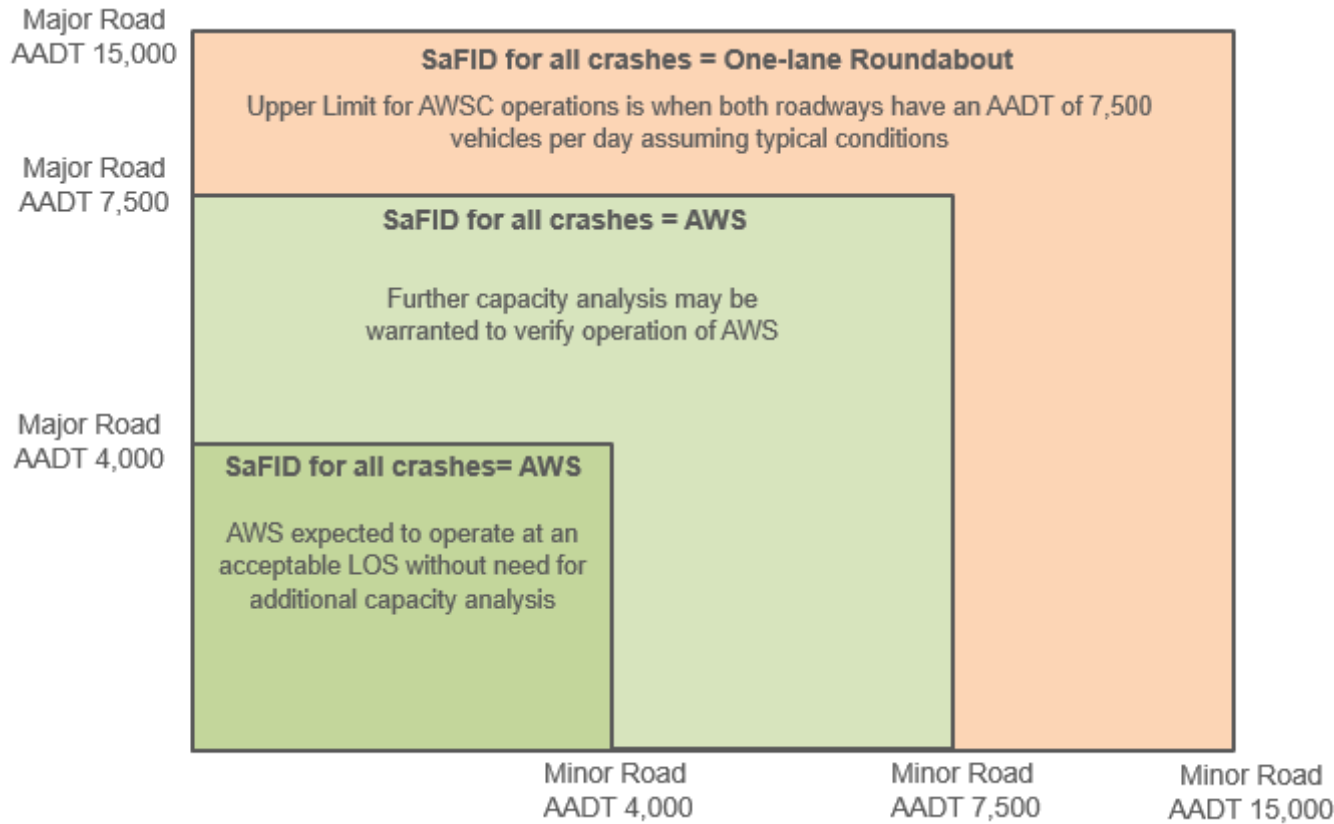
- Fatal and Class-A injury crashes per year: **92% Reduction** 
- Class-B and Class-C injury crashes per year: **72% Reduction**
- **Before AWS**, there were **81 fatal crashes** and 165 Class-A injury crashes
- **After AWS**, there were **NO fatal crashes** and 8 Class-A injury crashes

Overwhelming Effectiveness Across AWS Sites:

- 90% of intersections saw reductions in fatal and injury crashes

Mobility Impacts

Under lower volume conditions, AWSC does not pose a threat to operations



Major street demand, veh/day	Minor street demand, veh/day	Where delay is experienced	Average delay, sec/veh	
			TWSC	AWSC
1,000	1,000	Major street	2	7
		Minor street	10	7
		Overall	6	7
4,000	1,000	Major street	1	9
		Minor street	12	8
		Overall	3	9
4,000	4,000	Major street	3	10
		Minor street	17	10
		Overall	10	10
7,500	1,000	Major street	1	12
		Minor street	16	9
		Overall	2	12
7,500	4,000	Major street	2	20
		Minor street	42	13
		Overall	16	17
7,500	7,500	Major street	3	21
		Minor street	520	18
		Overall	260	20

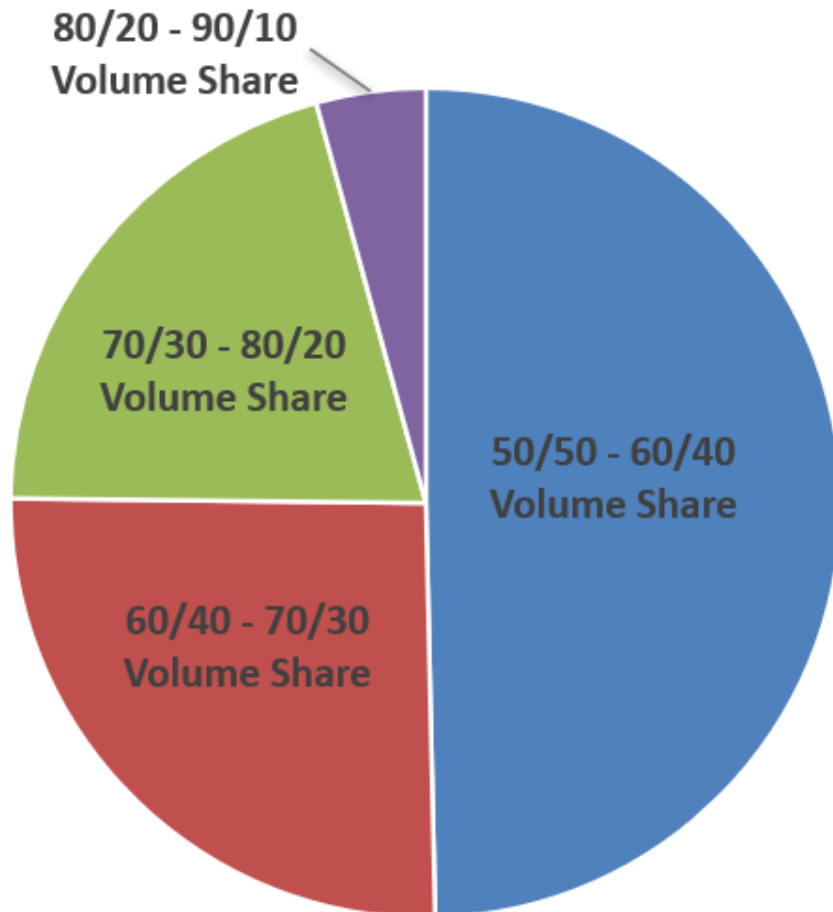
Delay estimates for representative demands at the intersection of two-lane roads

Operational analysis run for some (approaching 7,500 vpd or heavily unbalanced volumes)

Unbalanced Volumes

Don't disregard AWSC just because of unbalanced volumes.

We have some with 70/30, 80/20 or even 90/10 that work.



2009 MUTCD, Section 2B.07 (01) “Multi-way stop control is used where the volume of traffic on the intersecting roads is approximately equal.”

The MUTCD content related to selection of traffic control in Part 2B has seen only minor changes since 1971.

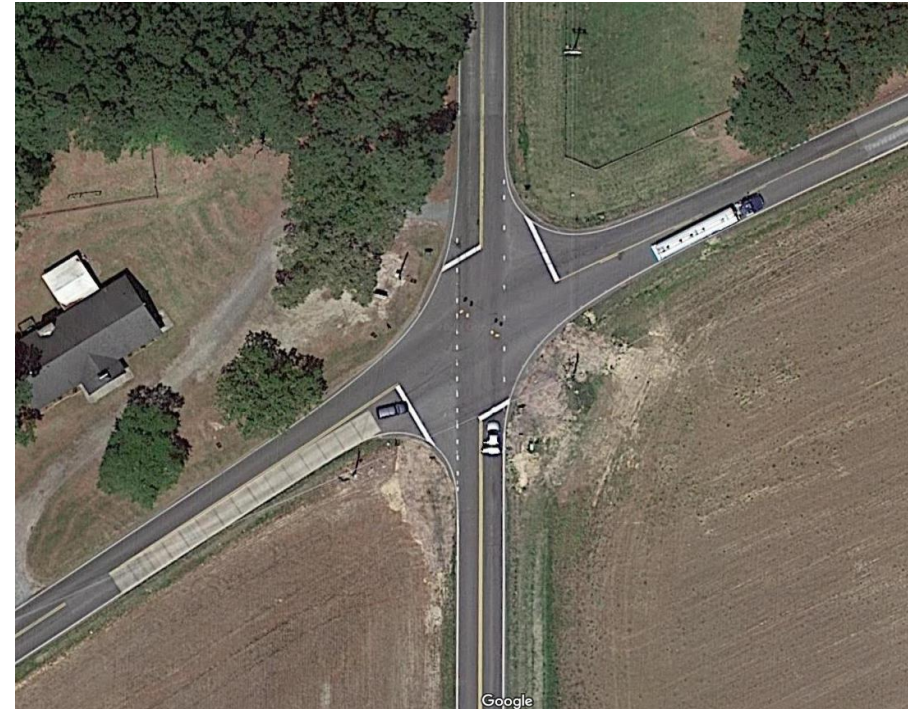
Research has shown under certain traffic conditions AWSC is “no less effective when approach volumes are unbalanced as when they are equal on all approaches” (Persaud 1986).

NCHRP 03-109 (2015) created proposed MUTCD criteria for determining appropriate traffic control at unsignalized intersections. In the AWS criteria, all language pertaining to unbalanced volumes was removed. (Note: I was a panel member.)

Other Concerns

Other Questions/Concerns We've Had to Field from Engineers:

- Stopping Traffic on Primary Routes
- Locations with High Truck Traffic
- Use as Interim Solution



Other Concerns

Other Questions/Concerns We've Had to Field from Engineers:

- Skewed Intersection
- Unique Configurations



Other Concerns

Other Questions/Concerns We've Had to Field from Engineers:

- Three Leg Intersection



Really Good Safety Solution... But Not Perfect Everywhere

Where Strong Peak Hours or AADTs exceeding SaFID thresholds

- Run operational analysis to check!

Sometimes we know it's not a perfect operational fit but...

- It's serving to reduce crash severities as an interim treatment until Roundabout is built.

It may have worked great for years, but now there's growth...

- In our growing areas, we have had some that don't work operationally anymore and need to be stepped up to a Roundabout.

Sometimes operations are ok, but crash totals have not reduced as dramatically as expected

- Review crashes and take another look at signing and marking.
- If severe crashes have decreased, it's probably still worth keeping.

Synergistic ASWC + Other Enhancements



SR 1604 (Hunter Hill Road) looking west toward SR 1603 (Old Carriage Road), Nash County, North Carolina

Synergistic ASWC + Other Enhancements



SR 1604 (Hunter Hill Road) looking west toward SR 1603 (Old Carriage Road), Nash County, North Carolina

Synergistic ASWC + Other Enhancements

3



SR 1604 (Hunter Hill Road) looking west toward SR 1603 (Old Carriage Road), Nash County, North Carolina

Synergistic ASWC + Other Enhancements


- Double Indicating Stop Signs
- Double Indicating Stop Ahead Signs
- Adding Distance Plaques to Stop Ahead Signs
- Oversized Signs
- Reflective Strips on Signs
- Flagging on Signs
- STOP and STOP AHEAD pavement markings
- Flashers on Signs
- Overhead Flashers
- Transverse Pavement Markings (Thermoplastic)
- Temporary – Portable Dynamic Message Signs
- Temporary – “New Traffic Pattern” Signs

*Varies by Region and Location



Synergistic ASWC + Other Enhancements

2010 NCDOT Research on Safety at 53 AWSC Intersections:

- AWSC where overhead flashers added with project saw greater reductions in total, injury and frontal impact crashes than AWSC without overhead flasher.
 - Total Crashes = 82% vs 61%
 - Injury Crashes = 87% vs 72%
 - Frontal Impact Crashes = 86% vs 70%
- 
- Also saw reductions in STOP sign running crashes
 - Signing/Marking Inventory underway for 350 AWSC to update this work
 - Enhancements add \$. Added benefit?

Outreach & Education Needs

SPREADING THE WORD

Information sharing at multiple levels to make a successful AWSC program

- Webinars with NCDOT engineers and decision makers @ HSIP Initiative Kick-Off (Back in 2020)

How Many Crashes Can We Potentially Save?

1,252 Intersections met 2020 HSIP – AWS Warrant

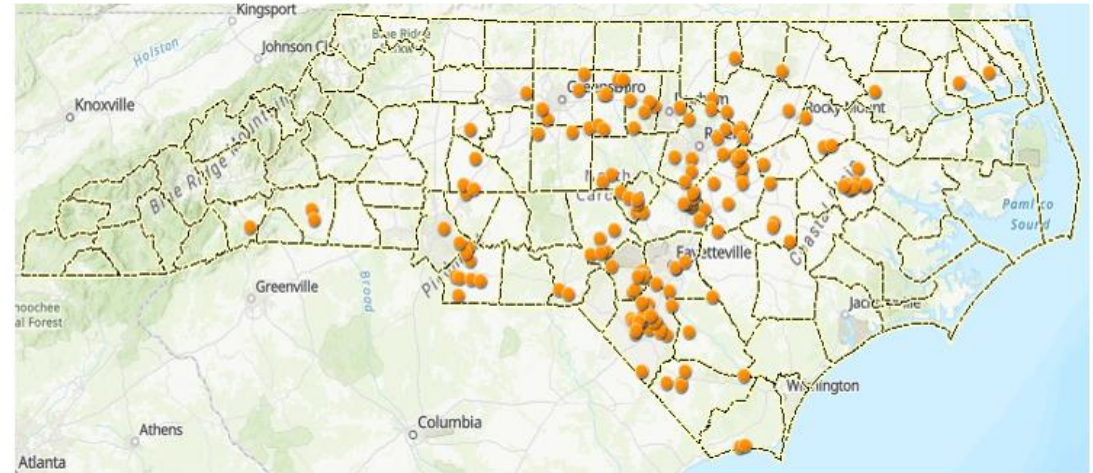
In the next 5-years with AWS we can potentially SAVE:

- ✓ 10,770 Total Crashes
- ✓ 8,376 Frontal Impact Crashes
- ✓ 5,235 Injury Crashes
- ✓ 124 Fatal Crashes



St. Louis Post-Dispatch

- As of 2019, over **150 AWS** conversions have been funded as safety projects across 11 Divisions in North Carolina.
- There has been a pronounced increase in projects for funding years 2016 – 2019.



2020 Presentation Slides

Outreach & Education Needs

SPREADING THE WORD

- Presentations at various State, Regional, and National meetings:
 - Webinars, ITE, FHWA, NCHRP Pooled Fund, Cities
- Resources developed to share with stakeholders:
 - All Way Stop Webpage
 - All Way Stop Presentations and Documents
 - Project Press Releases
 - YouTube Videos
- One Page Safety Summaries for each Division to show benefits specific to their area.
- Received 2023 National Roadway Safety Award

<https://www.ncdot.gov/initiatives-policies/Transportation/safety-mobility/all-way-stops/Pages/default.aspx>

<https://youtu.be/WK3OtyFsvfk>

<https://www.youtube.com/watch?v=qEPsXU5OqRE>

<https://connect.ncdot.gov/resources/safety/TrafficSafetyResources/All%20Way%20Stop%20Summary%20Brief.pdf>

All Way Stop Control Safety Initiative

ALL-WAY STOPS
An effective and cost-efficient way to improve safety

They have been shown to reduce deaths and Injuries by **77%!**

The N.C. Department of Transportation recommends an all-way stop only after a thorough evaluation of the intersection.

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All-Way Stops

Using An All-Way Stop Intersection

Watch later Share

Watch on YouTube

All Way Stop Safety Benefits NCDOT Division 4

All-way stops (AWS) can help alleviate crash problems at intersections experiencing frontal impact crashes. 35 intersections in Division 4 were studied where intersection control was changed from two-way stop to all-way stop as part of a safety project. Division 4 covers Edgecombe, Halifax, Johnston, Nash, Wayne, and Wilson Counties. Installation dates ranged from 2010 and 2022. The average intersection volume was 5,200 vehicles per day.

Case Study

NC 222 @ NC 581 in Wayne County – 2017 AWS Installation

- Total Crashes: **60% Reduction** (10 to 4 crashes)
- Frontal Impact Crashes: **89% Reduction** (9 to 1 crashes)
- Fatal and Injury Crashes: **75% Reduction** (8 to 2 crashes)

4.7 years before AWS: 1 Fatal, 2 Class-A injury, 4 Class-B injury, 1 Class-C injury & 2 PDO crashes
4.7 years after AWS: 0 Fatal, 0 Class-A injury, 0 Class-B injury, 2 Class-C injury & 2 PDO crashes

Overall Results

Overall Results From 35 Intersections Indicate Significant Crash Reductions with AWS:

- Total crashes per year: **64% reduction**
- Frontal impact crashes per year: **72% reduction**

Injury Crashes Significantly Reduced with AWS:

- Fatal and Class-A injury crashes per year: **96% reduction**
- Class-B and Class-C injury crashes per year: **83% reduction**
- Before AWS, there were 8 fatal crashes and 17 Class-A injury crashes
- After AWS, there were **NO fatal crashes** and 1 Class-A injury crash

Overwhelming Effectiveness Across AWS Sites:

- 86% of intersections saw reductions in total crashes
- 91% of intersections saw reductions in frontal impact crashes

Frontal Impact Crashes include crash types associated with higher severities such as head-on, angle, left-turn, and right-turn crashes.

Questions?



Contact Information:

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AWSC Conclusions

- ✓ Why AWSC?

 - In Niche: Low Cost, Quick to Implement, Systemic, Safe, Minimal Mobility Impact*

- ✓ Where is the AWSC niche?

 - Max 7,500 vpd for major and minor approaches, 2 Lane @ 2 Lane*

- ✓ What are the AWSC safety initiative warrants?

 - Volume and geometry constraints above, also crash pattern present and rural*

- ✓ What are the safety effects of AWSC?

 - > 90% Reduction in Fatal & Injury Crashes*

- ✓ What are the mobility impacts of AWSC?

 - In Niche: maybe a few added seconds per vehicle*

- ✓ What does it take to build a successful program?

 - Communication, Education, Acceptance and Time/Patience (Build the case)*