REMEMBERING RURAL:

Shaping Connected and Automated Vehicle Technology in North Carolina

Report by **VISHNU RAMACHANDRAN**

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ROOSEVELT INSTITUTE
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About the Author

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Executive Summary

Access to broadband internet has become necessary to participate in today's economy and attain an adequate quality of life. Life without the internet is a stunted one, with limited opportunities.

Led by connected and automated (i.e., self-driving) vehicles (CAVs), the internet is now improving transportation—a crucial public good. With internet-connected "smart" infrastructure, CAVs provide substantial benefits around safety, mobility, and productivity. Soon, like previous telecommunications technologies, smart infrastructure will no longer be an advantage but a necessity for rural economic development.

Relying on the market to allocate this technology and its benefits, however, will perpetuate the digital divide—the gap created from the uneven distribution of internet and the literacy required to use it. Universally, access and literacy will determine who will benefit from CAVs. A lack of public investment in rural smart infrastructure now will widen the digital divide and deepen vast economic disparities over time.

North Carolina, long a pioneer of equitable broadband access, should continue to champion inclusive, long-term growth for its 3.2 million rural residents. To do so, the state should invest in a rural CAV test site, and its smart infrastructure, and pass the BRIGHT Futures Act, which will allow public-private partnerships and workforce training in an age of automation.

To ensure rural communities are not left behind in the age of digitalization and automation, North Carolina should begin publicly investing in rural smart infrastructure. As the state prepares for its urban future, it must remember its rural one too.

Introduction

The internet has become a public good. Having replaced traditional telecommunication, the internet connects us the way the telegraph, radio, telephone, and television once did, and has become a vital connection to the rest of the world. Online services allow us to stay informed, communicate with others, find employment, and interact with the government. Increasingly, internet connectivity is necessary the way that water, heat, and electricity are necessary: They are all vital goods that help us achieve an adequate quality of life and participate in the global economy.[1] The internet is an essential service that allows us to meet our full potential and to take advantage of opportunities.[2]

Our transportation networks are rapidly changing because of internet connectivity. Led by connected and automated (i.e., self-driving) vehicles (CAVs), intelligent transportation systems will rely on the internet to

[1] Rakeen Mabud and Marybeth Seitz-Brown, "Wired: Connecting Equity to a Universal Broadband Strategy," Roosevelt Institute, http://rooseveltinstitute.org/wired-connecting-equity-universal-broadband-strategy/.

[2] K. Sabeel Rahman, "Losing and Gaining Public Goods," *Boston Review*, September 5, 2017, http://bostonreview.net/forum/k-sabeel-rahman-losing-and-gaining-public-goods.

function.[3] Such systems focus on "improving traffic conditions, minimizing delays, and increasing safety for all commuters," bettering our transportation networks and improving lives.[4] More specifically, CAVs will have far-reaching effects on our economy as a whole.[5] Safety, productivity, and mobility will be the main areas in which CAVs will benefit our economy.[6] For example, investing in digitalized and connected roads that support CAVs can spur productivity gains by making our transportation networks more efficient. Moreover, commuters who would no longer need to drive can redirect their labor or spend more time on leisure, and those who cannot drive will have more mobility options. Most importantly, without human error, traffic jams and road fatalities will likely be lower as well.[7]

However, if we do not take action to equitably implement connected infrastructure and intelligent transportation systems in rural areas, the digital divide—the uneven distribution of information and communication technologies (ICTs) and the technical know-how required to use them—will be exacerbated. ICT access and literacy will determine who will benefit from these technological innovations, especially from CAVs, which require internet-connected, sensor-embedded "smart" infrastructure. Implementing the technology could also significantly impact North Carolina's most common job: truck driving.[8] Allowing the market alone to allocate the infrastructure will produce an unequal distribution and further the digital divide, especially in rural areas, because it will unequally favor urban areas with high concentrations of wealth and investment. Soon, smart infrastructure, like previous telecommunication technologies, will no longer be an advantage but a necessity for rural economic development.[9]

North Carolina has already taken steps to invest in universal ICT access by bringing internet to rural communities.[10] The state should learn from its broadband-access efforts and focus on inclusive, long-term growth. As we begin to digitalize transportation, the digital divide now stands to impact not only the state's economic productivity but also its road safety and its citizens' mobility. Thus, smart transportation is the next frontier for tackling the state's digital divide. Investing now in smart-infrastructure transportation in North Carolina's rural communities will establish a potential economic advantage and reduce disparities in safety and mobility.

In the first section of this report, I will explain the potential benefits of CAVs, and how rural areas will be left behind if we do not intervene on the state and local levels. Building on this, the second section will highlight how the digital divide and road safety disproportionately affect North Carolina and its rural residents, giving the state reason to act on CAV technology now. From there, I will discuss why public involvement in smart-infrastructure investment will determine how universally people will benefit from CAVs. In the fourth section, I

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[3] Ryan McCauley, "How Infrastructure Disrepair Is Holding Back Automated Vehicles," *Government Technology: State & Local Government News Articles,* April 5, 2017, http://www.govtech.com/fs/how-infrastructure-disrepair-is-holding-back-autonomous-vehicles.html.

[4] "Intelligent Transportation System." NCDOT, accessed January 03, 2018, https://www.ncdot.gov/travel/trafficsystems/.

[5] Although CAVs include unmanned aircraft and autonomous ships, this report will focus on their implications for commercial and passenger transport (i.e., terrestrial transportation).

[6] "Automated Vehicles for Safety," NHTSA, February 07, 2018, https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety.

[7] Scott Corwin et al., "The Future of Mobility," *Deloitte Insights*, September 24, 2015, https://www2.deloitte.com/insights/us/en/focus/future-of-mobility/transportation-technology.html?id=us%3A2el%3A3dc%3Adup1374%3Aeng%3Acons%3Afom%3Adcpromo.

[8] Quoctrung Bui, "The Most Common Job In Every State," *NPR*, February 5, 2015, www.npr.org/sections/money/2015/02/05/382664837/map-the-most-common-job-in-every-state.

[9] Edward J. Malecki, "Digital Development in Rural Areas: Potentials and Pitfalls." *Journal of Rural Studies* 19, no. 2 (2003): 201–14. https://doi.org/10.1016/s0743-0167(02)00068-2.

[10] Michael B. Horn, "North Carolina's Digital Success Story," EdSurge, August 14, 2017, https://www.edsurge.com/news/2017-08-14-north-carolina-s-digital-success-story.

will explore how North Carolina can leverage its unique assets to create a public-investment model and pilot it through a rural CAV test site. Lastly, I will mention how North Carolina's involvement will help the broader project of developing CAVs while remembering our rural future.

Problem: Leaving Rural Communities Behind

THE DIGITAL DIVIDE AND WHY IT MATTERS

The digital divide is a modern infrastructure and human capital problem. It is an unequal distribution of ICTs, such as the internet, and the literacy to use them. From communicating with friends to accessing bank accounts, many basic tools have already moved online, and many more will join them. ICTs have slowly become a requirement to participate in the economy and to attain an adequate quality of life. As such, the digital divide has stymied development in disadvantaged areas and will prevent further development as we adopt CAVs. More specifically, "hard" telecommunication and "soft" human networks are required for development, especially in rural areas.[11] In other words, there needs to be both physical infrastructure and the people who know how to use it in order for rural areas to grow economically. Robust networks allow urban areas to connect and collaborate while rural areas become progressively more isolated from the global economy. In addition to geography, the digital divide exists on several other axes, including wealth, race, education, disability, and age.[12]

From computers to smartphones, rural Americans also use the internet and other digital technologies less than their urban and suburban counterparts, even when they do have them.[13] According to a Pew Research Center survey, rural Americans are 10 percent less likely to have home broadband than the average American.[14]

This difference is largely attributed to missing broadband infrastructure and slow speeds where the infrastructure does exist.[15] Unable to justify costs, private companies have not brought future-ready fiber-optic internet to rural North Carolina homes, leaving those communities less competitive.[16] As such, "digital readiness gaps" that prevent people from using ICTs to improve their quality of life persist throughout the country, especially in rural areas.[17]

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[11] Malecki, "Digital development."

[12] John B. Horrigan, "Digital Readiness Gaps," Pew Research Center: Internet, Science & Tech, September 20, 2016, http://www.pewinternet.org/2016/09/20/digital-readiness-gaps/.

[13] Ibid.

[14] Andrew Perrin, "Digital Gap Between Rural and Non-rural America Persists," Pew Research Center, May 19, 2017, http://www.pewresearch.org/fact-tank/2017/05/19/digital-gap-between-rural-and-nonrural-america-persists/.

[15] Blair Levin and Carol Mattey, "In Infrastructure Plan, a Big Opening for Rural Broadband," Brookings, February 10, 2017, https://www.brookings.edu/blog/the-avenue/2017/02/13/in-infrastructure-plan-a-big-opening-for-rural-broadband/.

[16] H. R. Trostle and Christopher Mitchell, "North Carolina Connectivity: The Good, the Bad, and the Ugly," Institute for Local Self-Reliance, October 2016, https://ilsr.org/wp-content/uploads/2016/10/NC-Broadband-Report_10_2016-1.pdf.

[17] Horrigan, "Digital Readiness Gaps."

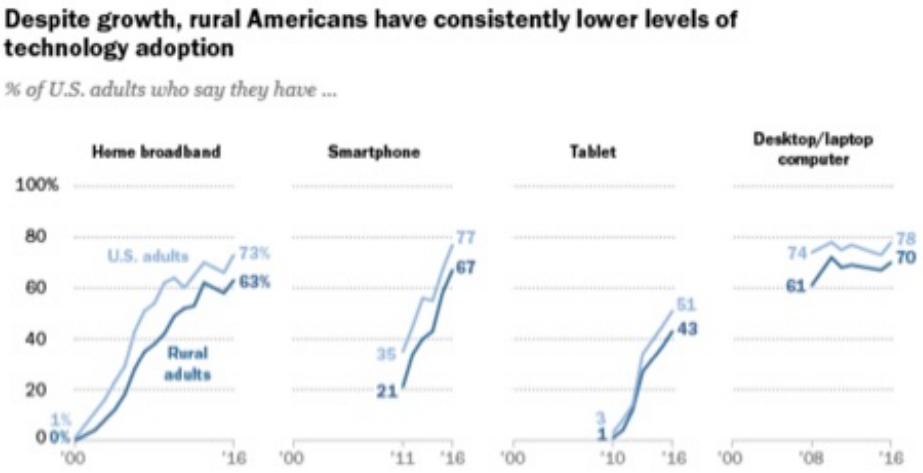

Figure 1: Rural and Non-Rural Broadband Access.

The digital readiness gaps are not only a problem for accessing existing online services; they will also impede the adoption of new technologies. According to the North Carolina Broadband Infrastructure Office, 93 percent of North Carolinians have access to broadband internet.[18] However, this rate reflects only the Federal Communication Commission's lowest connectivity standards. As such, internet connections in many rural communities will not be able to support CAVs, which will likely require new-generation 5G connections with download speeds up to 800 times faster than the aforementioned connectivity standards.[19] Private companies have little incentive to fix this disparity, since urban areas generate more profits and will see CAVs first.

The digital divide will only continue to grow as we make our systems "smart," particularly for sectors such as transportation. Markets will prefer dense, affluent urban cores and leave underprivileged communities increasingly behind. In short, there is a bidirectional relationship between CAVs and the digital divide. The digital divide prevents CAVs from entering and benefiting rural areas, while the investment in smart infrastructure needed for CAVs could help mitigate the digital divide by bringing fiber-optic internet. Increasing access to these technologies will help close the digital divide and help deploy CAVs in a more socially beneficial way.

SMART TRANSPORTATION: A NEW FRONTIER FOR THE DIGITAL DIVIDE

So far, the digital divide has primarily affected economic productivity. However, as we start to digitalize transportation, the divide will also begin to affect mobility and safety. This will leave rural areas not only more economically depressed but also more dangerous and inaccessible than urban areas. Therefore, rural residents have a disproportionate need for the productivity, mobility, and safety benefits that CAVs could bring. However, these prospects will be limited to wealthy urban areas unless we act now and deploy public funds.

Economically, building a new, smart transportation network would create opportunities by increasing productivity, just as building the interstate system did in the postwar era.[20] Investing in digitalized and

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[18] North Carolina Broadband Infrastructure Office, "Connecting North Carolina State Broadband Plan," June 2016, https://www.ncbroadband.gov/wp-content/uploads/2016/06/akljsnenx.pdf.

[19] Amy Nordrum and Kristen Clark, "5G Bytes: Millimeter Waves Explained," *IEEE Spectrum*, May 06, 2017, https://spectrum.ieee.org/video/telecom/wireless/5g-bytes-millimeter-waves-explained.

[20] Peter L. Singer, "Investing in 'Innovation Infrastructure' to Restore U.S. Growth," Information Technology and Innovation Foundation, January 2017, http://www2.itif.org/2017-innovation-infrastructure.pdf?_ga=2.79600279.2072571400.1525411293-2050394778.1525411293.

connected roads that support CAVs would spur productivity gains 60 percent more than investing in physical roads alone because the new network would unlock untapped resources and markets.[21] Increased productivity would help create markets for new services and goods based on the new technology. For instance, industries could develop around interactive, in-vehicle entertainment or a driverless fleet model for ridesharing. Furthermore, the new transportation network would connect commuters to more efficient transportation, thereby making them more productive as well. For example, commuters who would no longer need to drive could redirect their labor or spend more time on leisure, since they would spend an average of 50 fewer minutes driving.[22] (Strikingly, Americans collectively spent 6.9 billion hours in "traffic delays" in 2014.[23]) The saved time, in aggregate, would be a boon to our economy. Rural areas strongly benefited from the interstate highway system because of the increased productivity and development it brought to rural areas.[24] Similarly, a new smart transportation network would require significant investment in rural America, bringing capital and productivity to economically depressed areas.

Moreover, CAV technology can increase mobility for disadvantaged populations, such as the elderly and the disabled who struggle to transport themselves, especially in rural areas. For example, the 49 million people over the age of 65 and the 53 million disabled Americans could benefit from the technology.[25] CAVs could transport the elderly to the hospital or allow the disabled to work, "saving $19 billion in health expenditures" and increasing employment for "2 million individuals with disabilities."[26] Elderly and disabled rural Americans would especially benefit from these advances since they have many fewer transportation options than their counterparts in dense urban areas. For example, there are approximately 10 million elderly Americans living in rural areas, but "most have little or no public transit available" after losing the ability to drive safely.[27] The elderly and disabled need better transportation to lead "healthy and independent" lives, and they should not be denied transportation because they live in rural areas.[28]

Lastly, road safety is the most demonstrable benefit CAVs can provide, a benefit that the digital divide is increasingly affecting. "Human error" causes 94 percent of "serious crashes," which led to 35,092 deaths on American roads in 2015.[29] CAVs, if implemented properly, can prevent fatal accidents and save thousands of lives every year. The lives saved also have an economic impact. Based on a 2010 study conducted by the National Highway Traffic Safety Administration, accidents involving motor vehicles "cost $242 billion in economic activity…and $594 billion due to loss of life and decreased quality of life due to injuries."[30] Given the high costs of serious crashes, CAVs would only have to be slightly safer than human drivers for there to be measurable benefits.[31] Manufacturers are aiming for much higher standards. Rural areas would benefit the most

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[21] Ibid.

[22] Michele Bertoncello and Dominik Wee, "Ten Ways Autonomous Driving Could Redefine the Automotive World," McKinsey & Company, June 2015, https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/ten-ways-autonomous-driving-could-redefine-the-automotive-world.

[23] "Safety," NHTSA.

[24] Joseph Stromberg, "Highways Gutted American Cities. So Why Did They Build Them?", *Vox*, May 14, 2015, https://www.vox.com/2015/5/14/8605917/highways-interstate-cities-history &cd=4&hl=en&ct=clnk&gl=us.

[25] "Safety," NHTSA.

[26] Henry Claypool, Amitai Bin-Nun, and Jeffrey Gerlach, "Self-Driving Cars: The Impact on People with Disabilities," Ruderman Family Foundation, January 2017, http://rudermanfoundation.org/white_papers/self-driving-cars-the-impact-on-people-with-disabilities/.

[27] "Meeting Older Adults' Mobility Needs: Public Transit in Rural Communities," AARP, March 11, 2012, https://www.aarp.org/content/dam/aarp/livable-communities/act/transportation/public-transit-in-rural-communities-aarp.pdf.

[28] Ibid.

[29] "Safety," NHTSA.

[30] Ibid.

[31] Corwin et al., "Future of Mobility."

from these safety improvements since “the majority of highway fatalities take place on rural roads.”[32] Rural areas across the country have fatality rates that are more than twice as high as urban areas.[33] We should work to close the gap, not widen it by leaving the digital divide unaddressed.

However, the private sector is increasingly dictating how we will allocate this technology, and rural areas may fall behind. Recognizing the opportunity, the private sector has strongly supported CAVs to capitalize on the technology’s estimated $1.3 trillion in economic benefits.[34] For example, the top five car manufacturers spent $46 billion on developing CAVs in 2015 alone.[35] This investment will allow private companies to dictate how we allocate CAV technology, just as they did with the internet. The internet, when it was first developed in the 1970s and 1980s, did not garner much public interest, despite the vast economic impacts it would come to have. Similarly, wide deployment of CAVs—part of a larger “smart cities” trend—appears increasingly likely, although the public has not recognized the transition.[36] Fueled by private investment, the technology is moving from a fascination and a luxury to an economic reality and a way of life, whether the public realizes it or not.

The trend is similar to the internet’s proliferation in another way as well. Private companies have primarily built future-ready internet infrastructure in profitable urban areas. In the same way, if we do not influence the current trends, companies will primarily allocate CAV technology to more profitable urban areas while neglecting rural communities.[37] As such, CAVs will not improve everyone’s lives without public investment that helps equitably allocate them. Allowing the benefits to concentrate in affluent urban cores will further the digital divide, especially as CAVs push the limits of what is currently considered digital technology. Public funds should balance private investment so that we can ensure an equality of opportunity, something the market will not inherently support for public goods.

A CASE FOR STATE AND LOCAL ACTION

The federal government has tried to address the digital divide, but efforts have largely failed. State and local government have been left to make up for federal failure.

For example, the Federal Communication Commission's Lifeline program, which provides subsidies for ICT subscriptions, originally launched in 1985 for telephone subscriptions and was expanded to give discounts to internet plans as well.[38] Furthermore, between 2009 and 2015, the Obama administration, recognizing the digital divide and how it can limit people’s opportunities, upgraded over 100,000 miles of network infrastructure, allowing 45 million more Americans to use broadband internet.[39] However, the FCC voted to

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[32] "Local and Rural Road Safety Program," Federal Highway Administration, accessed March 9, 2018, https://safety.fhwa.dot.gov/local_rural/.

[33] Ibid.

[34] Claypool et al., “People with Disabilities.”

[35] Cameron F. Kerry and Jack Karsten. “Gauging Investment in Self-Driving Cars,” Brookings, October 16, 2017, https://www.brookings.edu/research/gauging-investment-in-self-driving-cars/.

[36] Rodger Lea, “Smart Cities: An Overview of the Technology Trends Driving Smart Cities,” *IEEE*, March 2017, https://www.ieee.org/content/dam/ieee-org/ieee-web/pdf/ieee-smart-cities-trend-paper-2017.pdf.

[37] Mabud and Seitz-Brown, “Wired.”

[38] “FCC Takes Major Steps to Transform Lifeline Program for Low-Income Americans,” FCC, November 16, 2017, https://apps.fcc.gov/edocs_public/attachmatch/DOC-347792A1.pdf.

[39] "Connecting America," National Archives and Records Administration, accessed November 12, 2017, https://obamawhitehouse.archives.gov/node/343086.

scale back the Lifeline program in 2017, and the Obama administration primarily offered basic broadband connections that need to be upgraded again to remain competitive.[40]

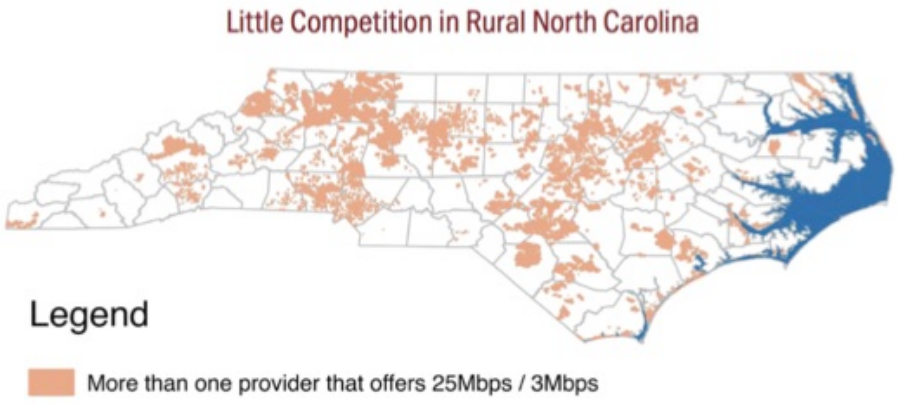
Ultimately, the federal government has failed to create a comprehensive program to address the digital divide or create ICT-connected communities. There have only been cursory or inconsistent policies. More importantly, there is no analog to the Rural Electrification Administration, which loaned money to electric cooperatives in unprofitable locations and helped build citizen-owned infrastructure.[41]

Because the federal government has failed to address the digital divide in a meaningful and comprehensive way, states and local governments are left to fill in the gaps. They must take initiative and invest in the technology they need, especially to be future ready. Although this is not ideal, since there is less money available, states and local governments can tailor solutions more specifically to their circumstances.

Background and Context: North Carolina

REASON FOR ACTION: DISPROPORTIONATE OUTCOMES

North Carolina has the second-largest rural population in the country, with over 3.2 million rural residents. These citizens are disproportionately impacted by both the digital divide and road safety issues, making CAV technology central to North Carolina's rural future.[42]



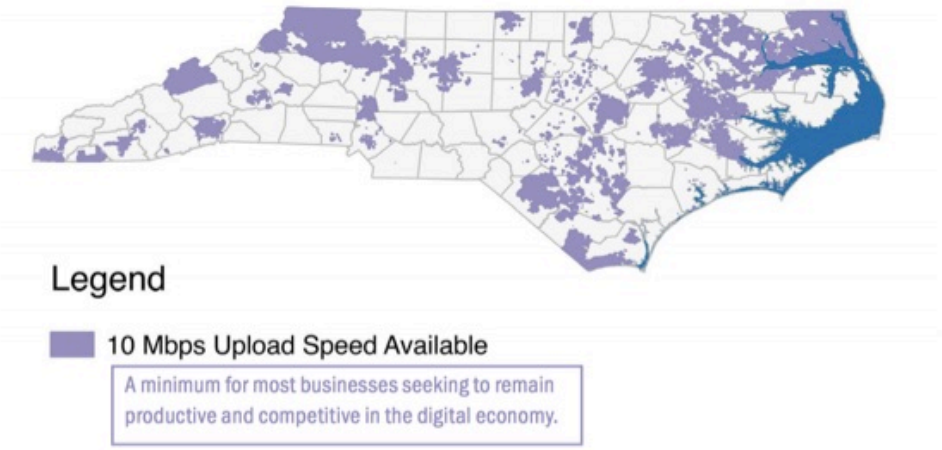
Map 2: High-Speed Internet Access Competition
Based on FCC Form 477 Data from June 2015, Released March 2016

[40] "FCC Lifeline Program;" "Connecting America."

[41] Harold D. Wallace, Jr., "Power From the People: Rural Electrification Brought More Than Lights," National Museum of American History, February 12, 2016, http://americanhistory.si.edu/blog/rural-electrification.

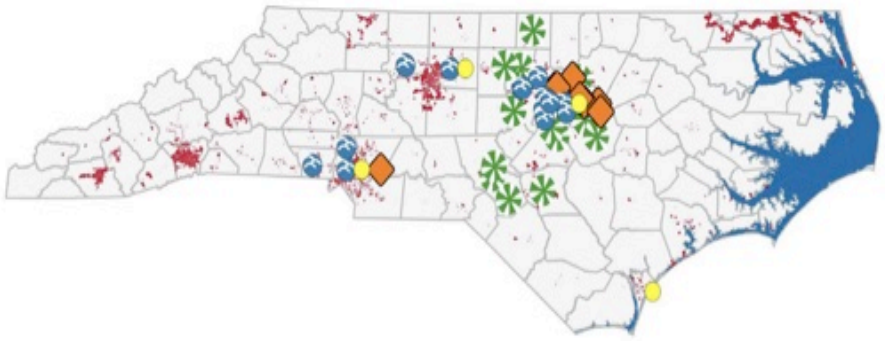
[42] "Growth in Urban Population Outpaces Rest of Nation, Census Bureau Reports," US Census Newsroom Archive, March 26, 2012, https://www.census.gov/newsroom/releases/archives/2010_census/cb12-50.html.

Rural Areas Lack Higher Capacity Connections



Map 3: North Carolina homes and businesses with access to a 10Mbps upload connection
Based on FCC Form 477 Data from June 2015, Released March 2016.

Private Providers' Future FTTH Plans Show Continued Metro Bias



Map 5: Private Providers' FTTH Expansion Plans
Based on 2010 Census Data and 2015 press releases/news reports (subject to change).
Time Warner Cable's are announced speed upgrades.

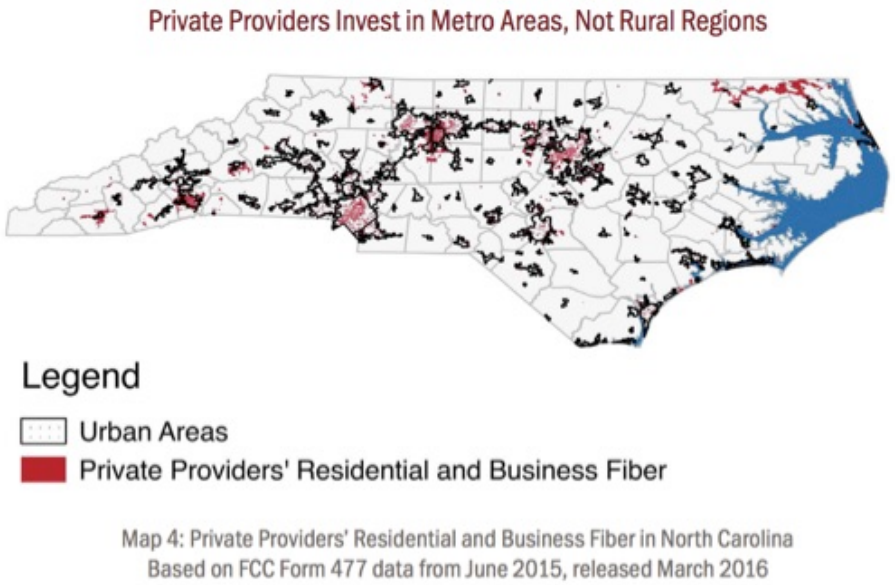


Figure 2: ICT Infrastructure Investment in North Carolina.

First, the state's rural residents generally have access to fewer and lower-quality broadband options than their urban counterparts, and this results in disparate economic outcomes. Four out of five rural North Carolinians do have access to the minimum standard for broadband connectivity (i.e., 25 Mbps download and 3 Mbps upload).[43] However, this figure is not as promising as it may seem. The minimum standard for broadband will not be fast enough for newer technologies, and the statistics on internet speeds are self-reported by providers and thus could be inflated. For the rudimentary connectivity that is available, 88% of rural residents only have one provider, thereby leaving consumers open to price gouging and poor service.[44]

Furthermore, private providers are not expanding next-generation fiber-optic networks in rural areas. Instead, using state and federal subsidies, they are investing in better networks for urban areas; there are no private providers investing in fiber-optic networks in rural North Carolina.[45] Together, North Carolina's digital divide has contributed to the widening economic disparities between urban and rural parts of the state.[46] While urban areas like the Research Triangle and Charlotte are experiencing high economic growth, rural North Carolina continues to decline.[47] North Carolina has a reason to act: to help publicly fund digital infrastructure to ensure fairer outcomes.

Moreover, rural North Carolinians are disproportionately impacted by dangerous roads. While only 31% of the population lives in rural areas, 62% of road fatalities in the state happen on rural roads.[48] CAVs can drastically decrease road fatalities, but they require robust testing and smart infrastructure backed by fiber-optic internet

[43] Trostle, "North Carolina Connectivity."

[44] Ibid.

[45] Ibid.

[46] "North Carolina Annual Economic Report," North Carolina Department of Commerce, June 30, 2017, https://www.nccommerce.com/Portals/47/Publications/NC 2016 Economic Report.pdf.

[47] Ibid.

[48] "Keeping North Carolina Mobile: Progress and Challenges in Providing an Efficient, Safe and Well-Maintained Transportation System," TRIP, May 2017, http://www.tripnet.org/docs/NC_Progress_and_Challenges_TRIP_Report_May_2017.pdf.

to do so.[49] The state should be an influencer in how CAV technology will manifest in rural areas because its millions of people need it to ensure fairer outcomes between urban and rural areas. North Carolina has a reason to act: to help test vehicles in rural areas and to build infrastructure to facilitate them.

The good news is CAV deployment is not the first time North Carolina has dealt with unequally distributed information and communication technologies. The state has a history of investing in ICT technologies and expanding access. North Carolina has demonstrated a commitment to not only increase access, but also to involve private companies in the process. In 1993, the state created the "longest public switched fiber-optic network in the world" and by 2018, it will finish connecting all public school classrooms with broadband Wi-Fi.[50] Both of these efforts were completed with both public and private partners. Drawing on its history with broadband access, North Carolina can find innovative solutions to prevent unequally distributed CAV technology.

RIPE FOR CHANGE: CAV TEST SITES AND STATE INFRASTRUCTURE

The CAV testing sites in North Carolina are both a part of the problem and the solution for the state's widening digital divide.

During the Obama administration, the DOT set out to designate automated vehicle proving grounds across the country to help facilitate testing. The DOT does not provide funding or technical assistance, but rather creates a community of proving grounds to test the technology, highlighting states and specific sites where there has been considerable technological innovation and state government support for it. According to the USDOT AV Proving Grounds:

> The U.S. Department of Transportation (DOT) has designated 10 proving ground pilot sites to encourage testing and information sharing around automated vehicle technologies. These proving ground designations will foster innovations that can safely transform personal and commercial mobility, expand capacity, and open new doors to disadvantaged people and communities. The proving grounds will also provide critical insights into optimal big data usage through automated vehicle testing and will serve as a foundation for building a community of practice around automated vehicle research.[51]

The North Carolina Turnpike Authority, an agency within the North Carolina Department of Transportation (NCDOT), was selected to administer one of the 10 proving grounds because of its advanced tolling technologies, which could be used to test CAVs. The North Carolina proving ground consists of two urban sites: the NC 540 Triangle Expressway toll road and the NC 55 connected corridor. The Triangle Expressway and its advanced tolling system were built to reduce congestion and connect previously underserved areas, while the connected corridor was created as a way to test dedicated short-range communication (DSRC) technology, a wireless channel similar to Wi-Fi.[52]

The smart infrastructure on the Triangle Expressway and the connected corridor can help inform what technologies are necessary to digitalize transportation. According to the NCDOT, the Triangle Expressway uses

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[49] McCauley, "Infrastructure Disrepair."

[50] "2017 Broadband Communities Summit," Broadband Communities, accessed January 3, 2018, http://www.bbcmag.com/2017s/17bio/Patterson-jane.php; Horn, "Digital Success Story."

[51] US DOT AV Proving Grounds, accessed January 3, 2018, http://www.nationalavpg.com/.

[52] "North Carolina Turnpike Authority: Triangle Expressway Project Engineering Report," North Carolina Department of Transportation, March 20, 2009, 24–27, https://www.ncdot.gov/projects/triangleexpressway/download/triex_docs_CER03-20-09with4-14-09addendum.pdf.

64 microwave vehicle-detector locations, one every mile; 14 CCTV camera locations; 11 dynamic message sign locations; and one environmental sensing station. The toll collection on the turnpike is cashless, relying entirely on electronic toll collection.[53] Customers may pay using transponders, and those without transponders will be charged via video-electronic tolling based on automatic vehicle identification and optical character recognition.[54] Finally, there are "two parallel fiber-optic backbone communication networks" to manage data for ITS and toll operations.[55] The connected corridor, on the other hand, has a series of intersections equipped to communicate with CAVs using DSRC.[56] For example, the intersection can notify DSRC-equipped vehicles when the traffic light is about to change.

The two sites demonstrate how the digital divide continues to worsen and favor urban, wealthy areas. Market-based technology investment will mostly happen in wealthy urban cores such as the Triangle, not rural areas. Simultaneously, the test sites have brought the prospect of CAVs to North Carolina, encouraging government officials and business people to discuss how to move forward with the technology in the state. Considering that North Carolina is in the early stages of adopting a smart mobility plan for CAVs, the state is ripe for change. North Carolina can think about how to include rural communities in this technological innovation from the beginning, and the way to do that is through smart infrastructure. The following section will explain how publicly funding smart infrastructure will give North Carolina control over how equitably it can allocate CAV technology and its benefits.

Technology Explained: Internet-Connected Infrastructure is Crucial

CAV INNOVATION: A PUBLIC-PRIVATE STORY

CAVs have grown as a project between industry, government, and academia in North America, Western Europe and East Asia. All three partners, especially industry and government, have shaped the direction that the technology has taken. The story began in 1977 when the "first truly autonomous car" made its debut in Japan.[57] Advances in processing power and embedded sensors have made the technology practical—ready for testing and eventually deployment. Most importantly, the historical collaboration between the public and private sectors on CAV technology demonstrates how we should continue to move the technology forward.

There have been three noteworthy developments since 1977 that illustrate how public-private collaboration has brought CAVs to their current state. German-led engineers in the late 1980s and early 1990s solidified the predominance of "vision-based systems."[58] Using cameras, cars can "see" road conditions, including "road markers" and "simulated traffic," and drive.[59] This was primarily done by industry. Then, starting in 2004, the US Department of Defense's Defense Advanced Research Projects Agency issued three "prize-based" races: two

[53] Ibid.

[54] Ibid.

[55] Ibid.

[56] Ibid.

[57] Tom Vanderbilt, "Autonomous Cars Through the Ages," *Wired*, February 06, 2012, https://www.wired.com/2012/02/autonomous-vehicle-history/.

[58] Ibid.

[59] Ibid.

in the desert and one in a simulated urban environment.[60] These Grand Challenges piqued interest in CAVs and spurred development. Lastly, in 2015, the University of Michigan opened Mcity, a mock city in Ann Arbor to simulate urban driving in various scenarios.[61] Several original equipment manufacturers have begun testing their technology in the facility. The DOT, the state of Michigan, and the city of Ann Arbor have also backed the initiative.[62] Mcity's development represents a push to refine and ultimately deploy automated vehicle technology.

Research is now happening on multiple fronts but is largely confined to urban areas. Industry and government have two different but equally crucial roles to play in developing CAVs. Industry has focused on automating vehicles, while the government has emphasized creating the connected infrastructure to support such vehicles and make them beneficial to all.

Thus, the twin processes of connecting and automating represent a partnership between government and industry. A similar relationship existed as the automobile rose to prominence; industry built the cars while government provided the roads and, in particular, the interstate that made the technology much more useful. With CAVs, the technology cannot function well without infrastructure that eases the vehicle's processing burden. Consequently, the way that the government can ensure that there is equal access to CAVs is by building the smart infrastructure to host them instead of letting the market allocate them. The CAVs and their benefits will go where the infrastructure is—just as the internet did.

AUTOMATING VEHICLES: A PRIVATE VENTURE

The private sector has spearheaded the process of automating vehicles. An automated vehicle can sense its surroundings, process the information, and act accordingly. More specifically, cameras have become a staple. Additionally, radar senses position and motion, laser-based light detection and ranging detect shape, and ultrasound registers close surroundings. Automated vehicles process this information using complex tools, such as machine learning, to classify sensor data as objects (e.g., a car or a pedestrian), thereby understanding the environment. Coupled with technologies like GPS, the car can navigate.

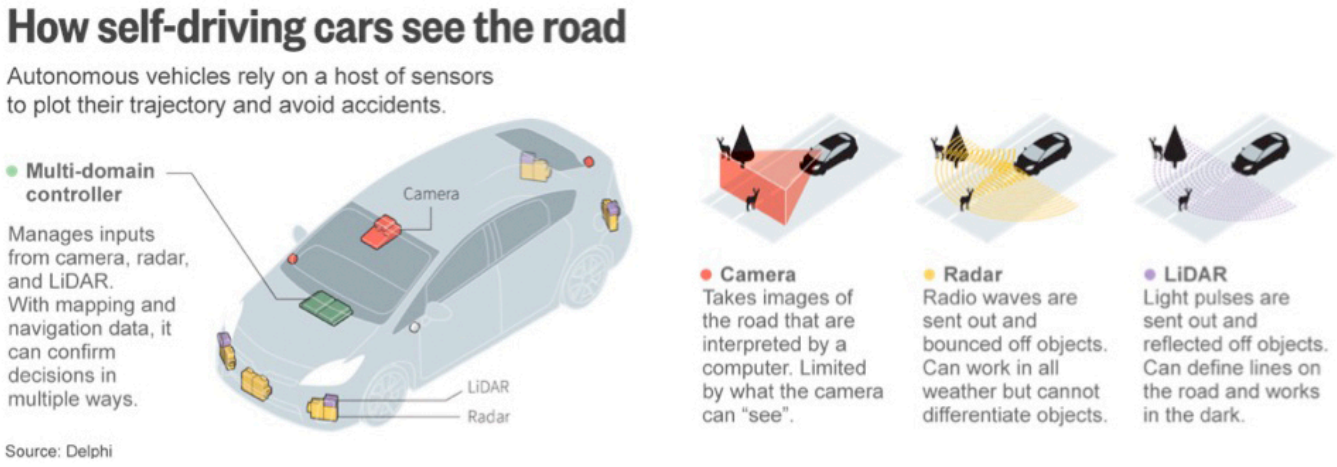

Figure 3: How Automated Vehicles See the Road.

[60] "The DARPA Grand Challenge: Ten Years Later," Defense Advanced Research Projects Agency, March 13, 2014, https://www.darpa.mil/news-events/2014-03-13.

[61] "Government," accessed February 6, 2018, https://mcity.umich.edu/our-partners/government/.

[62] Ibid.

An important distinction to make is that automation is not binary. The Society of Automotive Engineers and the National Highway Traffic Safety Administration have classified automation into five levels, from "no automation" to "full automation."[63] Each progressive level requires less human input than the last, incorporating features like cruise control at the lower end to automatic lane changing at the higher end. Progressing to level-five automation will require manufacturers to improve their sensing and processing capabilities. Machine learning models, for instance, need vast amounts of training and validation data to properly classify sensor readings as real-world objects. Therefore, thorough automated vehicle testing has become critically important.

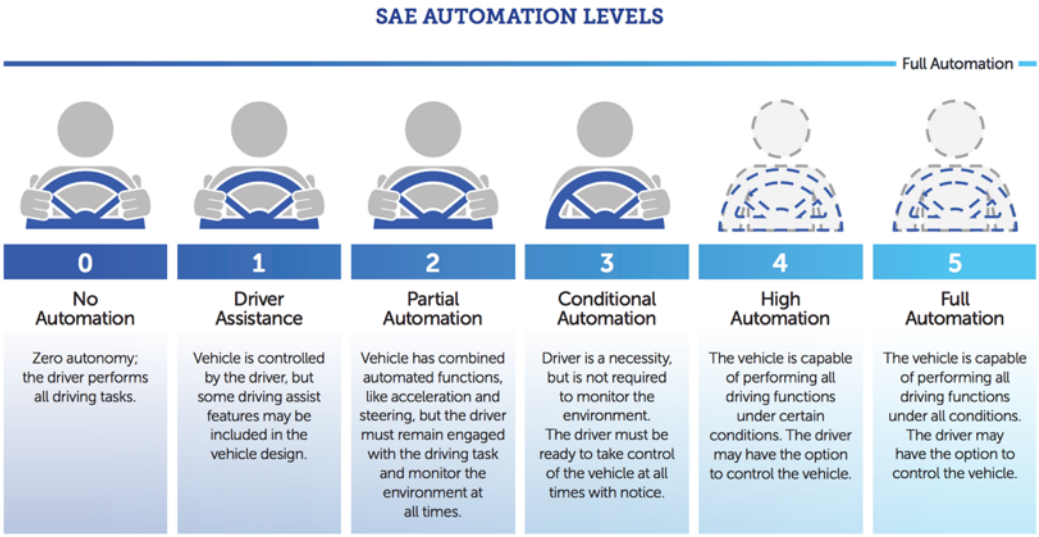

Figure 4: Levels of Automation.

CONNECTING VEHICLES: A PUBLIC RESPONSABILITY

Connectivity is a less discussed yet important dimension of the transformation happening in transportation technology—and one that the government will largely be responsible for. Creating fully automated vehicles capable of driving on varied terrain is incredibly difficult. Connected vehicles, on the other hand, would rely on vehicle-to-infrastructure (V2I) communication to ease their burden. Roads, intersections, and other sensor-embedded infrastructure can send important information to vehicles using V2I technologies. This can include data such as "construction zones and closed roads," transmitted through DSRC.[64] Vehicle-to-vehicle (V2V) communication allows vehicles themselves to transmit and read information about driving conditions and vehicle positions. V2V communication, which also often happens over DSRC, can play a crucial role in preventing collisions between vehicles, for example. Such capabilities will allow intelligent transportation systems to collect more data and manage traffic more effectively.[65] Essentially, connectivity will increase the productivity, mobility, and safety benefits CAVs can have by supporting the vehicles and democratizing the benefits.

[63] "Safety," NHTSA.

[64] McCauley, "Infrastructure Disrepair."

[65] Miad Faezipour et al., "Progress and Challenges in Intelligent Vehicle Area Networks," *Communications of the ACM* 55, no. 2 (2012): 90, https://doi.org/10.1145/2076450.2076470.

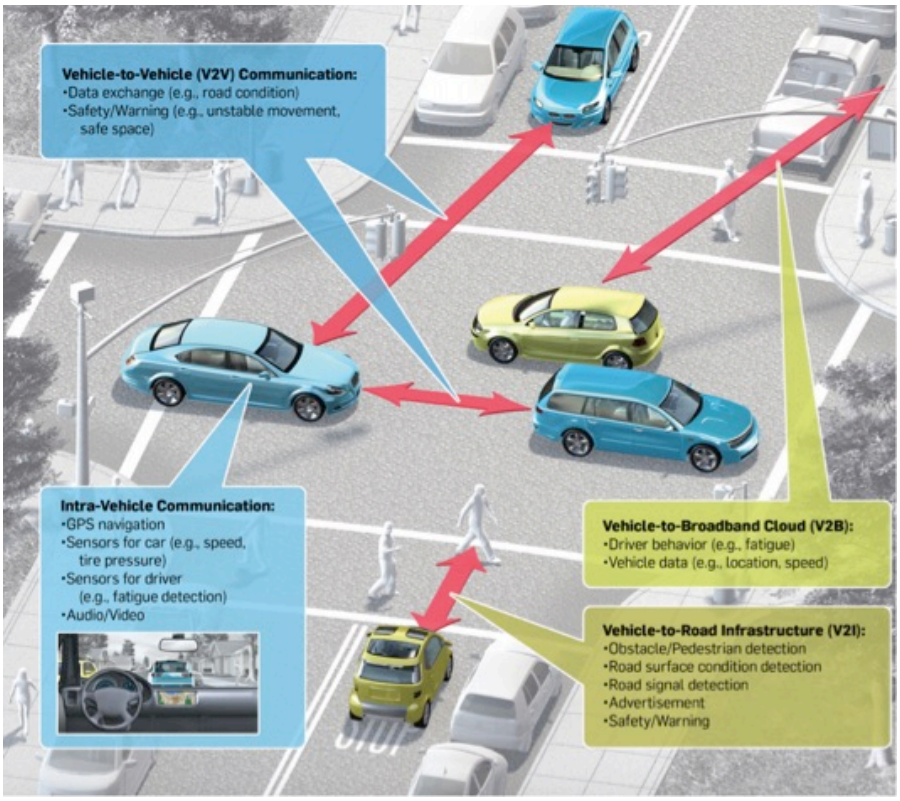

Figure 5: Connected Vehicle Technologies.

Solution: Public Involvement in Connected Infrastructure

BRIGHT FUTURES ACT: PUBLIC-PRIVATE PARTNERSHIPS AND WORKFORCE DEVELOPMENT

Legislators in the NC House of Representatives hope to support BRIGHT (broadband, retail online services, internet of things, grid power, health care, and training) markets in rural areas by passing the BRIGHT Futures Act. This piece of legislation will have a strong influence on how the state and municipalities will finance smart infrastructure and think about automation in transportation.

The bill, as passed by the NC House, acknowledges several points: (1) North Carolina has the second-largest rural population in the US; (2) rural areas receive infrastructure development last; (3) unevenly allocated advances in "gigabit connectivity and automation" threaten rural economic prosperity; (4) the North Carolina General Assembly has explored "member-owned utilities and public-private partnerships" to encourage development; (5) digital infrastructure is crucial to economic development.[66] Key provisions include the following: granting municipalities the authority to lease city-owned properties and enterprises; establishing the

[66] H.R. 68, North Carolina General Assembly (2017), http://www.ncga.state.nc.us/Sessions/2017/Bills/House/PDF/H68v2.pdf.

North Carolina Board of Science, Technology, and Innovation in the Department of Commerce to focus on BRIGHT market growth; and encouraging workforce development through NCWorks.[67]

The bill represents an initial systematic solution to the digital divide. However, there is no mechanism or entity that offers technical and logistical assistance to local governments hoping to expand into BRIGHT markets. The North Carolina Broadband Infrastructure Office (NCBIO) could be an important resource for local governments, as it is currently tasked with facilitating broadband infrastructure investment, development, and use. Despite that, it is not mentioned in the bill. To improve this, a provision should explicitly task the Broadband Infrastructure Office with exploring how to help local governments invest in not only broadband infrastructure but also internet-connected smart infrastructure more broadly.

The bill also does not directly address how to stem automation, which is especially important when considering CAVs in North Carolina. Trucking is the most popular job in the state.[68] As such, implementing the BRIGHT Futures Act with a special emphasis on automation will allow the NC Department of Commerce and NCWorks to prepare for the loss of trucking jobs. Under the No Adult Left Behind Initiative detailed in the bill, the NCWorks Commission should produce a report detailing how automation may affect the state's jobs and what sorts of community college degrees may help people find other opportunities if displaced.

A RURAL TEST SITE: A PILOT

Since the US DOT has designated an AVPG in North Carolina, the NCDOT should use the momentum to develop a rural testing location. Firstly, this will help demonstrate a rural smart infrastructure investment model based on public-private partnerships as outlined in the BRIGHT Futures Act. Any tests conducted at the site will help initiate further road safety improvement efforts by perfecting CAV technology. Simultaneously, connecting infrastructure to the internet will help mitigate broadband access disparities in rural areas. Lastly, a rural test site would encourage private research and development that would have beneficial public consequences. For example, companies would benefit by testing their CAVs in "conditions not easily replicated in cities," and the USDOT could use the research to help standardize protocols and regulations across the country.[69]

More specifically, local governments near the site and the NC DOT Research and Development group should fund the necessary smart infrastructure, including V2I sensors and fiber-backed wireless broadband. Furthermore, the University of North Carolina's Highway Safety Research Center should help administer the testing location to ensure that rural communities benefit from the private partnerships created and from the data collected.

National Rural Testing: An Additional Benefit

The only rural testing environments in the US are either simulated or poorly monitored. With a rural test site, North Carolina can help shape how the rest of rural America will test and adopt CAVs, setting a precedent for equitable infrastructure investment. For example, both the American Center for Mobility and the Virginia Smart Road plan to create simulated rural environments to test CAVs, and the Florida AVPG has stretches of rural road for live testing but not much monitoring.

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[67] Ibid.

[68] Bui, "Most Common Job."

[69] Derek Pankratz, "Rethinking Self-driving Cars in Rural Areas," Deloitte, September 04, 2017, https://innovation-in-manufacturing.deloitte.com/2017/05/23/self-driving-cars-rural-areas/.

There is a tradeoff between simulated and live testing. Simulated environments are very important for testing during initial development, but such testing locations do not allow manufacturers to test their vehicles on public roads set up the way they likely will be in the future. They do not allow manufacturers to test their vehicles with real drivers and other uncontrollable variables. More importantly, simulated and poorly monitored live testing environments do not help rural areas receive the same infrastructure investment as urban areas. Investing in rural smart infrastructure, on the other hand, will allow for well-monitored live testing that can ensure safety on roads while gleaning important insight. As CAV technology matures, these are the kinds of test sites manufacturers will need, and these are the sites that will help determine how we will improve our transportation infrastructures to equitably accommodate CAVs.

North Carolina is well-positioned to host national rural testing since it is home to several trucking companies, such as Daimler and Volvo, that are interested in testing their CAV technology. Rural areas are especially important for testing commercial CAVs such as freight trucks, since rural roads form a large part of their travel. Companies, especially trucking and logistics ones, are likely looking for locations to test their technology and may possibly fund the necessary infrastructure through public-private partnerships.

Conclusion: Remember Rural

The digitalization and automation happening in transportation have the potential to bring substantial benefits to all people, especially in terms of safety, mobility, and productivity. However, markets will unequally allocate necessary smart infrastructure and leave rural communities behind. Markets will exacerbate the digital divide, which already limits rural productivity and is now creeping into safety and mobility as well. As such, North Carolina should begin publicly investing in rural smart infrastructure by making a rural CAV test site. To do so, the BRIGHT Futures Act bill should be modified to task the NCBIO with facilitating public-private partnerships for local governments that want to invest in smart infrastructure. In short, as North Carolina prepares its urban future, the state needs to remember its rural one.

Appendix: List of Abbreviations and Acronyms

AVPG: Automated Vehicle Proving Ground
CAV: Connected and Automated Vehicle
DOT: Department of Transportation
DSRC: Dedicated Short Range Communication
ITS: Intelligent Transportation Systems
LIDAR: Light Detection and Ranging
Mbps: Megabits per Second
V2I: Vehicle-to-Infrastructure
V2V: Vehicle-to-Vehicle