



NORTH CAROLINA
Department of Transportation



NC MOVES 2050

Drivers and Opportunities –
Technology

March 2019

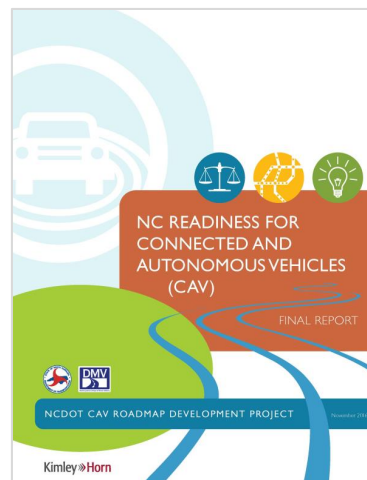
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EXECUTIVE SUMMARY

Executive Summary

- **Technology is a vital aspect** of North Carolina's future. It is a major force of change and has the potential to transform the transportation system in beneficial and challenging ways.
- **North Carolina** has already joined the national conversation around transportation technology with groups like NC Readiness for Connected and Autonomous Vehicles (CAV).
- **Automated and connected vehicles** are expected to comprise the majority of new vehicle sales within two decades. Whether autonomous vehicles will be shared or private remains to be seen; shared and private AVs will provide different sets of outcomes, benefits and challenges.
- **Electric vehicle (EV)** technology is improving and sales are increasing. While EVs are only 1% of US vehicle sales today, the US Energy Administration estimates that EVs will comprise 19% of US market share by 2050. Bloomberg New Energy Finance forecasts EVs are currently just under 2% of global vehicle sales, which will grow to 55% of all new car sales by 2040.



The Triangle Expressway in western Wake County

Sources, Top, Left to Right: NCDOT and NCDMV; Waymo; News & Observer photographer Chuck Liddy.

Executive Summary (continued)

- Unmanned aerial vehicles, or **drones**, offer many potential, cross-sector benefits.
- **Micro-mobility** – small, human- and electric-powered transportation solutions (scooters and bicycles) – are becoming increasingly important to mobility systems in urban areas.
- Growth is shaping new multi-jurisdictional boundaries and creating demand for **daily, high-speed connections** between regions. High-speed rail and less traditional alternatives (such as Hyperloop) are being considered across the country.
- **Technology offers a world of opportunities to North Carolina and North Carolina Department of Transportation (NCDOT)**, including investments in planning pilots, testing and deployment, exploration of new and emerging data sources, and engaging in discussions of cybersecurity risks.
- NCDOT has an **essential role** in the discussion of the future of technology in North Carolina. The growth of private transportation providers carries the risk of marginalizing the public good in areas such as equity and environmental sustainability.



Sources, Top to Bottom: Eric Baradat/AFP/Getty Images; Los Angeles, USA Today

INTRODUCTION

Technology, a Vital Aspect of North Carolina's Future

Successful implementation of NC Moves 2050 requires an understanding of what the future holds for transportation.

NC Moves 2050 enables NCDOT and its partners to:

- Identify emerging topics, trends and disruptors to lay the groundwork for possible transportation futures;
- Identify threats and opportunities;
- Develop and test strategies;
- Forecast potential impacts of action and inaction; and
- Craft an actionable plan to reach the State's goals.

Technology is a major force of disruption and it changes the transportation system in unexpected ways, including:

- Providing opportunities for greater efficiency;
- Improving safety; and
- Creating new ways to satisfy supply and demand for movement of people and goods.

There is great uncertainty surrounding the impacts of technology. Things like the timing of advances, level of implementation and the impact of third party data providers are unclear.

As a result, no forecast will be perfect and NCDOT must prepare for a variety of potential futures. One thing is certain - **technology will play a fundamental role** in all modes of current and future transportation by 2050.



Downtown Raleigh, N.C.



Lynn Cove Viaduct

Sources: Photographers Delores Wells, Matthew Paulson

Era of Change Provides Opportunities

The transportation industry is in a period of tremendous upheaval and uncertainty but also on the edge of exciting breakthroughs, including:

- **Automated vehicle (AV) technologies** to potentially transform personal and freight travel, business models, land use and quality of life;
- **Vehicle and personal connectivity** to shared platforms allowing for greater communication and coordinated operation than ever before; and
- **New fuels, vehicle ownership models, and even modes of transportation** fueled by innovation and the aspiration for on-demand transportation.

As technology evolves and transforms mobility solutions, public agencies will need to consider how these technologies can affect everyday work – both individually and collectively – and continue planning for these changes. State and local governments can:

- **Play a leadership role** by proactively engaging the technology industry and identifying partnership opportunities which benefit customer needs; and
- **Identify responsive policies and strategies** which prepare them to navigate the changing technological landscape and continue to advance goals, programs and objectives.



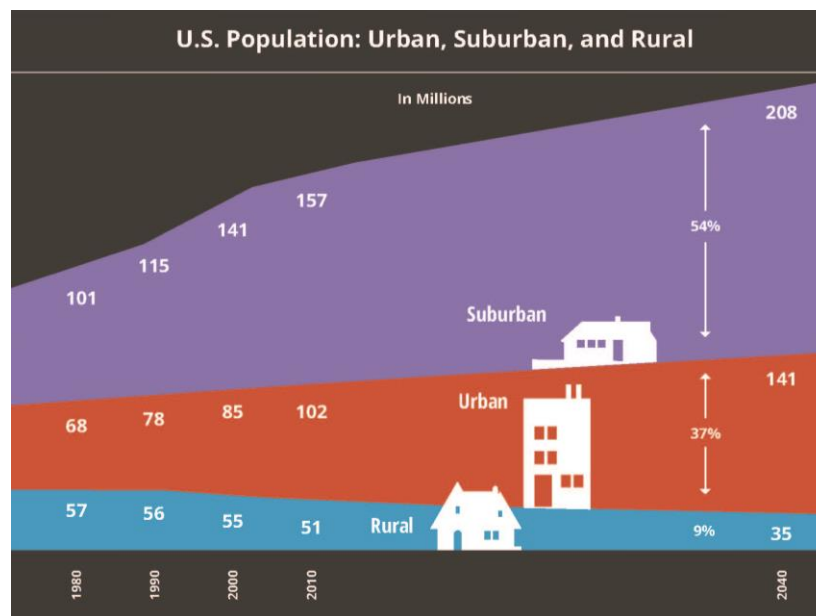
This era of change provides opportunities to harness emerging technology and make North Carolina safer, more efficient, more vibrant and competitive.

Source: Cambridge Systematics

WHERE ARE WE TODAY?

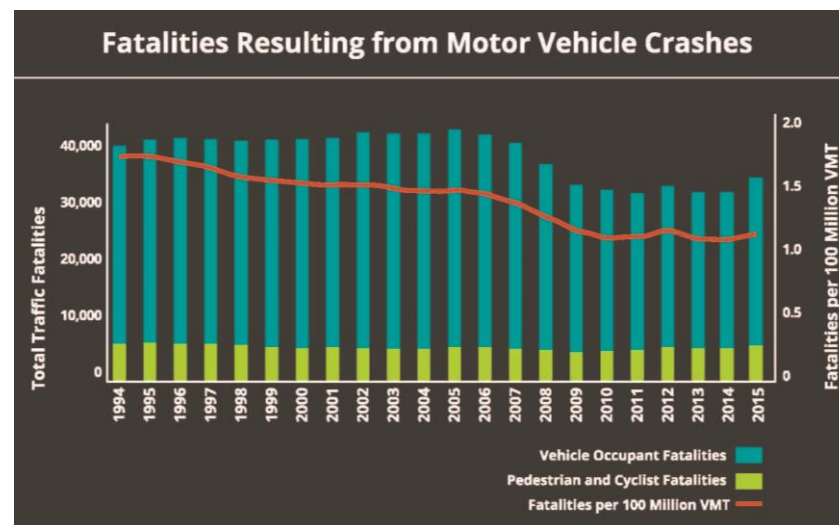
National Demographics Will Shape Demand for Transportation Technology

- Global economic, demographic and spatial forces have culminated in the growth and **revitalization of urban areas** across the US in the last two decades.¹
- Transportation plays a crucial role in connecting urban areas, surrounding suburbs and rural areas for North Carolina.
- Within metro areas, **suburbs may continue to see the highest growth rates** in North Carolina.
- National and state **demographic trends** – such as the senior population doubling by 2045 – **will shape travel demand** within and between regions in North Carolina and determine the demand for and role of transportation technology.
- In North Carolina, two-thirds of projected population growth is anticipated to concentrate in **the Triangle and Charlotte regions**.
- In North Carolina, and across the country, urban and suburban **regions have diverging travel demand** markets. For example, in dense, urban areas where auto congestion is common, there is a demand for short, non-motorized trips on electric scooters or bicycles.



National Transportation Trends Will Define Technology's Role in North Carolina

- **Automation** is likely to affect all modes of transportation. Infrastructure maintenance, travel safety, and adoption of autonomous vehicles are likely to experience rapid change in the near-term.²
- **Technological changes** and innovation may transform vehicles, infrastructure, logistics and the delivery of transportation services.
- For example, the **automation of trucks** is being tested today. With projected freight volumes increasing by more than 40% by 2045,² and demand for faster and more deliveries continues to increase, it is likely that automation will transform logistics in the short-, medium- and long-term.
- **Rising sea levels** and more frequent and intense **storms** are likely to affect the reliability, cost of maintenance and even the longevity of critical infrastructure like highways, bridges and coastal ports.

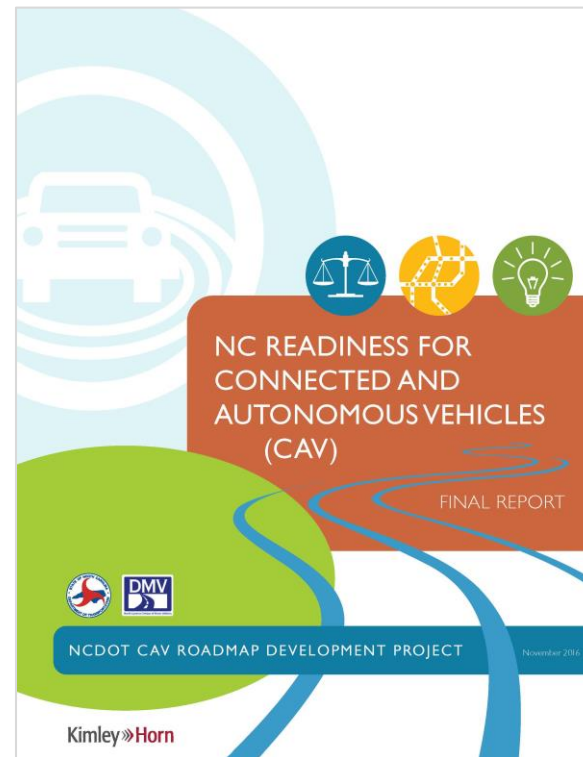


Source: U.S. DOT, *Beyond Traffic 2045*

North Carolina Begins to Advance and Deploy New Transportation Technologies

New legislation and emerging technology transportation companies are beginning to drive a conversation about the role of transportation technology in the state:

- **Automated Vehicles Roadmap for NC:** An intergovernmental group committed to assessing current AV technology and relating its current and potential future role in North Carolina.³
- **AV-friendly Legislation:** In 2017, the state passed two bills to authorize truck platoon testing and the operation of fully autonomous vehicles on state roadways.
- **Micro-mobility in urban North Carolina:** LimeBike, Bird scooters and Citrix Cycle have all launched in Raleigh, Charlotte and Greensboro in the last two years.



Source: NCDOT and NCDMV,
http://www.ncav.org/wp-content/uploads/2016/03/NC-Roadmap-for-CAV_Final_ALL.pdf

North Carolina Begins to Take Part in Growing Transportation Technology Fields

- **AV Testing on the Western Wake Freeway/Triangle Expressway:** This toll facility is one of only 10 test sites in the nation where truck platooning technology is being tested.
- **App Integration:** GoTriangle, Uber and TransLoc launched the nation's first regional service and Transportation Network Company (TNC) platform. The app provides a single platform for GoTriangle riders who want to hail an Uber to get to or from the bus stop.
- **NCDOT's Unmanned Aircraft Systems (UAS) Program Office:** NCDOT is a national leader in the development of regulations and permitting systems for drones and unmanned aircraft systems.
- **Signal Phasing and Timing (SPaT) Challenge:** NCDOT met an FHWA challenge to test coordinated signal systems and broadcasts to drivers at more than 20 intersections on NC55 in Cary.
- **Active Traffic Management System on I-95/US 70 (future I-42):** Communications related investments will enable NCDOT to utilize Integrated Corridor Management to operate US 70 (future I-42) and I-95 in a coordinated, reliable manner.



North Carolina Highway 540

Source: Commercial Carrier Journal, Justin Kase Conder

WHERE WE ARE GOING

Automated Vehicles: What and Why

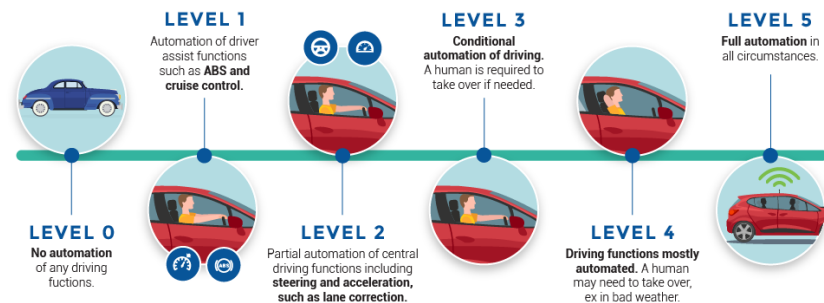
- Automated vehicles (AVs) are vehicles that can operate **without direct driver input** and are designed to perform driving tasks to the extent that the driver does not have to constantly monitor the road.
- The range of automated functions can vary. A Level 5 “fully automated” vehicle does not require traditional controls, such as a steering wheel or gas and brake pedals.⁴

There are **many potential benefits** to AVs, such as:

- Improved road safety
- More equitable access
- Reduced stress of driving
- Smarter acceleration and deceleration that could reduce fuel consumption and emissions
- Reduced crashes (and associated incident congestion)
- Economic gains of less “lost” productivity



Levels of Autonomous Driving Technology



Source, top to bottom: Transport Topics, rexworld/Flickr; CAA infographic

Automated Vehicles: Two Business Models

There are **two potential business models** for advancing AVs: a private ownership model or a shared mobility model.

Five variables will influence **when** AVs will arrive and **which model** is more likely to be adopted:

1. The speed of technological advancement
2. The economics – how inexpensive the technology, or the service, will be
3. Public acceptance
4. Political support
5. Whether there is a viable market and business case for a shared model in a particular place

Private Ownership



- Driven by auto industry
- Incremental moves in functionalities
- Privately owned
- Here today

Shared Mobility

MaaS/TaaS/Robo-Taxis



- Driven by tech and ride-hailing companies
- Jump to fully automated
- Mobility-as-a-service
- A few (or many, many) years away

Vehicles and Infrastructure Are More Connected than Ever

Connected vehicles (CV) and “smart” infrastructure use mechatronics, telematics and artificial intelligence technologies to interact with the environment and provide greater safety, comfort, entertainment and a “connected-life” experience.

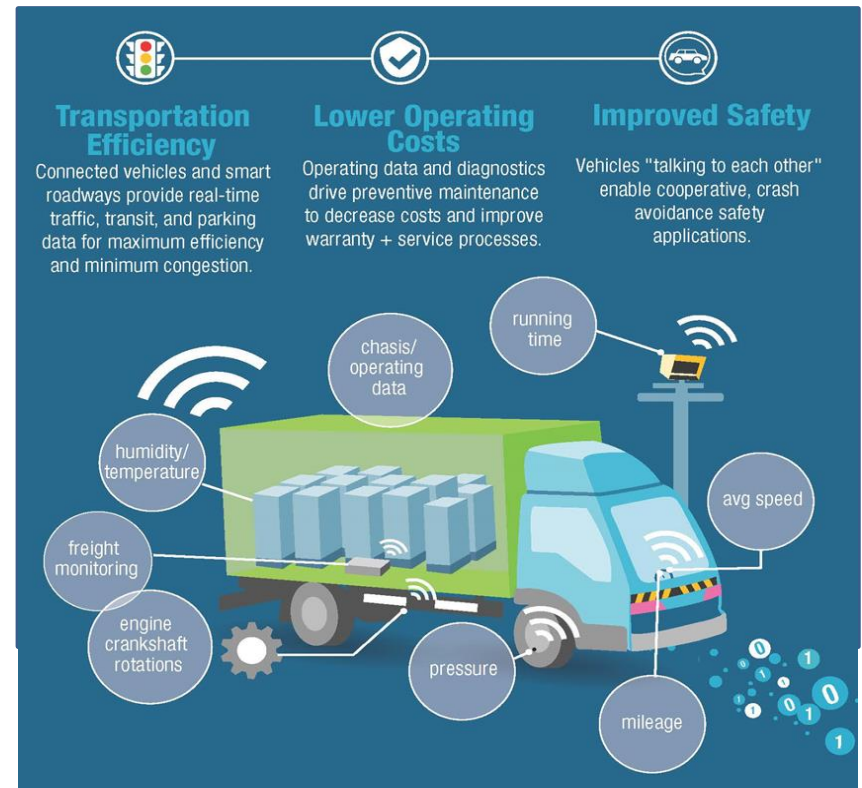
CV technology is capable of communicating with:

- **Other vehicles;**
- **Roadside infrastructure; and**
- **Other devices, like mobile phones.**

With the appropriate communications infrastructure in place, vehicles with on-board communications (whether it uses Dedicated Short-Range Communications, cellular, WiFi, satellite, Bluetooth, etc.), can send information such as location and speed to roadside units.

Smart infrastructure can provide valuable real-time information to:

- **Predict travel times** with information on roadway conditions, congestion levels, travel times and incident-related information; and
- **Improve system performance** with timely and accurate performance data to better manage systems during unpredictable weather events or incidents.



Better communication between infrastructure and vehicles can improve safety and enhance system efficiency.

Source: Datastax Infographic, <https://jaxenter.com/Internet-things-data-go-112274.html>, 2014

Automated Commercial Vehicles Drive Change in Freight & Urban Goods Movement

Automated commercial vehicles and other emerging technologies are addressing the challenges of last-mile delivery and satisfying consumer demand for fast, precise, local deliveries. Various technologies include:

- **In Testing** - Truck platooning, where several trucks closely follow each other with the aid of communicating driving support systems. This improves safety, lowers fuel consumption and improve traffic conditions.
- **Deployed** - Aerodynamic efficiencies and semi-autonomous features (e.g., automated braking systems).

A report by McKinsey & Company⁸ on the future of commercial transport predicts:

- Trucking companies can expect **revenues to increase** by 50% over the next decade, with the bulk of that value created by new technologies;
- At least one-third of new heavy trucks will be **semi-autonomous** by 2025; and
- **Increased demand** for more non-stop trucking operations as consumers expect deliveries more and more quickly – known as the “Amazon Effect.”

North Carolina must prepare for a future with more trucks on the roads, in many cases automated, which provide high-value delivery services to consumers and businesses.



New technology advancements are anticipated to generate an increase in revenues of over 50% for trucking companies within the next ten years.⁸

Source: Daimler, 2016

Technologies Are Impacting Deliveries and Distribution

Optimized delivery and streamlined logistics for freight and goods movement may drive economic growth and satisfy consumer demand while supporting efficient use of congested roadways.

Better decision making is supported by optimization technologies through:

- Route development;
- Forecasted and real-time traffic;
- Incident avoidance;
- Freight/warehouse facility loading dock hours; and
- Driver scheduling and hours.

Companies large to small are benefitting:

- FedEx, UPS and Wal-Mart have sophisticated software systems optimizing truck movements for long-haul and local trips.

- Medium and small companies are using freight movement optimization software paired with fleet management/GPS tracking systems for route optimization and processing of pickups and deliveries.

Shorter delivery times are enabled by:

- **More local and regional manufacturing** near last-mile distribution points, powered by 3D printing, which reduce port and air cargo traffic and long-haul shipping.
- Future **mobile 3D printing** may spawn autonomous manufacturing hubs, potentially reducing storage costs and increasing the speed of delivery, eliminating the need to stock products at warehouse hubs close to customers.
- **Drones**, not affected by roadway congestion, may solve last-mile challenges and impact the speed that packages or emergency supplies are delivered in urban areas. Safety concerns and logistics challenges remain unresolved.



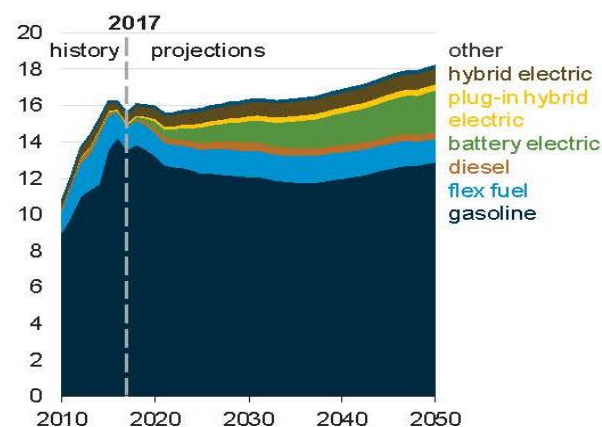
Emerging technologies support tools to optimize freight movement and logistics, making the flow and storage of goods more efficient.

Source: Routific, 2018

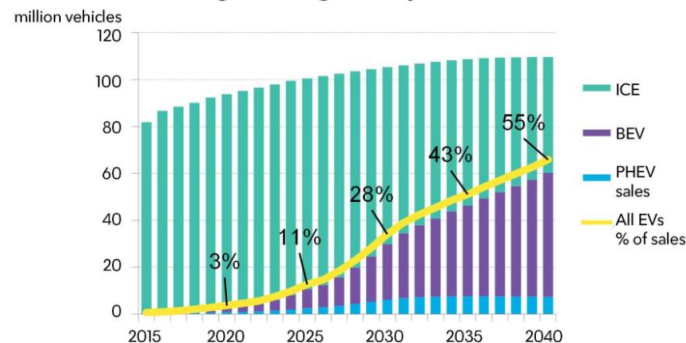
Electric Vehicles Take a Market Lead

- Alternatives to gasoline, and to internal combustion engines (ICEs), have been available for decades, but due to several factors – cost, supporting infrastructure, and limited range – capturing significant market share has been limited.
- Electric vehicles are powered by electricity from the energy grid and store that energy in a battery, which powers an electric motor. Hybrid vehicles are also available on the market, which rely on both ICEs and electric motors and batteries.^{9,10}
- **The technology behind many of these alternatives has been improving** in recent years.^{9,10}
- Between 2016 and 2017, **sales of electric vehicles have increased by 26%**, from 0.9% of the new sales market to over 1.2%.¹¹
- The US Energy Information Administration projects that electric vehicles will comprise 19% of US vehicle sales by 2050.¹² Bloomberg New Energy Finance forecasts anticipate that by 2040, 55% of all new car sales and 33% of the global fleet will be electric.¹³

Light-duty vehicle sales by fuel type
millions of vehicles



Annual global light duty vehicle sales



Sources: Top: US Energy Information Administration, 2018, Bottom: Bloomberg NEF, 2018

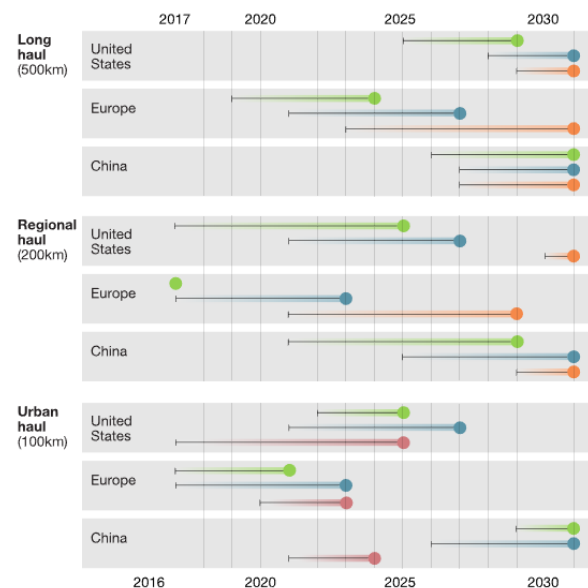
Transit and Commercial Vehicles Go Electric

- Commercial vehicle electrification – light duty trucks, long haul trucks, and city buses – will happen at different rates. McKinsey names three drivers that will affect adoption rates:¹⁴
 - Total cost of ownership** as compared with diesel alternatives;
 - EV technology and infrastructure becoming **cost competitive** and available, and;
 - EV-friendly **regulation** or emissions goals.
- Adoption of electric buses and light duty urban stop-and-go delivery trucks are estimated to occur as early as the 2020s. Electrification of longer-haul operations are expected to occur around 2030, meaning urban/suburban and rural **regions in North Carolina will experience electrification of commercial and transit vehicles at different times.**
- The Greensboro Transit Authority launched the state's first electric buses in January 2019. GoTriangle, the transit operator in the greater Raleigh area, won a federal grant for just under \$1 million in 2018 to buy its **first electric bus.**¹⁵
- Electric buses and charging equipment can cost \$300,000-\$450,000 more up front than a diesel bus, but have **lifespan operating savings** of \$250,000 to \$400,000 over diesel buses.¹⁵

Different applications and weight classes will see varying breakeven points for electric vehicle total cost of ownership.



Timing of battery electric vehicle total cost of ownership parity with diesel vehicle, year achieved range



Cost is the major driver for the electrification rates of different vehicles.

Source: McKinsey Center for Future Mobility

The Potential of Unmanned Aerial Vehicles

Unmanned aerial vehicles (UAV), known as drones, are a promising tool in asset management, traffic management, incident management response and urban freight delivery and incident management. Drones provide aerial surveillance for many typical DOT needs¹³, including:

- Inspections of confined spaces, culverts and pump stations (micro-UAV platforms);
- High-resolution imaging of transportation infrastructure (hexacopter paired with optical and thermal sensors);
- Rapid imaging of a scene, i.e. construction site (quadcopter); and
- Monitoring traffic (blimp) by approximating the level of service, estimating traffic volumes, reporting on intersection operations and observing parking lot utilization.

NCDOT's Aviation Division is active in exploring and implementing UAV applications and policies and includes an Unmanned Aircraft Systems Program Office, responsible for implementing, testing and permitting systems for the public to safely and legally operated drones and unmanned aircraft systems in North Carolina.

Concerns over safety, privacy and logistics remain unresolved. Regulatory actions shape considerations for drone usage, including:

- NCDOT enabling legislation, the first regulatory guidance of Unmanned Aircraft (or Aerial Surveillance) Systems;¹⁴ and
- Presidential Memorandum establishing a flexible regulatory framework for UAV operations.¹⁵



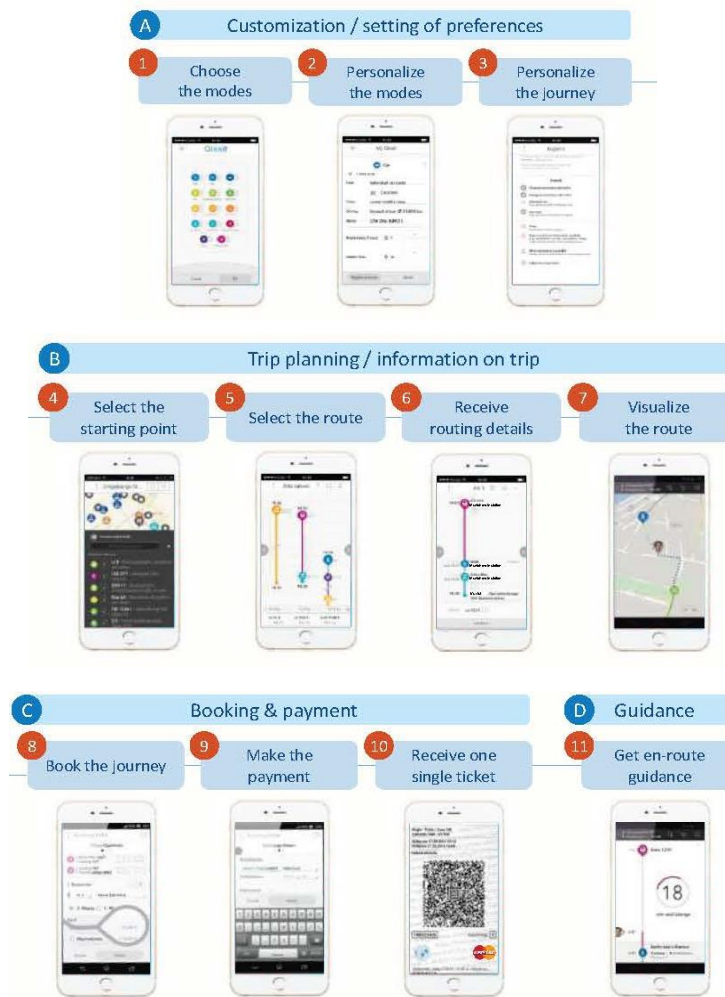
Unmanned aerial vehicles provide a low-cost opportunity to gather information on existing assets and performance.

Source: Michigan Tech Research Institute, http://www.mtri.org/mdot_uav_phase1.html, 2018

Unmanned aerial applications also include the movement of packages (see Delivery and Distribution Technologies on page 20) and people (see Emerging Intercity Travel Technologies on pages 26-27).

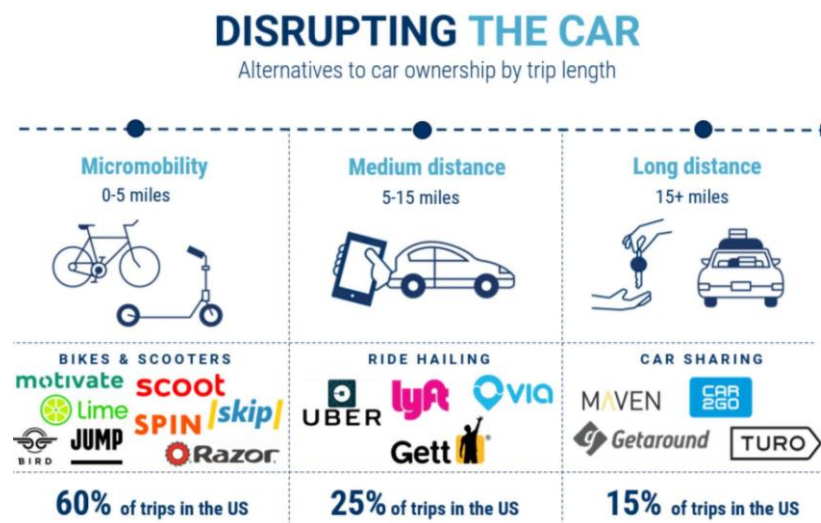
Demand for Simplifying Multimodal Travel into a Single Platform

- Transportation is moving on **from single operators** or modes and **into a user-focused service** where there is a need for simple, integrated and highly customized end-to-end solutions that can incorporate individual travel preferences such as price, speed, convenience and environmental impact.^{19,20,21}
- Digitization and modernization of other parts of transportation, such as real-time travel information and electronic payment, have begun to transform and prioritize information, convenience and user experience.
- A **unified, digital platform where users could plan, book, and pay for any transportation mode** could leverage existing and new technology to create a seamless customer experience that provides mobility-as-a-service.^{21,21}
- The wealth of personal data that is available and may be available in the future creates an **opportunity for improving and customizing mobility** experiences. However, this also presents several challenges in relation to the ownership of data, data sharing and privacy.



The Emergence of Micro-Mobility Answers a Significant Urban Demand

- Micro-mobility is “**small, human- and electric-powered transportation** solutions such as shared bikes, scooters and mopeds.”²²
- Bikes, scooters and mopeds are either docked at stations or can be left and picked up anywhere. They are **unlocked and paid for via mobile applications** and priced on a minute, hour or daily basis.
- In October 2018, Charlotte residents took e-scooters for about 120,000 rides, an average of 3,900 rides per day.²³
- Micro-mobility **targets shorter trips** and/or first- and last-mile trips. 45% of trips made in the US are three miles or less, creating a market for cheap, time-saving transportation options that reduce roadway congestion.
- Many cities are developing **regulations and policies for micro-mobility**. For example, in December 2018, Raleigh regulated the number of shared bicycles and scooters which can be deployed, and instituted a fee for micro-mobility companies: \$300 per scooter to fund program administration and law enforcement.²⁴
- Micro-mobility is becoming **increasingly more important in urban areas**.
- While the quick rise of micro-mobility has created regulatory and safety challenges in some cases, it has also created **opportunities for new transportation partnerships** and strategies.



Source: CB Insights

https://entrepreneurs.princeton.edu/sites/entrepreneurship/files/resource-links/cb-insights_disrupting-car-briefing.pdf

More Demand for Intercity Travel Technologies

As the share of the population living in interconnected cities, or multi-jurisdictional megaregions, continues to rise, regions are growing more connected in terms of economy, culture and transportation. The increasing demand for daily travel from one city to another is leading regions to search for transportation solutions which extend beyond conventional planning boundaries.

The development of intercity travel solutions have been led by both the public and private sectors. Demand for time and cost competitive passenger rail in some metropolitan markets is generating private sector investment.

Several high-speed rail connections aim to better connect regions, including:

- **California high-speed rail** connecting Los Angeles and San Francisco (under construction).

- **Northeast Corridor**, connecting Washington D.C., Philadelphia, New York and Boston, operates the only high-speed (150 mph) train service in North America. A proposed vision for high-speed rail (220 mph) is projected to reduce travel time between New York City and Washington D.C. to 100 minutes.
- **Gulf Coast Passenger Rail**, a cross-state partnership, called the Southern Rail Commission, focused on restoring and improving passenger rail connections from New Orleans to Orlando.
- **Florida's Brightline**, an intercity rail system connecting Miami and West Palm Beach is the only privately owned and operated U.S. passenger railroad.
- NCDOT is looking at high-speed rail opportunities in the **Southeast Corridor** with critical links from Charlotte to Raleigh and Raleigh to Richmond.



Florida Brightline – the only privately owned, operated and maintained passenger rail system in the U.S.

Source: Brightline, 2019

Intercity Travel Meets the Future

Lack of transportation choices and limited direct connections between major economic zones have led to the development of various intercity travel solutions by both the public and private sectors. Short-haul aviation services and other experimental technologies, like Uber Elevate, are being explored.

The private sector has invested resources in developing concepts to improve intercity travel, including:

- **Uber Elevate**, a partnership focused on developing fleets of small, electric vertical take-off and landing sites in Dallas and Los Angeles to enable shared, multimodal air transportation within and between cities.
- **Hyperloop**, a Telsa and SpaceX partnership to develop a reduced pressure tube system concept facilitating movement of pressurized vehicle capsules, potentially traveling up to 760 mph.



Uber Elevate – an on-demand urban air transportation future.

Source: Uber, 2016

FINDINGS AND FUTURE DIRECTION FOR NORTH CAROLINA

NCDOT has a World of Opportunities

This paper highlights the variety of potential technology impacts on transportation. There is little certainty about the scope and scale of these impacts and the traditional roles of public and private sector stakeholders will evolve. Nevertheless, there are key system planning considerations and opportunities for NCDOT as we look to 2050.

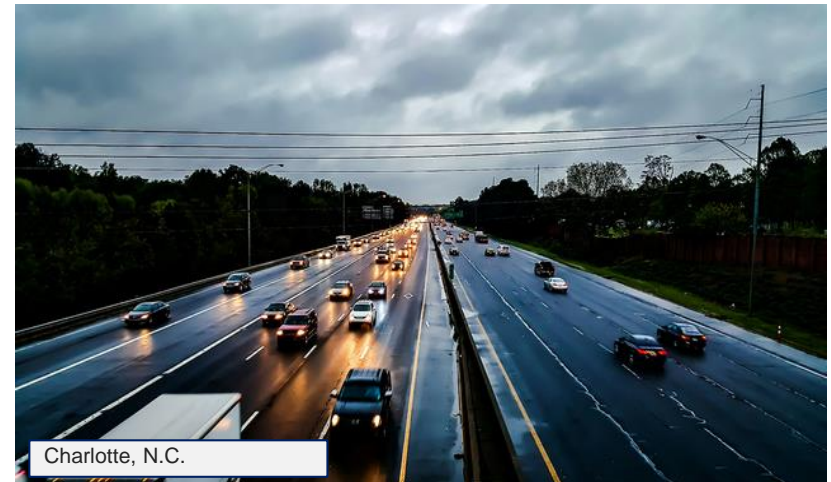
- **Continue Investing in Technology Planning and Pilots:** NCDOT is a leader in embracing and preparing for innovation through the AV Roadmap, pilot testing, research institutions and involvement in UAV regulation development. These activities will support NCDOT's preparation for the coming innovations.
- **Support Future Projects Featuring Technology and Innovation:** By reviewing regulatory, contractual and proprietary standards and promoting flexibility in regards to technology projects, NCDOT can ensure that when beneficial opportunities arise, there is preparation to undertake unique projects, partnerships with the private sector and set goals to achieve.



Sources, Top, Left to Right: Eyragon Eidam/Government Technology; Volvo Trucks from BulkTransporter.com; Flickr/David Joyce

NCDOT has a World of Opportunities

- **Target Technology Pilots and Research Towards North Carolina's Unique Opportunities:** North Carolina has unique opportunities and challenges. Technology applications should focus on these. One example of NCDOT putting this into practice is the use of UAV and advanced bridge inspection techniques to achieve a more comprehensive structural review. Identifying key challenges with the transportation network and working internally and with private sector partners to identify new, technology-based solutions is key.
- **Continue Exploring New Data Resources:** One of the promising early results of newly deployed technologies is a significant increase in data. As experts anticipate massive increases in the connectivity of the vehicle fleet (and infrastructure), more data will become available. What is done with this data to optimize decision making is important, but how the data is shared with third parties to add value to mobility is more important.
- **Recognize the Risks Associated with Technology and Cybersecurity Needs:** Each of the disruptive technologies discussed carries risks. Cybersecurity is a critical element to innovation. It is critical that cybersecurity roles and responsibilities are clearly defined and regularly updated as the operating environment of NCDOT and partnerships evolve.



Sources, Top, Bottom: WSOC-TV, Ildar Sagdejev.

NCDOT has a World of Opportunities

- **Develop Mechanisms and Tools for Partnership:** Innovation requires partnership with non-traditional entities including research institutions, the military, software and systems developers and AV testers. Mechanisms such as the Fully Autonomous Vehicle Committee formed as part of the AV Roadmap can support regular interface with partners and identify opportunities and obstacles.
- **Use Scenario Planning and Tools to Address Uncertainty:** Plans for the future (such as NC Moves 2050) need to provide strategies that perform well across a variety of future alternatives.
- **Address Goals the Private Sector Will Not:** The private sector, a driving force of change, will not always prioritize all of NCDOT's goals. NCDOT needs to keep goals of equity and environmental sustainability at the forefront of relationships with technology. Technology can support the mission of supporting a healthy population with good employment opportunities in North Carolina.



APPENDICES

End Note Sources

Thank you to our interviewees, who provided their expertise in short subject matter interviews: Fred Judson, DriveOhio (UAV); Adrienne Lindgren, WSP (UAV); Dan Sperling, UC-Davis (EVs); Tasha Keeney, Ark Investment (AVs); Regina Clewlow (Cityfi).

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