The NC FIRST Commission was created in March 2019 to evaluate North Carolina's transportation investment needs. Their job is to advise the Secretary of Transportation of new or better ways to ensure that critical financial resources are available in the future. As part of this process, we'll be looking for input from you, the people of North Carolina! This brief is part of a "Disruptor Series" that examines technological and societal trends impacting our transportation system. This edition considers transformative technologies and the enormous challenges they present to the transportation network and how it is funded.

DISRUPTOR SERIES: PART 4

Technology and the Future of Transportation

Overview

Transportation is in the midst of its greatest technological revolution since the rise of the automobile a century ago. Although no one knows exactly what the future of transportation will look like, new innovations are already reshaping how we move from place to place. These trends are predicted to be game changers for North Carolinians and the public agencies that serve them. From driverless cars to drones, many hope that emerging technologies will create a safer, cleaner, more efficient, and better connected transportation system. But these developments have also raised serious concerns, including their possible effects on critical revenue streams for transportation investments.

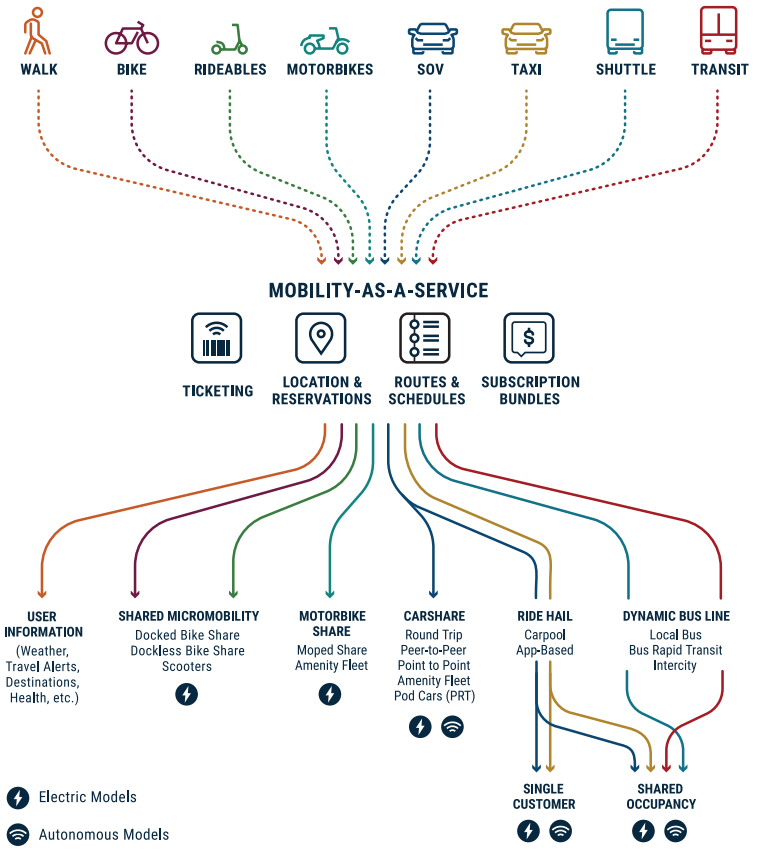
What technological changes are affecting transportation in North Carolina?

In recent years, stakeholders have identified four technology-driven, mutually reinforcing trends that are poised to transform the transportation sector: sharing, automation, connectivity, and electrification.[1] Critical developments are also underway in the world of e-commerce and last-mile delivery. To some degree, all of these trends are already here and altering the movement of people and goods. But some are predicting that the disruption will go much further, bringing about a new world in which many cars will be self-driving, packages will be delivered by drone, and whether you book a car for the day or use a ride-hailing app to get to work, the vehicle you travel in will likely be electric. Some of these possibilities may be closer than others, with faster adoption expected in more urban areas.

Sharing. Around the world, a host of shared mobility options have sprung up as part of a larger trend known as "Mobility-as-a-Service" (MaaS). This trend describes a shift away from buying vehicles and towards buying trips. The idea is that, instead of needing to drive their own cars everywhere, travelers will be able to choose from an array of on-demand services for each trip based on how much it costs, how long it takes, and personal preference.

Although it is a fairly new phenomenon, shared mobility already represents more than $60 billion in value across China, Europe, and the United States, its three largest markets. Services that are widely offered include car sharing (e.g., Zipcar, Car2Go), ride-hailing (e.g., Uber, Lyft), micromobility options such as bikeshares and e-scooters (e.g., Bird, Lime),[2] integrated, multimodal travel apps (e.g., Citymapper, TransLoc), and flexible "microtransit" such as on-demand vanpools and shuttles (**Figure 1**).[3] As innovations in vehicle types and features, autonomous technologies, and service models continue to expand, the annual growth rate for shared mobility is forecast to exceed 20 percent for the next decade. By 2030, up to one out of 10 new cars sold may be a shared vehicle.[4]

Figure 1: Mobility-as-a-Service



Source: Alta. "The Rise of Micromobility." By Jean Crowther. Alta Innovation Lab: 20 September 2018.

[1] See, for example, www.mckinsey.com/industries/automotive-and-assembly/our-insights/disruptive-trends-that-will-transform-the-auto-industry, www.iea.org/reports/digitalisation-and-energy, and www.cbinsights.com/research/facebook-amazon-microsoft-google-apple-auto-mobility/. These four trends are sometimes referred to together by the acronyms "ACES" or "CASE."

[2] For more about shared micromobility, see the NC FIRST Commission Brief 7: The Rise of Micromobility and its Potential Impacts for North Carolina, March 2020, www.ncdot.gov/about-us/how-we-operate/finance-budget/nc-first/Pages/resources.aspx, and commission meeting materials from April 24, 2020, www.ncdot.gov/about-us/how-we-operate/finance-budget/nc-first/Pages/meeting-dates.aspx.

[3] Crowther (2018), The Rise of Micromobility, Alta Innovation Lab, as cited in NCDOT's NC Moves 2050 Drivers and Opportunities Fact Sheet: Technology, July 2019, www.ncdot.gov/initiatives-policies/Transportation/nc-2050-plan/Pages/drivers-opportunities-fact-sheets.aspx

[4] www.mckinsey.com/features/mckinsey-center-for-future-mobility/overview/shared-mobility; www.mckinsey.com/industries/automotive-and-assembly/our-insights/disruptive-trends-that-will-transform-the-auto-industry

By providing alternatives to personally owned vehicles, these new mobility options may erode key state revenue sources for transportation, such as motor fuels taxes, driver licensing and vehicle registration fees, and the highway use tax on vehicle sales. Currently, some services—such as car sharing and car subscriptions—are taxed by the state, but nearly all of the revenues go to the General Fund rather than toward transportation investments.[5] Transportation Network Companies (TNCs) such as Uber and Lyft pay annual permit fees to the DMV, corporate taxes if nexus is established, and pick-up and drop-off fees at some airports; however, state law prohibits all other state and local fees.[6] In contrast, 15 other states levy per-ride or percentage-based fees on these companies.[7] Although some local governments in North Carolina assess fees on shared micromobility services, the state does not.

Automation. Over the past decade, innovations in vehicle technologies have introduced higher levels of automation into the cars we already drive and moved us toward the possibility of fully autonomous, or "driverless," vehicles. The U.S. Department of Transportation has adopted a six-level scale of vehicle automation that ranges from no automation (a human driver does everything) to full automation (the vehicle performs all driving tasks without human intervention) (**Figure 2**). All new vehicles being sold today are at levels 1 or 2 of this scale because of semi-automated features such as electronic stability control, adaptive cruise control, lane centering systems, or preemptive braking systems.[8]

There is much speculation, but no certainty, about when fully autonomous vehicles might become commercially available. Dozens of companies are working to develop driverless cars, and testing is already taking place on public roads across the U.S. and globally. In North Carolina, the Turnpike Authority's NC-540 Triangle Expressway has served as a pilot site for the testing of automated vehicle technologies since 2017.[10] Some predict that as soon as 2030, fully autonomous vehicles will represent up to 30 percent of light vehicle sales and a small but growing share of the trucking industry.[11]

Proponents claim that mass adoption of self-driving vehicles could reduce traffic accidents, lower energy usage, reduce shipping costs, and increase access and mobility for people who do not or cannot drive.[12] In the freight arena, self-driving vehicles could help address the record-level driver shortages facing the trucking industry.[13] But many questions—practical, technical, legal, and moral—would need to be answered first. A high-profile crash of a test vehicle that killed a pedestrian in 2018 called attention to the challenges of relying on artificial intelligence to handle complex, real-life driving situations, while other legitimate concerns persist about safety, liability, privacy, and cybersecurity.[14] In addition, current models indicate that autonomous vehicles could dramatically increase vehicle miles traveled, thereby straining existing roadway capacity and exacerbating sprawl, congestion, and greenhouse gas emissions.[15]

Figure 2: Levels of Vehicle Automation[9]

Level	Name	Automated System Role	Human Role
0	No automation	None	All driving functions of the vehicle
1	Driver assistance	Can sometimes assist the human driver conduct some parts of the driving task	All core driving functions
2	Partial automation	Can actually conduct some parts of the driving task such as steering, acceleration, and deceleration	Continues to monitor the external driving environment and performs all remaining aspects of the driving task
3	Conditional automation	Can actually conduct some parts of the driving task and monitor the driving environment in some instances, but may request human intervention for specific driving tasks	Must be ready to take back control and respond appropriately when the system requests intervention
4	High automation	Can conduct the driving task and monitor the driving environment, but only in certain environments and under certain conditions	Human driver is present but does not need to take back control
5	Full automation	Can perform all driving tasks under all conditions that a human driver could perform them	None, except providing destination or navigation input

[5] All revenues from the alternative highway use tax on car sharing and vehicle subscription services go to the General Fund, except for a $10 million annual transfer to the Highway Fund for airport improvements (N.C. Gen. Stat. §105-187.5 and §105-187.9).

[6] N.C. Gen. Stat. §20-280.10

[7] See commission meeting materials from April 24, 2020: www.ncdot.gov/about-us/how-we-operate/finance-budget/nc-first/Pages/meeting-dates.aspx

[8] crsreports.congress.gov/product/pdf/IF/IF10658/3; crsreports.congress.gov/product/pdf/R/R45985; www.enotrans.org/eno-resources/beyond-speculation-2-0-automated-vehicles-and-public-policy/

[9] Based on SAE Levels of Automation, as adopted by the U.S. Department of Transportation. See www.transportation.gov/AV/federal-automated-vehicles-policy-september-2016, www.transportation.gov/av/3/preparing-future-transportation-automated-vehicles-3, crsreports.congress.gov/product/pdf/R/R45985, and www.enotrans.org/eno-resources/beyond-speculation-2-0-automated-vehicles-and-public-policy/.

[10] www.ncdot.gov/news/press-releases/Pages/2017/USDOT-Picks-NC-Turnpike-Authority-for-Dr.aspx

[11] www.spglobal.com/en/research-insights/articles/The-Road-Ahead-for-Autonomous-Vehicles; www.cbinsights.com/research/autonomous-driverless-vehicles-corporations-list/; techcrunch.com/2019/06/11/over-1400-self-driving-vehicles-are-now-in-testing-by-80-companies-across-the-u-s/; www.mckinsey.com/industries/travel-logistics-and-transport-infrastructure/our-insights/distraction-or-disruption-autonomous-trucks-gain-ground-in-us-logistics

[12] www.transportation.gov/policy-initiatives/automated-vehicles/av-40

[13] www.fleetowner.com/technology/autonomous-vehicles/article/21704489/automation-and-technology-could-help-cull-the-driver-shortage-next-decade

[14] Ibid.; crsreports.congress.gov/product/pdf/R/R45985

[15] www.nap.edu/catalog/24872/; www.fehrandpeers.com/autonomous-vehicle-research/

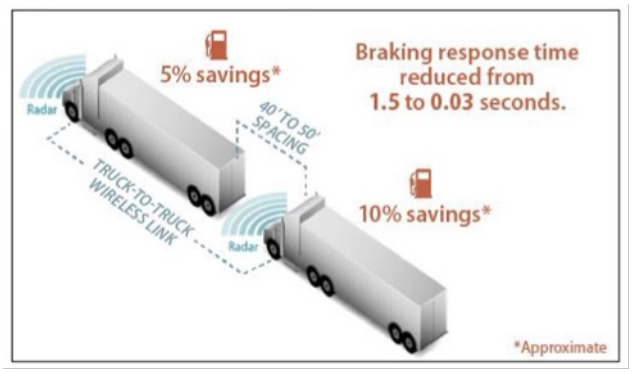
Given the tremendous disruption that widespread adoption of self-driving vehicles could present, North Carolina and other states are already preparing for the possibility. Many relevant issues fall under state jurisdiction, including driver licensing, vehicle registration, traffic laws and their enforcement, insurance, liability, and vehicle safety inspections. As of February 2020, at least 40 states, including North Carolina, had enacted legislation or issued executive orders related to autonomous vehicles.[16] Further, our roads were designed for humans, not computers. To facilitate the adoption of fully autonomous vehicles, states would need to make significant investments in upgraded road markings, signs, signaling, mapping, and other infrastructure accommodations that such vehicles would be able to recognize and navigate.

Connectivity. Connected vehicles use wireless technologies to communicate with each other (vehicle-to-vehicle or V2V), with roadside infrastructure (vehicle-to-infrastructure or V2I), or with any other connected user or device, including personal devices such as smartphones (vehicle-to-everything or V2X). Although connected vehicles are distinct from autonomous vehicles, they are often discussed together because connectivity in driverless vehicles could accelerate their deployment and more fully unlock their potential benefits.[17]

Connected vehicle technologies have many possible uses for safety, mobility, and the environment. For example, the National Highway Traffic Safety Administration (NHTSA) has estimated that, by warning drivers about impending hazards beyond what is possible with in-vehicle crash avoidance systems alone, V2V and V2I safety applications could eliminate or mitigate 80 percent of non-impaired crashes.[18] Other applications—such as optimizing traffic signals, dynamically adjusting and coordinating cruise control speeds, and alerting drivers to traffic conditions—could help reduce congestion and fuel consumption.

Connectivity could also enable truck "platooning" (**Figure 3**),[19] in which two or more trucks are wirelessly linked into a convoy that can automatically accelerate and brake together, while following closely enough to significantly lessen wind resistance. Early studies have shown that 65 percent of current long-haul truck miles could potentially be platooned, lowering total truck fuel use by 4 percent.[20]

Figure 3: Truck Platooning



Governments, researchers, and industry have been working together for more than a decade to advance connected vehicle technologies. In 2017, NHTSA issued a Notice of Proposed Rulemaking to require V2V communications in all new light vehicles as of 2023,[21] and limited deployments are already underway in several states including North Carolina.[22] But many hurdles remain, including concerns about privacy, cybersecurity, liability, and driver distraction. In addition, connected vehicles would increase state transportation costs while decreasing revenues. Needed investments to facilitate vehicle connectivity could include the widespread installation of V2I technologies in roadside infrastructure and reliable, universal broadband coverage.[23] Meanwhile, applications that reduce fuel consumption, such as truck platooning and coordinated cruise control, would continue to erode fuel tax revenues.

[16] 2017 N.C. Sess. Laws, Chap. 2017-166 (N.C. Gen. Stat. §§20-400 et seq.); 2017 N.C. Sess. Laws., Chap. 2017-169 (N.C. Gen. Stat. §20-152); www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx; www.ncsl.org/research/transportation/autonomous-vehicles-legislative-database.aspx

[17] www.its.dot.gov/cv_basics/cv_basics_20qs.htm; safety.fhwa.dot.gov/its/; www.enotrans.org/eno-resources/beyond-speculation-2-0-automated-vehicles-and-public-policy/

[18] one.nhtsa.gov/About-NHTSA/Press-Releases/ci.nhtsa_v2v_proposed_rule_12132016.print

[19] crsreports.congress.gov/product/pdf/IF/IF10737/2

[20] www.energy.gov/eere/articles/platooning-trucks-cut-cost-and-improve-efficiency

[21] www.federalregister.gov/documents/2017/01/12/2016-31059/federal-motor-vehicle-safety-standards-v2v-communications; www.nhtsa.gov/technology-innovation/vehicle-vehicle-communication

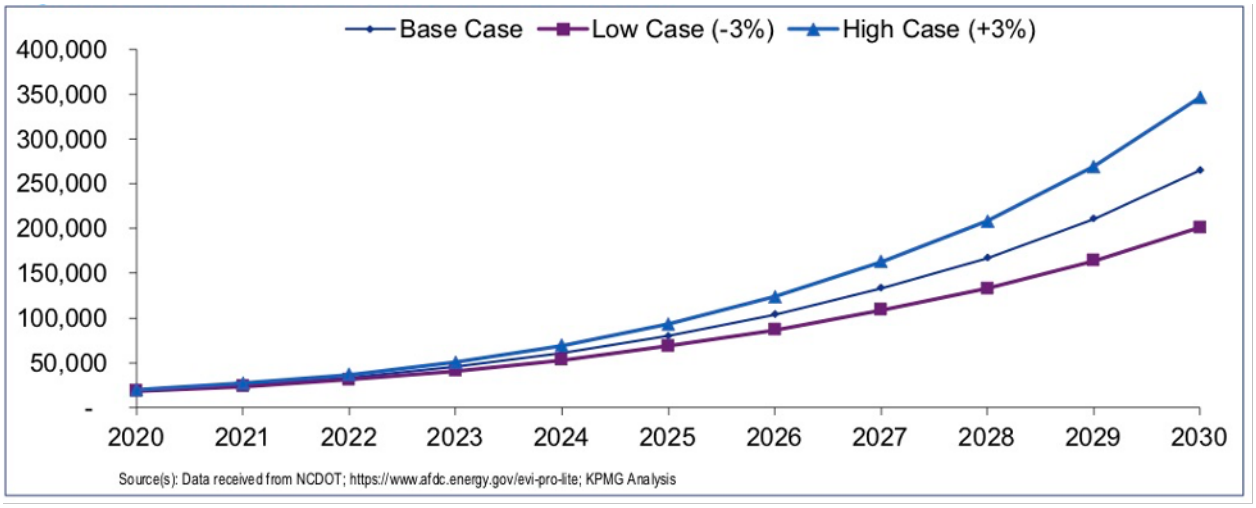
[22] www.transportation.gov/research-and-technology/operational-connected-vehicle-deployments-us; www.its.dot.gov/pilots/index.htm; transportationops.org/spatchallenge; www.mhlnews.com/transportation-distribution/article/22055093/trucks-platoon-across-north-carolina-turnpike; youtu.be/JD5QoI_mYP0

[23] For more about broadband deployment challenges and efforts in North Carolina, see the NC FIRST Commission Brief 4: Rural Transportation Issues in North Carolina, November 2019, www.ncdot.gov/about-us/how-we-operate/finance-budget/nc-first/Pages/resources.aspx, and www.ncbroadband.gov/broadband-nc/state-broadband-plan.

Electrification. Although electric vehicles (EVs) make up a relatively small share of the nation's fleet today, analysts predict that their popularity will quickly escalate as charging infrastructure expands and battery costs decrease. As soon as 2026, IHS Markit predicts that 7.6 percent of vehicle sales in the U.S. will be electric and hybrid vehicles, compared to only 1.2 percent in 2018.[24] Commercial adoption is aggressive, with retail giants like Walmart and Amazon investing in hundreds of electric semi-trucks and thousands of electric delivery vans.[25]

In North Carolina, EV sales grew 69 percent from FY 2018 to FY 2019; as of September 2020, more than 13,739 EVs and 135,730 hybrids were registered in the state, making up 1.8 percent of all vehicles. Under Executive Order 80, issued by Governor Roy Cooper in October 2018, North Carolina created a plan to increase the number of zero emission vehicles (ZEVs) to at least 80,000 by 2025 as part of its efforts to combat climate change. The plan forecasts a presence of 200,000 or more EVs in the state by 2030 (**Figure 4**).[26]

Figure 4: North Carolina Electric Vehicle Forecast



Electric and hybrid vehicles represent one of the most significant threats to how the transportation system is currently funded.[27] In general, North Carolina drivers contribute to state infrastructure investments through a combination of fuel taxes, DMV fees, and highway use taxes on vehicle sales and long-term leases or rentals. For the average driver, fuel taxes make up nearly 80 percent of their annual contribution. Even considering the additional EV registration fee of $140.25, North Carolina's electric vehicle owners pay about $50 less per year in state transportation taxes and fees than owners of conventional gas-powered vehicles. Hybrid vehicle owners, who use some fuel but have no additional registration fee, pay about $85 less per year today; with expected improvements in fuel efficiency, they are predicted to pay about $130 less per year by 2030. By 2030, electric and hybrid vehicles combined could lead to a total annual revenue loss of $35.7 million to $46.4 million.

[24] www.reuters.com/article/us-autos-electric-forecast/outside-of-tesla-future-ev-sales-in-u-s-may-be-thin-for-most-brands-study-idUSKCN1SZ20I

[25] www.greenbiz.com/article/8-electric-truck-and-van-companies-watch-2020

[26] www.ncdot.gov/initiatives-policies/environmental/climate-change/Documents/nc-zev-plan.pdf

[27] For more about electric and hybrid vehicles, see the NC FIRST Commission Brief 8: Revenue Impact from Electric and Hybrid Vehicles, May 2020, www.ncdot.gov/about-us/how-we-operate/finance-budget/nc-first/Pages/resources.aspx.

E-Commerce and Last-Mile Delivery. The rapid growth of e-commerce—the buying and selling of goods over the Internet—has fundamentally changed the movement of freight, both in North Carolina and beyond.[28] Online retail sales of physical goods in the United States are predicted to grow to $599 billion by 2024, up 64 percent from 2019[29]—a trend that has been accelerated by the COVID-19 pandemic. As of mid-2020, e-commerce accounted for more than 16 percent of all U.S. retail sales,[30] with 39 percent of those sales due to Amazon alone.[31]

According to the American Transportation Research Institute, as more consumers have opted to have online purchases delivered directly to their homes or workplaces, more truck traffic has become concentrated on "last mile" trips that get items to their final destination. Thus, as freight travel has grown with the economy and placed more demand on the transportation system overall, e-commerce has shifted trucking patterns toward more frequent, shorter trips in denser urban and suburban neighborhoods. Higher truck activity in these areas strains capacity and worsens traffic congestion on local roads, especially during peak hours. Meanwhile, the common use of smaller, more fuel-efficient vehicles for last-mile deliveries may counter the increase in fuel taxes that might have been expected from the ongoing rise in total truck travel.[32]

Several other technological developments are being pursued to address the last-mile transportation challenges of e-commerce. One possible alternative is the use of unmanned aircraft systems, or "drones," to deliver packages. Although federal authorization is still pending,[33] companies including Amazon, Alphabet, UPS, Walmart, and DHL are all exploring drone delivery. In North Carolina, authorized pilot projects have delivered take-out food in Holly Springs, groceries in Fayetteville, prescription drugs in Cary, and medical supplies to WakeMed, Novant Health, and Wake Forest Baptist hospitals. A 2018 NASA study estimated that by 2030, drones could be making around 500 million deliveries each year with a fleet of 40,000.[34]

By offering an alternative to trucks, however, drones could further erode fuel taxes and other transportation revenues. While North Carolina's sales and use taxes apply to delivery costs[35]—which would include the costs of drone deliveries or other last-mile options currently being tested such as sidewalk delivery robots—the proceeds are directed to the General Fund.

What do these technological trends mean for the future of our transportation system?

The landscape for technological innovation is complex and evolving, and there is no consensus on what transportation will look like in coming years. The widespread sentiment is that massive changes are on the horizon, yet the real-life impacts for passenger and freight travel remain largely unclear. What is clear, however, is that emerging technological trends do not fit neatly into ways of thinking about transportation that are at least decades, and often a century, old.

One critical issue at stake is how we pay for transportation investments. New alternatives to conventional fuel-powered vehicles—such as electric vehicles, shared micromobility, and delivery by drones or robots instead of trucks—threaten motor fuel taxes, the state's primary revenue source for transportation since 1921. Mobility options that bypass personal vehicle ownership—such as car sharing, ride-hailing, and on-demand transit—could erode other key revenue sources, such as vehicle-related fees and taxes on vehicle sales. Yet today, some of these emerging trends are not taxed by the state at all, and others only support the General Fund rather than transportation. Meanwhile, fast-developing technologies such as autonomous and connected vehicles will require substantial additional investment in transportation infrastructure to be implemented safely. To secure critical financial resources for the future, North Carolina will need to close the gap between 20th century funding models and 21st century investment needs.

[28] For more about disruptions to freight transportation, see the NC FIRST Commission Brief 5: Transportation, Distribution, and Logistics in the Future, January 2020, www.ncdot.gov/about-us/how-we-operate/finance-budget/nc-first/Pages/resources.aspx.

[29] crsreports.congress.gov/product/pdf/IF/IF11194/3

[30] www.census.gov/retail/mrts/www/data/pdf/ec_current.pdf; www.statista.com/chart/14011/e-commerce-share-of-total-retail-sales

[31] www.emarketer.com/content/us-ecommerce-growth-jumps-more-than-30-accelerating-online-shopping-shift-by-nearly-2-years

[32] truckingresearch.org/wp-content/uploads/2019/02/ATRI-Impacts-of-E-Commerce-on-Trucking-02-2019.pdf; see also the North Carolina Statewide Multimodal Freight Plan, November 2017, connect.ncdot.gov/projects/planning/Statewide-Freight-Plan/Documents/NCDOT_SWFrtPln_FinalReport_180209.pdf

[33] The FAA Reauthorization Act of 2018 directed the Federal Aviation Administration to develop, within one year, a rule to authorize "the carriage of property by small unmanned aircraft systems for compensation or hire" (P.L. 115-254, §348). As of July 2020, FAA was still working on a regulatory framework for delivery drones, but had issued a few drone operator certificates under existing charter flight regulations to carry out demonstration projects (crsreports.congress.gov/product/pdf/R/R42781).

[34] www.nasa.gov/sites/default/files/atoms/files/uam-market-study-executive-summary-pr.pdf

[35] N.C. Gen. Stat. §105-164.3(203)