TRANSIT EQUITY AND CLIMATE: MOVING TO A CLEANER FUTURE

FULL REPORT

SEPTEMBER 2021

COMMUNITY CLIMATE
COLLABORATIVE

Acknowledgements

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1 Introduction

Transportation is a central part of everyday life, connecting us to essential services, economic opportunity, recreation, and each other. The quality of our infrastructure and our access to it has a direct and significant impact on the quality of our lives and our ability to care for ourselves, provide for our families, and achieve our goals.

Access to affordable and convenient transportation should be considered a right, not a privilege, but that is not a reality for many families. The last century of transportation planning in the United States has largely focused on accommodating our obsession with personal vehicles. A car-centric approach to urban and transportation planning leads to low-density urban spaces, fragmented by roadways that are increasingly hostile to other modes of travel such as walking or biking.

Cars are also expensive to purchase, operate, and maintain, making up the second largest household expense on average. For lower-income households with less room in their budget, having to own a car (or multiple cars) represents an even larger-than-average share of their overall budget. **This inequitable transportation burden, combined with a lack of alternatives, creates a structural barrier to putting food on the table, getting ahead economically, and building financial stability and generational wealth.**

Car-centric planning also generates more emissions of deadly pollutants and climate-warming greenhouse gases (GHG). Thousands die prematurely every year due to air pollution, driven largely by transportation. The burden of pollution and climate change impacts is also unequally distributed. Lower-income communities are saddled with a higher-than-average share of the dangerous health impacts of pollution and the negative impacts of climate change.

The good news is that affordable, equitable, convenient, and clean transportation is within our reach. Policies embracing a wide variety of transportation modes and creating dense, walkable, transit-oriented communities can improve all residents' quality of life and better serve historically underserved communities and lower-income residents.

Robust public transit services that provide affordable and convenient connectivity are a critical element of an equitable and sustainable transportation system. In Charlottesville and Albemarle, much like most of the country, public transit has long seemed to be an afterthought when compared to the resources the City and County invest in car-centric infrastructure. But it does not have to be that way.

Charlottesville Area Transit (CAT), the City of Charlottesville and Albemarle County have a unique opportunity in 2021 to make a renewed commitment to their residents:

- Making transit permanently free;
- Reconfiguring routes to serve those that need the service most;
- Expanding service; and
- Laying out a plan for eliminating pollution from its bus fleet.

This report lays out a clear case for investing in transit services in Charlottesville and Albemarle and has the following objectives:

- **Give voice** to the communities of Charlottesville and Albemarle that rely on transit every day to access essential services and opportunities;
- Demonstrate the **positive feedback loop** between equity-focused, low-emission transit and long-term transit ridership increase;
- **Raise the ambition** of transit planning and investments in Charlottesville and Albemarle by providing recommended actions that are both feasible and impactful.

To deliver on these objectives, we conducted a community survey and a series of focus groups' sessions to listen and learn more about the experiences that community members have had with CAT. We also conducted a review of literature on improving transit services and developed a scenario analysis to illustrate some of the benefits that could come from growing ridership and improving equity in public transit in Charlottesville and Albemarle.

As the COVID-19 vaccine slowly allows life to return to something resembling normal, there are some things that should be left behind. A low-quality transit system is one of them.

2 Background

Key Takeaways

- Transportation energy burden. Transportation is the second highest expense for U.S. households after housing-related expenses (BTS, 2019).
- Air pollution. Transportation contributes to emissions of fine particulate matter, an air pollutant that costs Virginia ≈$750 million annually from direct health burdens and $23 billion in reduced productivity and increased healthcare costs (EF & VCCA, 2020).
- Planning for affordable housing and transit should be developed and reviewed together, exploring synergies and aiming to favor increasing the location-efficiency of areas selected for future affordable housing developments.
- Climate Change. In Albemarle County, transportation represented 52% of greenhouse gas emissions in 2018 (Albemarle County, 2021) and 28% for Charlottesville in 2016, according to the Greenhouse Gas Inventory for the City.
- Transit delivers jobs. Transit investments create or enhance jobs by allowing for more options for people to go to work (DRPT, 2019).
- Diesel buses that are operated consistently at low occupancy may actually produce more emissions per passenger-mile of travel than a modern light-duty vehicle, a problem that can be remedied by converting to battery electric buses.
- Battery electric buses (BEB).[1] BEBs enjoy better performance, efficiency, cheaper maintenance, zero tailpipe emissions, and predictable fuel costs. Economically, the lifecycle expenses of four diesel buses justify the acquisition of five BEBs at nearly no extra cost.
- Barriers to BEB deployment: upfront costs such as charging infrastructure, new complex planning, lower operating range dependent on charger placements, and unfamiliarity with the technology.

2.1 Charlottesville Area Transit (CAT)

CAT has been in operation in the City of Charlottesville and surrounding areas since 1975. CAT operates 13 routes within the City of Charlottesville, which also extend to certain areas of Albemarle County and the University of Virginia (UVA). All routes typically operate Monday through Saturday between approximately 6:30 a.m. and 6:30 p.m., with nine routes continuing night service until 10:00 p.m., 11:00 p.m. or 12:00 a.m. Four routes operate on Sundays (Route 2, Route 9, Route 12, and the Free Trolley).[1] Figure 1. CAT Service Hours, 2018-Present offers a summarized version of CAT's service hours, while Figure 2. CAT Transit System Map, 2018-Present shows a map of the agency's transit system map (CAT, 2018).

[1] During the pandemic, CAT is currently operating on a reduced lifeline service schedule, with altered hours.

Figure 1. CAT Service Hours, 2018-Present (CAT, 2018)

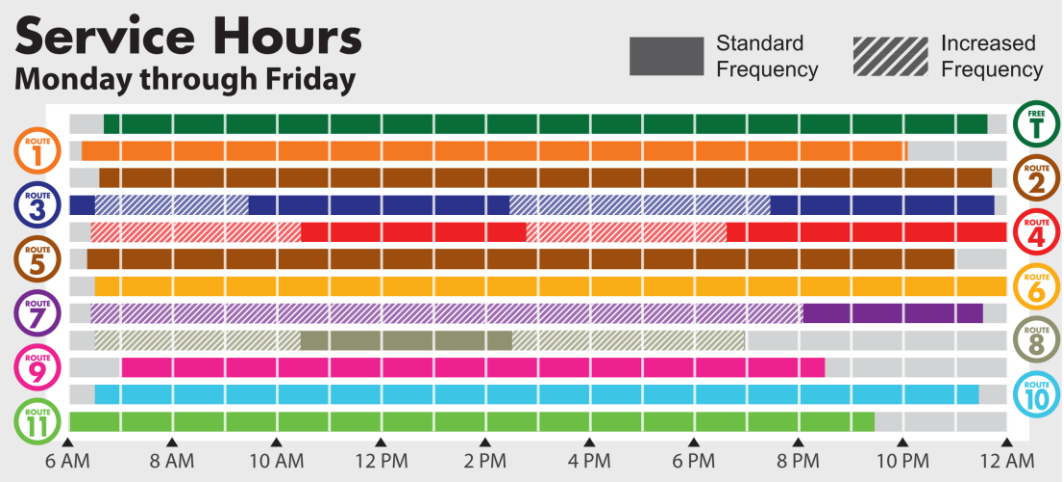
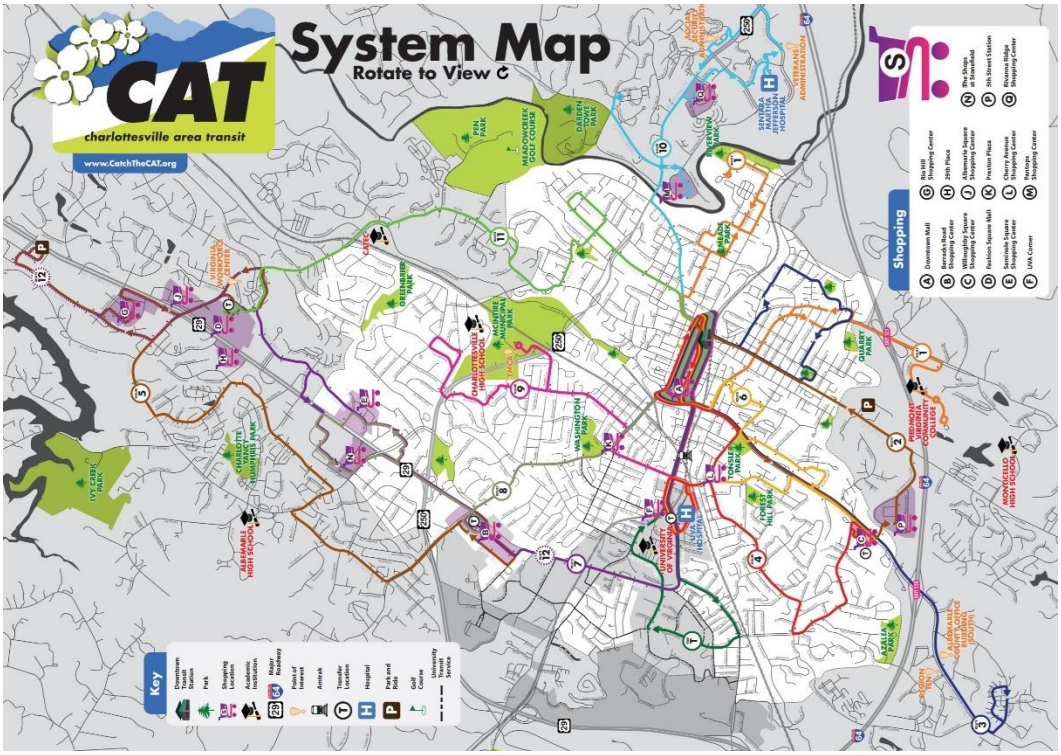


Figure 2. CAT Transit System Map, 2018-Present (CAT, 2018)



Three agencies provide public transit service throughout Charlottesville. In addition to CAT, the University Transit Service (UTS) and JAUNT Paratransit Service have major presences in the Charlottesville area. UTS is a free shuttle bus service for UVA students, faculty, staff, and the general public. JAUNT is a public regional transportation system providing broad service to Charlottesville, Albemarle, Louisa, Nelson, Fluvanna, and Buckingham counties.

2.1.1 Cost of riding CAT

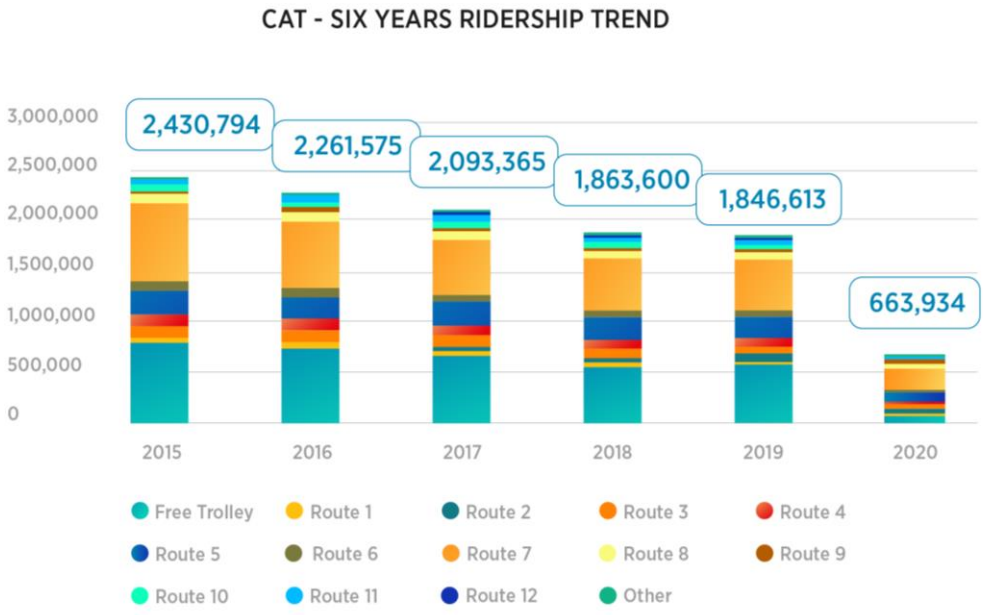
Before the pandemic, CAT buses accepted cash fares and smart card passes. CAT offered reduced fares to customers aged 65 and older, people with qualifying disabilities, Albemarle County employees, and holders of Medicare cards. Youth under 18, employees of the City of Charlottesville, and UVA students and staff ride free of charge.

In March 2020, CAT announced that during the COVID-19 pandemic it would be offering fare-free service to ensure availability of essential transit services to all (CAT Media Release, 2020). In March of 2021, CAT announced that they had secured sufficient federal stimulus funding to offer fare free service for at least the next three years (CAT Press Release, 2021). CAT has also publicly stated that they are actively working to secure long-term funding to support permanent fare free service. See Section 6.1 "Increase equity and affordability" for an in-depth discussion of why a fare-free service is a critical step in creating a more accessible, equitable, and sustainable transit system.

2.1.2 Ridership

Similar to many small transit systems around the country, CAT's ridership has been declining steadily for some time. From 2015 to 2019, ridership dropped 7% every year on average, roughly equivalent to losing 157,000 rides per year. From 2018 to 2019, all CAT routes except Free Trolley, Route 2, and Route 12 were losing ridership. In 2020, due to the COVID-19 pandemic, ridership dropped 64% from 2019, shedding over one million rides and dipping below 100,000 rides a month for the first time since at least 2015.

Figure 3. CAT Ridership, 2015-2020



The Free Trolley route and Route 7 have consistently been the most populated CAT routes. The Free Trolley connects UVA to the Downtown Mall while Route 7 connects Fashion Square Mall to the Downtown Mall. Route 5, which connects Walmart to Barrack's Road, is another highly-utilized route, although its ridership has been steadily decreasing along with other CAT routes. The Free Trolley was the only longstanding route gaining ridership before the COVID-19 pandemic; Route and Route 12, the other two routes that saw ridership increase between 2015 and 2020, were only launched in 2016 (Cville Tomorrow, 2016).

2.2 Other Relevant Studies

Several studies from the last five years help shed light on CAT's historical ridership profile and riders' experience using CAT services.

2.2.1 2017 Transit Customer Service Survey

In 2017, CAT conducted the 2017 Transit Customer Service Survey, collecting feedback from 332 riders. Key insights include (CAT, 2017):

- Most riders rely on CAT as their primary mode of transportation.
    - 59% of respondents did not have regular access to a vehicle;
    - 47% did not have a driver's license.
    - 61% responded that CAT was their only option for reaching their destination.
- Walkability in Charlottesville is critical to providing high-quality transit service.
    - Over 90% of riders walk to and from bus stops to reach their final destination.
- Riders' experience with CAT is positive overall, with room for improvement.
    - Key comments indicate that CAT should consider the reasonableness of some rules and regulations (particularly on routes that intersect with UVA buses, where rules are not the same).
    - Comments also indicate that extra attention paid to bus stop cleanliness and safety would be welcome by riders.

2.2.2 2018 Transit Development Plan

In 2018, CAT commissioned the Transit Development Plan (TDP), which included the setting of goals and the definition of planned investments through roughly 2028 (MBI; Foursquare ITP, 2018). Key insights include:

- Integrating hybrid buses into the fleet proved challenging:
    - CAT found that diesel-electric hybrid buses were difficult to maintain and did not yield the environmental benefits expected.
- Improving service penetration:

    - CAT has committed to providing high-frequency service y (i.e., every 30 minutes or less) within a quarter mile of at least 70% of the region's population during at least four hours per day.

- Over the long-term, CAT envisions a Bus Rapid Transit service along the US-29.
    - The US-29 corridor is the second busiest transit corridor in the region, with only the Main Street corridor (between Downtown and UVA) generating more trips.

The TDP also outlined short and medium-term recommendations for modifying or expanding CAT service. Short-term plans (1-3 years), which are intended to be cost-neutral, included slightly reducing weekday service hours while expanding Saturday and Sunday service and optimizing scheduling and coordination of bus service to improve on-time performance. Medium-term recommendations (3-10 years) build on the short-term recommendations with an additional 30-minute peak-period service for every route.

2.2.3 2020 UVA's Equity Center's Transportation Equity and Accessibility Study

In 2020, researchers affiliated with the Equity Center at UVA released a study called Transportation Equity and Accessibility in the Charlottesville Region (Burnett, et al.). This study conducted focus groups, mapping exercises, and stakeholder interviews.

While the full findings of the study have not been released publicly, a key insight is that focus group participants shared was that both inefficient routes and facilities (e.g., dirty or unsafe bus stops) feels disrespectful to them as customers of the service. In other words, some riders consider that the City has underinvested in transit services, which translates to a lack of respect for the people and communities that rely on CAT services, sometimes exclusively. To build long-lasting relationships with riders, which helps to ensure sustainability of the service, it is critical to communicate respect through decision-making and investment decisions.

The study also offers recommendations for introducing on-demand mobility[2], increased community engagement, emphasis on respect for riders, comprehensive regional transportation planning, and investment in bike and pedestrian infrastructure.

2.3 Transportation Equity

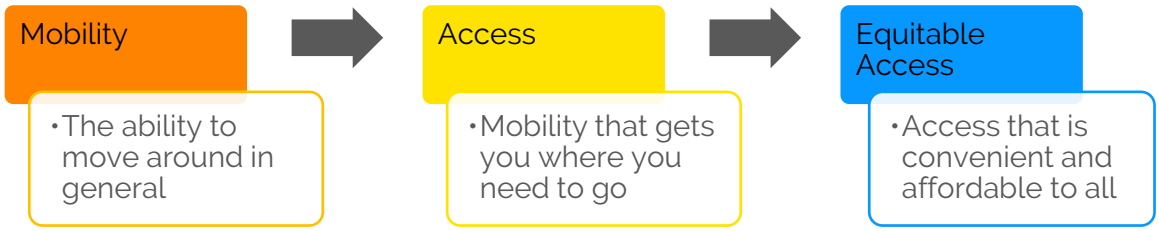
In the context of transportation, equity analysis considers the fairness of how the benefits and costs of our transportation infrastructure are distributed across society.[3] The main benefit of transportation is *access* to essential services, economic opportunity, recreation, and community. Mobility—the ability to move around in general—is insufficient if the transportation infrastructure does not give us access to where we need to go.

[2] Advanced forms of mobility on demand (MOD) incorporate trip planning and booking, real-time information, and fare payment into a single user interface. Modes facilitated through MOD providers include carsharing, bike or scooter sharing, microtransit, shuttle services, public transportation, and others (Shaheen, et al., 2017).

[3] For an excellent overview of the complexities of transportation equity analysis, see "Evaluating Transportation Equity" (VTPI, 2021).

Unfortunately, a transit system can also enable access in a way that is not fairly distributed, marginalizing some communities while disproportionately benefiting others. **We achieve *equitable access* when all community members have transportation options that get them where they need to go and are reasonably convenient, affordable, and safe.**

Figure 4. Mobility vs. Access vs. Equitable Access

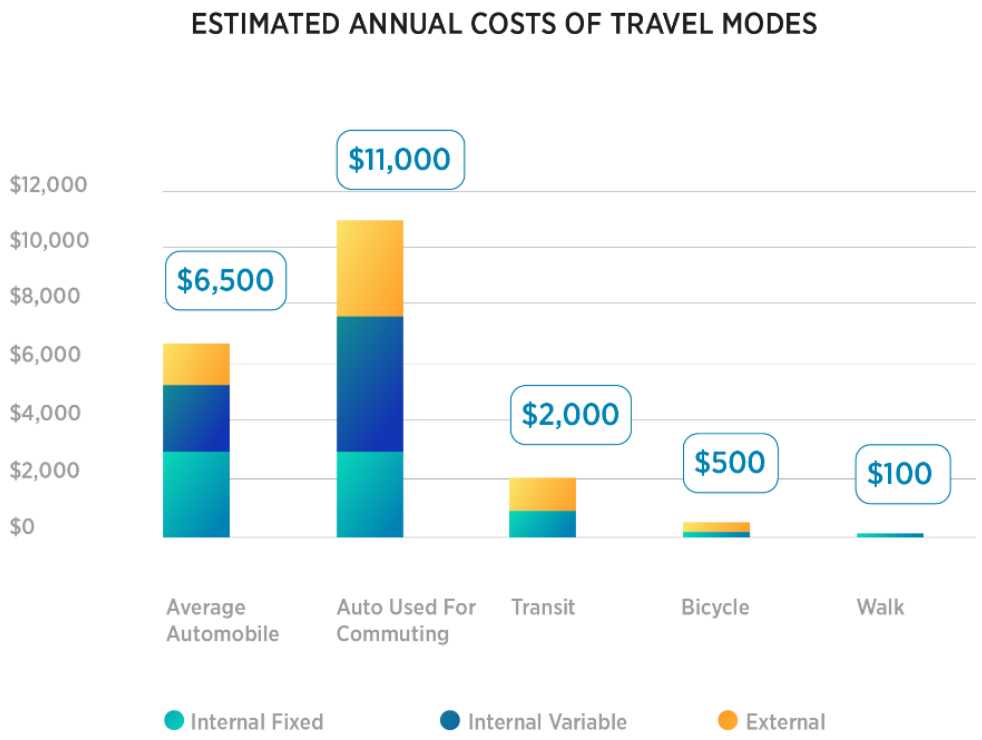


Our transportation system needs to be more equitable in several ways:

Transportation energy burden. Transportation is the second highest expense for U.S. households after housing-related expenses (BTS, 2019). These costs disproportionately burden lower-income households, rural communities, minorities, as well as the differently abled and the elderly (Hacker, et al., 2011; Jansuwan, et al., 2013; Wallace, et al., 2005). While the average American household spends almost 20% of its total income on transportation expenses, lower-income households face an average burden as high as 30% of their income (Vaidyanathan, 2016). This percentage, the share of income allocated to face transportation expenditures, is known as the *transportation energy burden*.

Car-centric transportation planning. Transportation energy burden is exacerbated by transportation planning that historically focuses disproportionately on accommodating privately-owned vehicles, making it difficult to get around by other means. As Figure 5 shows, owning and operating a vehicle is expensive to the individual owner (internal costs), but cars also impose significant external costs that are borne by society, including by those who do not use cars and historically underserved communities (Litman, 2021). These external costs encompass land taken up by road infrastructure and parking, congestion, air and water pollution, noise, car accidents, and other costs (Litman, 2020).

Figure 5. Estimated Annual Costs of Travel Modes (Litman, 2021)



Under-investment in public transit. The other side of the coin to car-centric transportation planning is a historical underinvestment in public transit, which can be a critical equalizer of access to individuals that do not have a car or for whom owning a car is a disproportionate burden on their household budget. Lack of funding for public transit has caused a major disparity within the transit systems, which leaves many urban and rural areas without reliable and equitable transportation (Climate Justice Alliance, 2020).

Neglect of transit infrastructure also creates and perpetuates disparities in access to essential services and economic opportunity for riders that have no alternative mode of transportation (also known as **captive riders**). For example, long walks to bus stops and infrequent or unreliable service make it more difficult, and in some cases impossible, to reach destinations in a timely manner (Spieler, 2020). In the case of a lower-income individual who may be working multiple jobs to make ends meet, extra time spent in transit represents real and significant costs to them, further limiting her or his ability to get ahead.

Air pollution. Transportation pollution significantly contributes to emissions of fine particulate matter (PM2.5), an air pollutant that causes heart and lung problems as well as premature deaths. PM2.5 in Virginia is estimated to cause thousands of new or exacerbated cases of asthma, 3,600 hospitalizations every year, and 3,000 premature deaths. These health issues cost Virginians $23 billion in the form of reduced productivity and increased healthcare costs (EF & VCCA, 2020). Vulnerable populations are far more susceptible to adverse effects of PM2.5, especially in the form of premature death. In Virginia, the most vulnerable census

tracts experience PM2.5-attributable mortality incidence rates that are 61% higher than analogous rates in the least vulnerable tracts. Overall, the direct health burden of vehicle emissions in the state is approximately $750 million per year (EF & VCCA, 2020).

Racial history of transportation planning. Much like other long-standing urban design practices, transportation infrastructure planning has also been used as a mechanism to intentionally underserve communities of color. Redlining practices have forced Black homebuyers into segregated neighborhoods, while highway projects have been deliberately built through Black communities to spare wealthier, largely White, communities; creating *de facto* segregated suburbs and unhealthy air pollution concentration levels for underserved households (CLIHC, 2020).

Ensuring equitable access through transit and other equity-focused transportation investments requires a recognition of the racist legacy of transportation planning that has reinforced segregation, depressed Black-owned property values, and subjected communities of color to higher levels of pollution (Spieler, 2020).

2.4 Affordable Housing and Zoning Practices

Equitable access in the Charlottesville region is not simply a transit or transportation issue. Instead, inequities in access are driven by a complex network of interacting factors, including housing affordability and zoning practices.

First, land closer to employment centers, transit, and amenities is often more expensive, pushing affordable housing sites to the outskirts of urban communities and forcing residents to have cars or walk long distances to access public transit. In Charlottesville, rents are so high that many voucher holders can only find rental units meeting HUD rent limits outside the City's borders (CLIHC, 2020). However, suburbs and areas outside of transit service territories are often effectively dead zones for transportation modes other than a privately-owned car, resulting in longer commutes and higher transportation costs for lower-income households (Vaidyanathan, 2016).

To better gauge housing affordability and design better solutions for the problem, planners should consider how location affects other household costs, including transportation, utilities, food, and education (CLIHC, 2020). Affordable housing should be placed in locations like the Downtown Mall and North Downtown because they offer transportation hubs, economic opportunities, and education (CLIHC, 2020). **Planning for affordable housing and transit should be developed and reviewed together**, exploring synergies and aiming to favor increasing the location-efficiency of areas selected for future affordable housing developments.

Zoning practices also contribute to decreasing connectivity and equitable access, largely due to an emphasis on single-family home development, which forces a stark separation between residential and commercial development. Combined with a lack of transit development, restrictive zoning practices lock communities into car-dependence and manufacture the need for ever more road infrastructure and parking to accommodate people travelling from far and wide to reach frequent destinations.

Instead, well-crafted zoning codes seek to maximize *location efficiency*, which encourages development of mixed-use, compact communities that are walkable, well-served by transit, and have reduced parking requirements. Conventional zoning codes often have minimum parking requirements for commercial buildings that claim significant surface area and drive-up development costs. These practices prevent denser, more-compact development from flourishing and perpetuate car-oriented neighborhoods. To enable the growth of compact developments, developers need to facilitate access by non-vehicle modes and set aside less land for parking (Vaidyanathan & Ribeiro, 2017).

2.5 Transportation and Climate

Climate change is the greatest threat to the planet and the prosperity of the human race that we have ever faced. To avoid the worst effects of climate change, we need to limit global warming to 1.5˚C, which means cutting emissions by at least 45% by 2030 and reaching net zero emissions by 2050 (IPCC, 2019). Currently, transportation is the number one source of GHG emissions in the United States, accounting for 29% of total GHG emissions in 2019 (EPA, 2021). In Albemarle County, transportation represents a massive 52% of the community-wide GHG emissions for the year of 2018 (Albemarle County, 2021). In 2016, transportation accounted for 28% of Charlottesville's greenhouse gas emissions, with personal cars and SUVs making up the vast majority of those emissions (EPA, 2018; Lewis, 2020; Watson, 2019).

At the state level, Virginia is taking important steps to transition away from fossil-fuel dependent transportation systems. In 2021, the Virginia legislature passed HB 1965, requiring the state to adopt Clean Cars Standards. The standards would require automakers to improve the average fuel economy of the vehicles they sell in the state over time as well as impose binding targets on the number of electric and plug-in hybrid vehicles sold in the state.

Additionally, the legislature passed bills commissioning a statewide transit equity study (HJ 542) and approved a rebate program to lower the cost of electric vehicles (HB 1979), with additional subsidies for lower-income households.

The recent action at the state level is historic and places Virginia as a clear leader in the southeastern United States on reducing transportation emissions. New standards will also benefit Charlottesville as cars get cleaner over time, but that does not mean the work is done. **Decarbonizing transportation at the pace required calls for not just a transition to electric vehicles—we must also reduce vehicle travel overall by investing in alternative modes of travel and rethinking how we plan our communities.**

Well-designed transit systems can significantly reduce transportation emissions by aggregating travel demand from many, often single-occupancy, vehicles' trips into a single bus (for a deeper analysis, refer to Section 5 "Scenario Analysis".) Increased reliance on transit can also prevent the need for new road infrastructure and parking, which takes up valuable land, decreases density, and has emissions implications of its own. The benefits of using transit to displace car-based trips are especially potent if transit vehicles are powered with cleaner fuels (e.g., electricity), as analyzed in Section 2.7 "Electrifying Transit."

While public transit is the focus of this report and is a critical component of a diverse and sustainable transportation system, we can also reduce vehicle travel and associated emissions by maximizing location efficiency (see above) through transit-oriented development. Individuals' habits such as where they live, work, and spend leisure time are highly correlated with transportation emissions (EPA, 2019).

Reducing GHG emissions from transportation also relates directly to creating a just transition to transit-oriented community. If implemented with equity and access to affordable housing in mind, a transit-oriented development would reduce aggregate vehicle-miles traveled (VMT),[4] avoid air and climate pollutants, while further reducing transportation burden levels of historically underserved demographics; these results were illustrated by the thought-exercise done in Section 5 "Scenario Analysis."

2.6 Benefits of Transit Investment

A well-designed and affordable transit system is critical to achieving equitable access for all, because it can provide a foundational level of transportation service to all community members. On top of that, transit delivers a wide array of social and environmental benefits.

For every dollar invested, transit investments double direct economic benefits. Virginia's Department of Rail and Public Transportation (DRPT) estimates that every dollar invested into transit generates $2.17 in direct benefits and $2.91 in economic activity statewide. Transit investments benefit the economy by saving commuting time, decreasing emissions/fuel consumption, lowering costs of auto ownership, connecting people to employment, and reducing accidents (DRPT, 2019).

Transit delivers jobs. Transit investments create or enhance jobs by allowing for more options for people to go to work (DRPT, 2019). Transit supported 29,940 jobs in Virginia for fiscal year 2018, generating approximately $3.5 billion in the state economy and $607 million in tax revenue.

Transit improves air quality and lowers GHG emissions relative to light-duty vehicle travel. According to the Kansas City Area Transportation Authority, a single person switching from a 20-mile commute alone by car to public transit reduces their annual CO_2 emissions by 20 pounds per day, or more than 48,000 pounds in a year — equal to a 10% reduction in all GHG produced by a typical two-adult, two-car household. U.S. public transit saves 37 million metric tons of CO_2 ($MtCO_2$) emissions annually, equivalent to the emissions resulting from the electricity generated for the use of 4.9 million households.

Transit investments pay for themselves in reduced congestion. Transit delivers sustained congestion relief whereas new roadway results in induced demand for travel that eventually leads to more congestion. Following a temporary shut-down of Los Angeles' public transit system in 2003, researchers from Berkeley and the National Bureau of Economic Research estimated that transit saved Los Angeles commuters $4.1 billion (1% of

[4] Vehicle-miles traveled (VMT) stands for the number of miles traveled by all vehicles in a group over a given period of time, typically a one-year period.

the City's GDP) annually that they would otherwise have spent in either freeway or arterial roads congestion (Anderson, 2013).

Transit improves access to essential services. By enhancing affordable mobility options for physically, economically, and socially disadvantaged people (many of whom lack cars and need assistance in finding resources outside their primary residence area), high-quality public transit can promote economic opportunity by increasing access to education, employment, affordable goods and essential services (Litman, 2020).

Transit is an affordable mobility option to lower-income communities. Many households spend more on transportation than is affordable, particularly lower income households in automobile-dependent areas. Due to insurance costs, registration fees, maintenance, and fuel costs, it is difficult to legally drive a motor vehicle for less than about $3,000 annually (VTPI, 2021). In Charlottesville, a monthly CAT pass used to cost $20 pre-pandemic and will now be free for the next three years (CAT Press Release, 2021).

Transit saves lives. Robust transit systems save lives by providing an alternative for high-risk and vulnerable automobile users and by promoting safer traffic speeds. A 2018 study by the American Public Transportation Association illustrates that metro areas with over 40 annual transit trips per capita have about half the traffic fatality rate of metro areas with fewer than 20 transit trips per capita (Hughes-Cromwick, 2019).

Despite the many well-established benefits of public transportation, conventional transportation planning tends to focus on a limited set of impacts that usually do not include detailed analyses of equity impacts, indirect environmental impacts, or other impacts such as parking costs, and long-term vehicle costs (Litman, 2020). This results in transportation plans failing to incorporate all the expected benefits of a cleaner and more equitable public transit system, such as accessible, affordable, and reliable public transportation for residents of historically underserved communities. These omissions might result in an undervaluation of transit improvements with equitable and environmental focus and favor project designs that do not properly optimize for these benefit categories.

2.7 Electrifying Transit

As mentioned above, public transit can be an important solution to reducing emissions from the transportation sector.[5] However, diesel buses that are operated consistently at low occupancy may actually produce more emissions per passenger-mile of travel than a modern light-duty vehicle (LDV). **Bus occupancy is therefore a critical factor in reducing emissions through transit** (see Section 5 "Scenario Analysis" for a deeper analysis). One way to guarantee that buses deliver significant emissions reductions (and operational savings) is to convert diesel buses to battery electric buses (BEBs).

[5] A report produced for C3 and the City of Charlottesville assessed the potential of three alternative strategies for mitigating the GHG emissions of the transportation sector in the City: #1 "Let Present Trends Continue;" #2 "Advance Personal Electric Vehicle Use and Charging Infrastructure;" #3 "Shift City Transit Bus Fleet To Electric Power." The report concluded that strategy #3 would be the best alternative (Watson, 2019).

2.7.1 General Benefits of BEBs

While adoption of BEBs is still in the early stages, the data is clear—BEBs are cheaper over the life of the bus and its deployment can offer other benefits such as better performance, and produce zero tailpipe emissions.[6]

- **Fuel Costs.** Because utility rate structures are typically less volatile than diesel prices, agencies enjoy more predictable fuel costs, making financial planning easier;
- **Fuel Economy.** BEBs are roughly four times more efficient than diesel buses (Aamodt, et al., 2021). While BEBs operate at around 17.35 miles per diesel gallon equivalent (DGE), a typical diesel bus achieves a fuel economy of about 4.2 miles per gallon (OEERE, 2016; Prohaska, et al., 2016);
- **Maintenance.** Because electric powertrains use significantly fewer fluids and moving parts than internal combustion engines, BEBs are cheaper to maintain by over 20%. While diesel engines buses cost roughly $0.88/mile to maintain, BEBs average $0.64/mile (Johnson, et al., 2020);
- **Performance.** The electric propulsion system within BEBs relies on magnetic induction rather than combustion, resulting in less vibration and a smoother, quieter ride. Additionally, BEBs have instant maximum torque capabilities (low-end torque), making them better than internal combustion vehicles for carrying heavy loads and accelerating up hills (Clean Cities, 2012; Aamodt, et al., 2021);
- **Emissions.** BEBs emit zero tailpipe emissions and are as clean as its electricity source, reducing local air pollution (CO_2, NO_x, HC, PM) in dense urban areas. The majority of CO_2 emissions from BEB operations arise from electricity generation. Under the C3's LCCA for the four BEBs vs diesel buses, the four diesel buses are predicted to emit 3,800 $MtCO_2$ over 12 years, while the four BEBs are predicted to emit 654 $MtCO_2$ (avoiding 83% of total lifespan CO_2 emissions); when taking into account Virginia's steadily decarbonization of the electrical grid (Shobe, et al., 2020).

  While other alternative fuel options may also lower tailpipe emissions, BEB usage results in the least amount of air pollution. Compressed natural gas (CNG) buses release similar levels of CO_2 from their tailpipes as diesel buses, while biofuel buses actually emit more NO_x than diesel buses (MJB&A, 2013). The GHG emissions from hybrid-diesel-electric buses are 20-30% lower than traditional diesel buses but efficiency benefits are heavily impacted by route length and driver efficiency (Steer 2019). Diesel buses retrofitted with clean-diesel technology ("clean-diesel buses") emit 85% less air pollution than traditional diesel buses. Emissions reductions from clean-diesel are significantly lower compared to CNG, biofuel, and hybrid-diesel-electric bus emissions, but miss out on the other significant benefits of electrification. Hydrogen buses also have zero tailpipe emissions, but they are currently in an experimental stage with high production costs. BEBs are the only commercially available option with zero tailpipe emissions;

[6] For a detailed overview of the benefits and costs of BEBs deployment, as well as practical guidelines for deployment, we refer you to (Aamodt, Cory and Coney 2021): https://www.nrel.gov/docs/fy21osti/76932.pdf.

- **Environmental Justice:** As mentioned in Section 2.3 "Transportation Equity", multiple studies have shown that disadvantaged individuals are more likely to be exposed to traffic emissions and suffer from the negative health effects from conventional vehicles (CUB, 2020; Pinto de Moura & Reichmuth, 2019). The reduction in local air pollution associated with BEB fleet deployment can help lessen this injustice. Clean transportation should be accessible to communities that have been historically more burdened by the adverse health effects of air pollution.

2.7.2 General Challenges of BEBs

However, it is worth mentioning a few of possible barriers to BEB deployment:

- **Economic Challenges:** Upfront cost is higher; beyond the bus itself, funding is needed to install BEB charging stations. These extra expenses for charging infrastructure include the cost of the charging equipment, installation, and coordination with the utility and other project partners;
- **Planning Burden:** Planning for a BEB fleet and charging infrastructure is complex and fundamentally different than for diesel bus deployment. Routes may need to be altered in order to simultaneously optimize transportation service, BEB performance, and recharging efficiency;
- **Operating Range:** The distance a BEB can travel is constrained by the placement of chargers, limiting BEBs to certain routes and areas. Meeting the charging infrastructure requirements of BEB routes throughout a larger city or region may take time and impact the BEB deployment schedule;
- **Unfamiliarity:** BEBs have a current predicted lifespan of 12 years (Eudy & Jeffers, 2017), but the technology is in an early enough stage of deployment that there is not yet a proven understanding of BEB lifetimes. Typical diesel buses have an FTA-required expected life of 12 years, but they last 15 years on average (Lave, et al., 2007).

2.7.3 Life Cycle Cost Analysis (LCCA) of Battery Electric Buses (BEBs) vs. Diesel Buses

To better understand the costs and benefits of electrifying transit services, we compared the costs and benefits of acquiring four BEBs to acquiring four diesel buses, estimating key financial metrics to develop a Life Cycle Cost Analysis (LCCA).[7] According to our LCCA, BEBs appear to be the most promising type of alternative bus on the market, as they can be completely free of fossil fuels if electricity generation comes from carbon-neutral sources (such as hydropower, solar, and/or wind). BEBs depend solely on rechargeable battery packs to store electricity for power, similar to plug-in electric cars.

In recent years, BEBs have emerged as the preferred alternative fuel bus technology for cities seeking to reduce emissions. However, while BEB fleets may provide benefits such as lower fuel and maintenance costs, improved performance, lower emissions, and energy security, there are a variety of challenges associated with BEB deployment. These challenges

[7] See Annex for a more detailed explanation of the used assumptions, data sources and methodology.

could include upfront cost premiums, planning burdens, lower operating range, and unfamiliarity with BEB technology. Performing financial valuations and a LCCA of BEBs helps make the benefits and challenges associated with BEBs transparent and provide users with an in-depth view of the differences between diesel buses and BEBs.

Though costs have been decreasing, BEBs still have high purchase prices compared to diesel buses (Quarles, et al., 2020). Using data from NREL (Johnson, et al., 2020), our LCCA assumed a total purchase price of $954,400 per BEB, including the bus's battery and a depot charger, and $480,000 per diesel bus. In spite of the bigger purchase costs, due to their lower operations and maintenance costs, the purchase of four BEBs lead to net savings over the buses' lifetime with respect to fossil-fuel based options.

Considering that state funds could match up to 68% of the costs of local transit agencies fleet expansions, and of its related infrastructure, our LCCA projects that four diesel buses would be purchased with an upfront capital expenditure of $614,400 have a total lifetime cost of $3.66 million due to a maintenance cost of $110,400 per year; assuming a 12 years lifespan (DRPT, 2020). For the purchase of four BEBs, with an upfront capital expenditure of $1,221,600, our LCCA yields a total lifetime cost of $2.81 million with a maintenance cost of $80,300 per year. Additionally, our LCCA determines the purchase of four diesel buses to require $87,000 in fuel consumption per year, whereas the purchase of four BEBs would require $32,000 in electricity costs per year.[8]

Overall, our LCCA shows how the purchase of four BEBs is a better long-term investment than the purchase of four diesel buses. The calculations include the net present cost (NPC) of each choice, which is a measurement that depicts the present value of all the costs associated with purchasing and operating the buses over their 12-year lifetimes. Our LCCA details that the four diesel buses will have an NPC of $3.03 million, while the four BEBs will have an NPC of $2.49 million. In other words, over a life-time of 12 years, buying and operating four diesel buses would be nearly 22% more expensive than buying and operating four BEBs; or even, to put it simply, **the lifecycle expenses of four diesel buses would be high enough to justify the acquisition of five BEBs at nearly no extra cost**.

[8] Our analysis included as part of the electricity costs the effects on peak electricity demand/draw. For future fuel costs, we assumed that the price of commercial electricity will grow at an annual rate of 2.9% (even though it grew only at an annual rate of 0.7% between 2010 and 2019) and diesel prices will grow at an annual rate of 5.0% (as a consequence of possible carbon pricing policies in the transportation sector).

Figure 6. Cumulative Net Present Cost – 12 Years

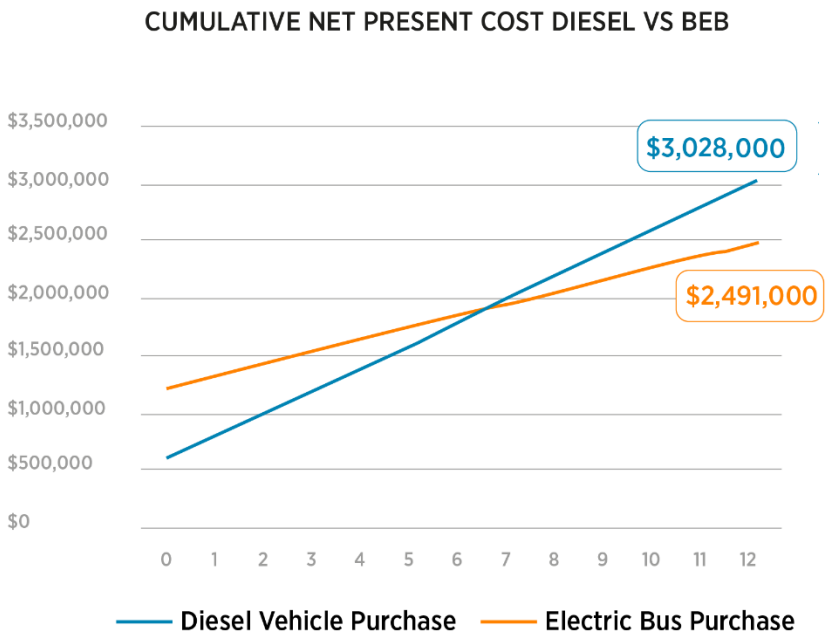


Figure 6 tracks the difference in NPC between the purchase of four diesel buses (grey line) and the purchase of four BEBs (blue line). Although the blue line is the highest at the date of purchase, it is projected that five years after the buses purchase the blue line would cross below the grey, showing that the cumulative NPC of BEBs would already be lower than that of the diesel buses by the beginning of the sixth year after purchase. By year 12, the cumulative NPC of the BEBs purchase is significantly lower, revealing it as a more economical option than diesel buses.

As the technology and the market matures, it is likely that the cost and performance of BEBs will continue to improve, further strengthening both the environmental and business case for going electric.

2.7.4 Case Studies of Bus Electrification

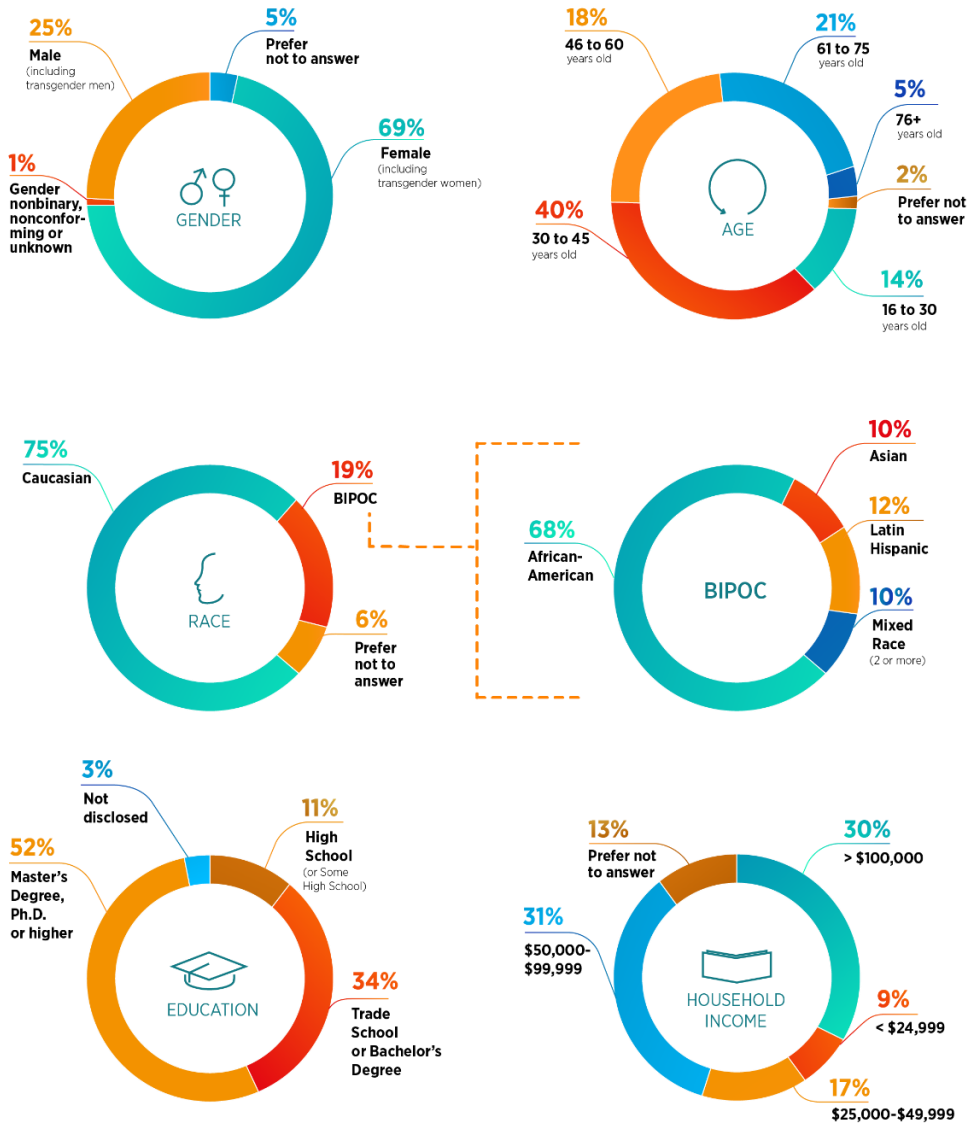
Though the market is still young, some cities, including in Virginia, are already moving to electrify their bus fleets. In 2020, Hampton Roads Transit in Norfolk received dedicated funding from the state to purchase six BEBs to serve one of its busiest routes in central Norfolk (HRT, 2020). Additionally, Blacksburg and Alexandria have started to integrate BEBs into their transit fleets (Cardone, 2021).

In North Carolina, the City of Greensboro became the first city in the state to have an all-electric bus fleet in 2019 (Greensboro, 2019). On top of reducing emissions of both GHG and other harmful pollutants (e.g., particulate matter), the City expects that each BEB will save $350,000 in fuel and maintenance costs over its lifetime.

3 Community Surveys

One of our objectives in this project is to aggregate and amplify the voice of the people of Charlottesville and Albemarle and allow their experience with local transit to inform our research and recommendations. To that end, in late February 2021, we distributed a community survey (full list of questions here) to gather information about individuals' perspectives on transit service, what it does well and where it can improve. The survey received 265 responses. See Figure 7 for a more detailed breakdown of our survey sample.

Figure 7. Survey Sample Breakdown (265 total responses)



As we know from overall ridership data published regularly by CAT, COVID-19 affected individuals' travel choices significantly. Prior to the COVID-19 pandemic, half of respondents were at least occasional users of CAT services. However, during COVID-19,

roughly 75% of respondents did not use CAT services at all, and an additional 13% reduced their usage. When considering race and income, **White and higher-income individuals were more likely to reduce their usage, suggesting greater access to transportation or remote work alternatives during the pandemic**. Outside of questions asking specifically about how COVID affected their usage of CAT, we also asked respondents to consider their habits under "pre-COVID circumstances."

Key Takeaways

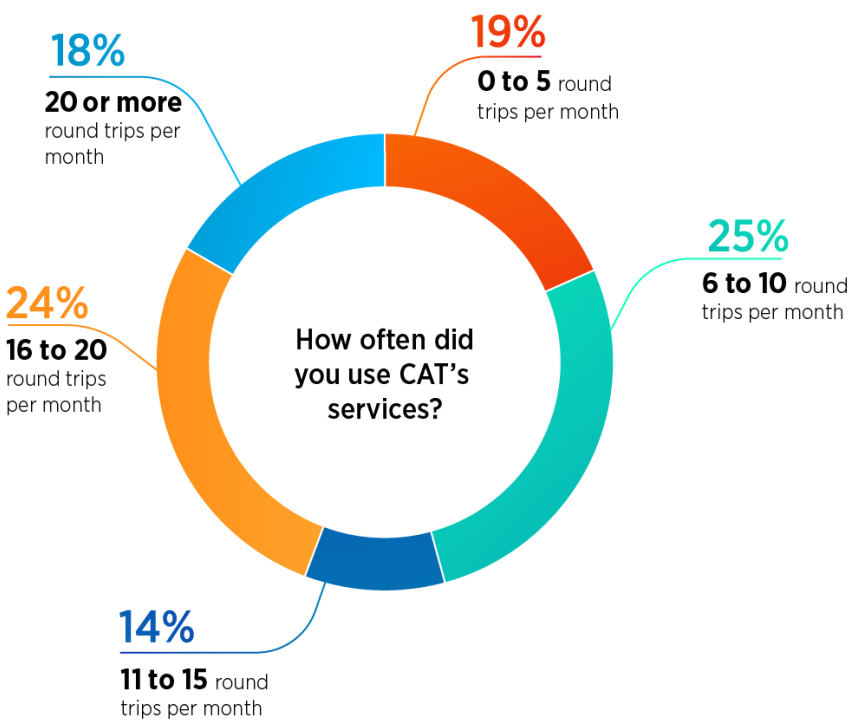
- Regular CAT riders' transit usage varies widely from using it roughly once a week to more than 25 round trips per month. The highest-frequency users were more likely to be lower-income individuals and renters.
- Trip length can be a significant burden on individuals' schedules. We found that BIPOC populations, on average, experience trip lengths that are 18% longer.
- Captive riders are more likely to be low-income or BIPOC individuals
- Overall, rider respondents gave high ratings to many aspects of CAT's service, with room for improvement.
- Frequency was the lowest rated aspect of CAT's service and one of the most requested features as well. Infrequent bus arrivals complicate trip planning and make the cost of missing a bus much higher.
- Nearly 40% of our rider respondents rated bus stops as unsatisfactory or unacceptable. Open-ended survey questions and our focus group conversations reinforced the need to improve the cleanliness, safety, and placement of bus stops.
- Riders expressed frustration with the circular loop all routes follow. Additionally, buses that run along divided roadways in some areas are not well connected to pedestrian infrastructure.
- Respondents also expressed a desire for more flexible payment methods and fare passes, as well as for CAT services to be free.

3.1 Regular CAT Users (Riders)

Of the 265 responses, 63 individuals (or 24%) identified themselves as "regular CAT users." Among our survey sample, all older individuals (76 and older) did not identify as regular users. The most common age groups included young adults (16-30 years old) and middle-aged adults (46-60 years old).

Roughly 75% of regular riders live in the City of Charlottesville. Riders that responded from Albemarle County largely depend on CAT for essential services like accessing healthcare and commuting to school. Overall, the most common destinations for CAT riders were commuting to and from work and running errands. Regular riders' usage varies widely from using CAT roughly once a week to more than 25 round trips per month (see Figure 8). **The highest-frequency users were more likely to be lower-income individuals and renters**.

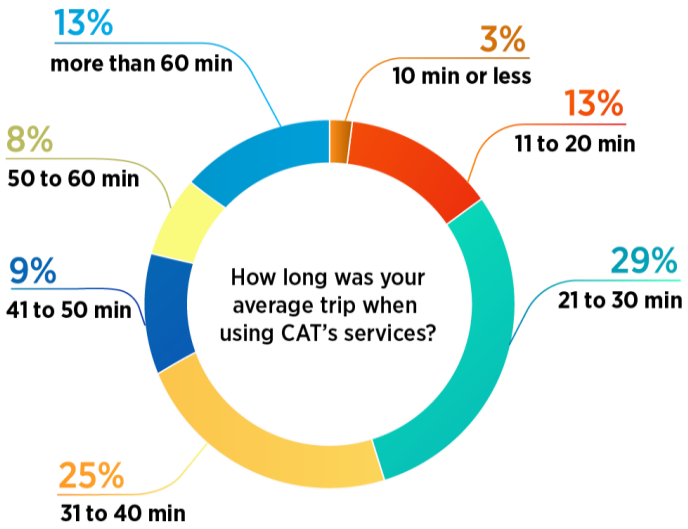
Figure 8. Considering pre-COVID circumstances, how often did you use CAT's services? (n=63)



Trip length, which includes the time it takes to reach the bus stop, is a key determinant of rider experience and the convenience (or inconvenience) of transit. To reach their bus stop, 33% of riders walked 6-10 minutes while 27% walked 11-15 minutes. With respect to total trip length, the most common trip length was 21-30 minutes (29% of respondents), but when combining multiple options, we found that 55% of respondents had a trip length of at least 31 minutes, with 13% reporting trips of over an hour (see Figure 9).

Particularly for riders that rely heavily on transit to get around and commute to work, trip length can be a significant burden on individuals' schedules. When considering the demographics of the responses, we found that **BIPOC populations, on average, experience trip lengths that are 18% longer than non-BIPOC riders**. Additionally, **African Americans, households with less than $50,000 annual income, and renters were overrepresented among riders with average trip lengths of more than one hour**. We used these findings in our Scenario Analysis to estimate the benefits of enhancing CAT's equity focus.

Figure 9. Considering pre-COVID circumstances, how long was your average trip when using CAT's services? (n=63)

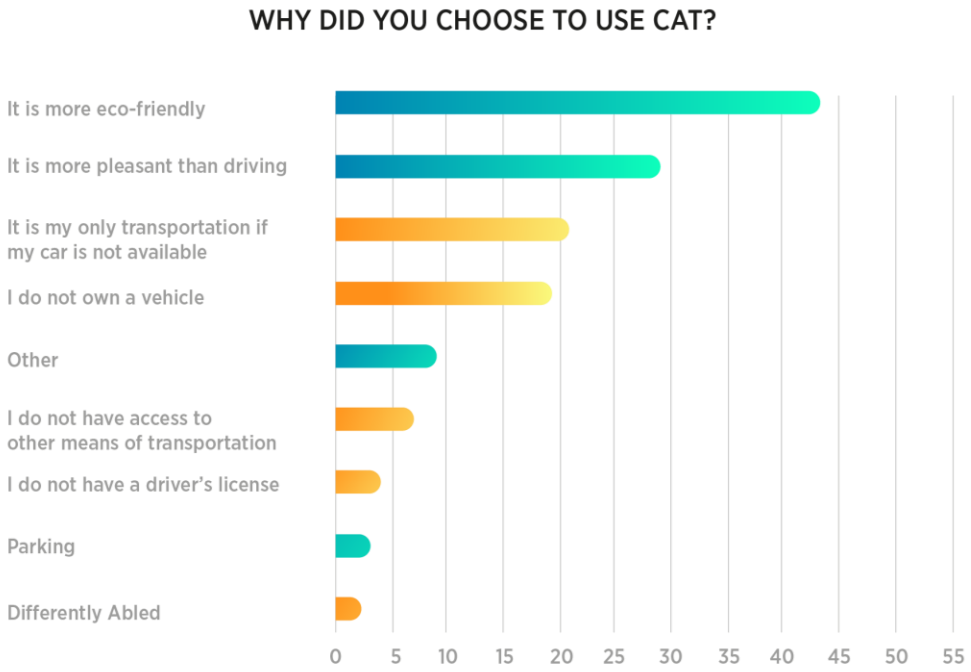


We also asked CAT riders why they chose to use CAT. The most common reason, selected by 44 participants, was that "It is more eco-friendly." Some of these riders may be *choice riders*, or riders that have alternative means of transportation. **Choice riders** often choose transit for its environmental benefits, avoiding driving traffic, or saving money, even if taking transit may result in longer trips (Perk, et al., 2008).

This question also shed light on captive ridership. ***Captive riders*** are transit users that have very few or no alternatives to transit service and, therefore, must use transit out of necessity rather than choice. Their lack of transportation alternatives means that their access to essential services, economic opportunity, and community are heavily influenced by the quality, frequency, and coverage of CAT services. **Over half of the rider respondents answered survey questions in a way that could suggest captive ridership, including answers as "not owning or having access to a vehicle", "having to share one vehicle with others", "not having a driver's license", or "being differently abled"** (see responses highlighted in orange in Figure 10).

We also found that **captive riders are more likely to be low income or BIPOC individuals. In our sample, BIPOC individuals made up a larger share of the captive rider group (24%) than the overall sample (19%). Captive riders were much more likely to be lower-income; 54% of captive rider respondents come from households earning less than $50,000 a year, but these households make up just 26% of the overall sample**.

Figure 10. Considering pre-COVID circumstances, why did you choose to use CAT? (check all that apply) [n=63]



Route preferences also offer insights into CAT ridership. Overall, the Free Trolley and Route 7 (which serves the US-29 corridor) were the most commonly used routes among survey respondents. This is not surprising because these routes consistently serve the largest number of riders. However, when considering different demographic groups, route preference is more varied. For example, African Americans and lower-income individuals (less than $25,000 a year) are less likely to use the Free Trolley serving the Downtown area and more likely to use a wide variety of routes (though Route 7 is still widely used across all demographic groups).

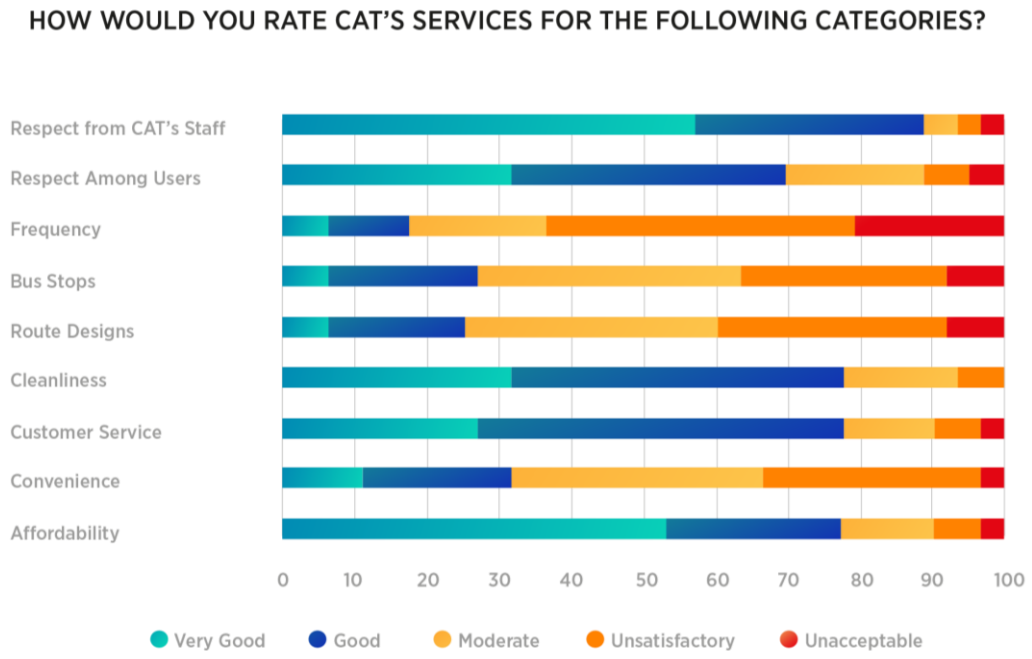
Finally, we asked CAT riders to rate CAT services across the following categories:

- Respect from CAT staff
- Respect among users
- Frequency
- Bus Stops
- Route Designs
- Cleanliness
- Customer Service
- Convenience
- Affordability

Overall, rider respondents gave high ratings to many aspects of CAT's service, with room for improvement. As shown in Figure 11, most rider respondents feel respected by CAT staff and fellow riders. They also gave high marks to the cleanliness of buses, customer service, and the affordability of CAT service. However, riders also highlighted areas of much needed improvement. **Frequency, bus stops, route designs, and service convenience**

received the lowest ratings of the attributes listed. These areas of improvement align well with responses to other questions and feedback collected during focus groups.

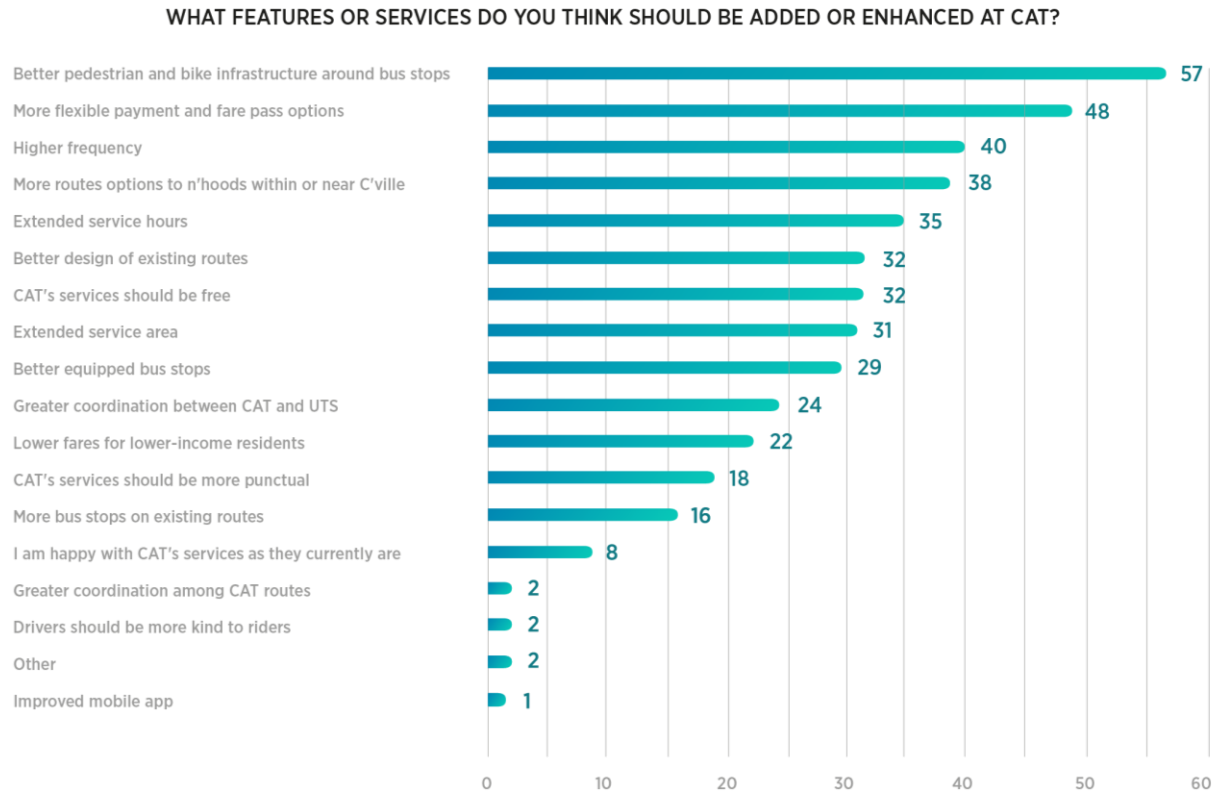
Figure 11. How would you rate CAT's services for the following categories? (Pre-COVID) [n=63]



One of the last questions we asked each of our survey respondents was suggestions for improving CAT service. Figure 12 below summarizes the responses for rider respondents.[9] The top result is an aggregation of multiple choices in the survey focused on making bus stops more accessible through bike and pedestrian infrastructure, including bike lanes, sidewalks, and bike parking. The third most popular feature was increased frequency of service. The importance of high frequency service is reflected in our review of best practices and focus groups discussions as well.

[9] It is important to note that the survey was distributed before CAT announced an extension of fare-free service. Because CAT is going to be free for the next several years at least, we do not discuss findings related to fares and payment options.

Figure 12. What features or services do you think should be added or enhanced at CAT? (Check all that apply) [n=63]



Recommendations that garnered votes from roughly half of our rider respondents include extended service hours, improving route design, extended service areas, and better equipped bus stops. Several answers to open-ended questions as well as focus group comments highlighted the need for service that connects more remote neighborhoods to central Charlottesville, reflecting the reality that many lower-income households are being forced out of the urban core by rising cost of living. Participants across the survey and focus groups have also reinforced the need for bus stops with better lighting and weather protection (for more information, refer to Section 4 "Focus Groups and T&E Survey's Open-Ended Questions").

3.2 Non-Riders

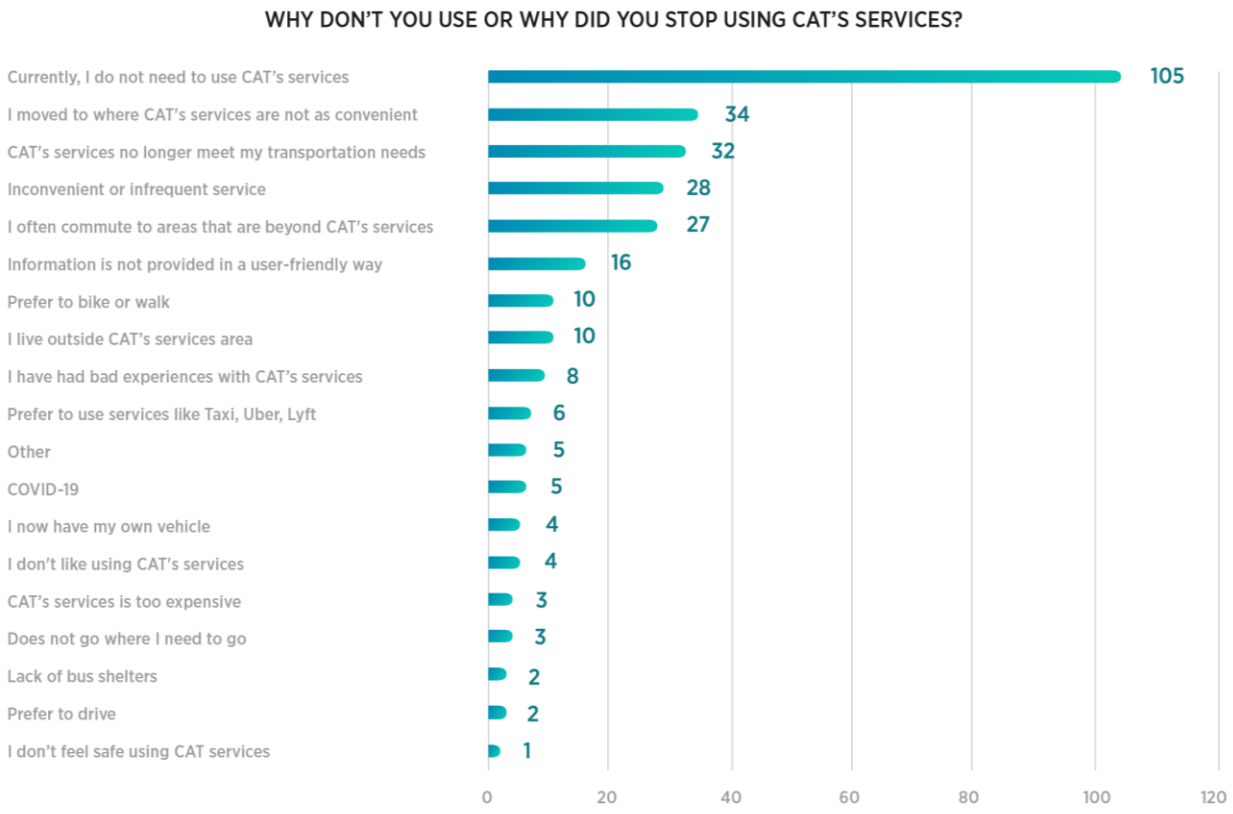
Of the 265 responses to our survey, 202 (or 76%) individuals identified themselves as *not* regular users of CAT services. Of that group, 58 individuals (or 22% of the whole sample of 265 respondents) said that they were regular CAT users at one time, while the remaining 144 respondents said they had never been a regular CAT user. For the purposes of this report,

we are referring to these individuals as *non-riders*, but it is important to note that this does not mean that respondents have *never* used CAT—only that they would not consider themselves regular users.

The respondents that reported being CAT users at one time contained higher proportions of BIPOC individuals, lower-income individuals, renters, and individuals without any college education than the overall sample. While not conclusive, this may indicate that as riders that may be captive advance economically or otherwise gain other transportation options, they choose to use CAT less frequently.

When asked why respondents chose not to use CAT services (see Figure 13), the most common answer was that they did not need to use CAT services. Of these respondents, all but two individuals own or have access to a vehicle when they need it. Other common answers covered living in areas that are not well-served and generally feeling the service was too infrequent or too inconvenient to justify using.

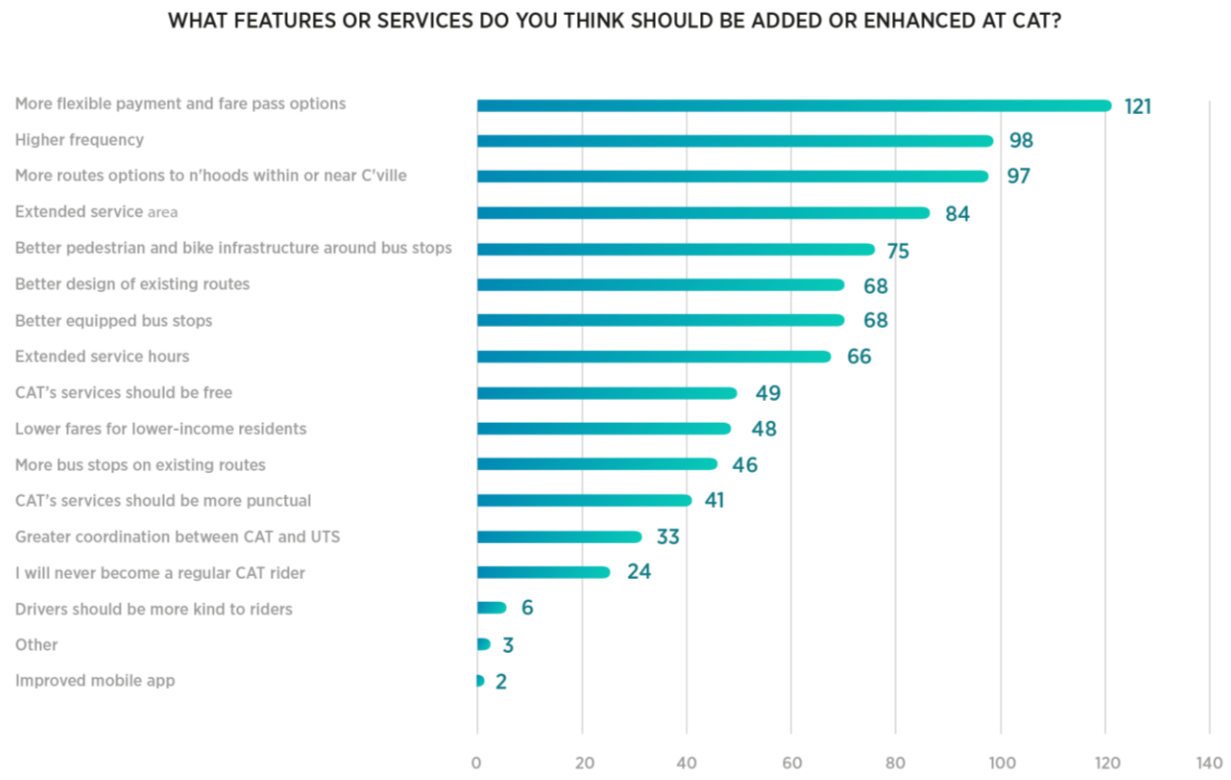
Figure 13. Why do not you use or why did you stop using CAT's services? (Check all that apply) [n=202]



Like respondents that considered themselves frequent riders, we asked non-riders about features or services that they would like to see implemented at CAT (see Figure 14). The most commonly selected answers related to alternative payment and fare pass options, though this is currently a less pressing issue considering that CAT service is expected to be free for the next three years (CAT Press Release, 2021). The next four most common

responses echoed featured requests of riders, including higher frequency, expanded service, and improved pedestrian and bike infrastructure around bus stops.

Figure 14. What features or services do you think should be added or enhanced at CAT? (Check all that apply) [n=202]



3.3 Summary of Findings

When considering all the feedback we collected in the community survey, several key takeaways surface, all of which are also supported by our focus group conversations.

- **Frequency.** In our survey, frequency was the lowest rated aspect of CAT's service and one of the most requested features as well. The frequency of bus arrivals has a significant impact both on the usability of the service and on customer experience. Infrequent bus arrivals complicate trip planning and make the cost of missing a bus much higher. For commuters who have to arrive at work at a specific time, lining up bus schedules and work schedules may mean they have to arrive at their destination well ahead of time just to avoid being late. On the other hand, high frequency service creates the sense (and reality) of convenience and flexibility, better approximating the experience of owning a car.

- **Bus Stops.** Nearly 40% of our rider respondents rated bus stops as unsatisfactory or unacceptable. Open-ended survey questions and our focus group conversations

reinforce the need to improve the cleanliness, safety, and placement of bus stops. Some riders expressed feeling unsafe because of poor lighting at stops. Nearly half of riders that participated in our survey noted a need for bus stops to be better protected in bad weather, while a similar number expressed that bus stops needed to be better connected to pedestrian and bike infrastructure to improve accessibility.

- **Route Designs.** Drawing from other survey questions and focus group conversations, riders in particular expressed frustration that all routes operate on a circular (one-way) loop which significantly extend trip lengths depending on origin and destination. Additionally, buses that run along divided roadways in some areas are not well-connected to pedestrian infrastructure, making it difficult and unsafe to cross the road to access. Some examples cited were routes 7 and 8 when trying to access shopping at US-29 and Hydraulic.

In addition to the above items, it is worth noting that respondents also expressed a desire for more flexible payment methods and fare passes, as well as for CAT services to be free. We do not discuss this at great length because CAT has already made this a reality by extending free service for at least the next several years.

4 Focus Groups and T&E Survey's Open-Ended Questions

In addition to the structured survey responses, we also collected feedback through open-ended survey questions and a series of four hour-long focus groups sessions. Each focus group consisted of 4 to 6 community members and participation was very demographically diverse, with 50% of participants being African Americans or Latinos. This section summarizes the key insights from these data points.

Key Takeaways

- CAT's frequency. The participants were in agreement that improved frequency would allow commuters to get to their jobs on time, families to pick up children from school on time, and incentivize community members as a whole to utilize CAT more often.
- CAT's schedule. The bus schedule is prohibitive to nurses or other working class community members. There needs to be extended service to ensure that those who commute to and from work during alternative hours have adequate transit access.

4.1 Service Reliability/Safety

One of the main topics touched upon by our focus groups was service reliability and safety. All focus group participants agreed that the bus system is often unreliable, too infrequent, and inefficient, often leading them to prefer to walk or drive to their destination instead. Participants elaborated that the Catch the CAT App – CAT's former app, which was discontinued on 9/4/2021 (CAT, 2021 a; CAT, 2021 b) – was often incorrect about bus arrival times and that buses arrive late.[10] A few participants also mentioned the **need for better infrastructure at bus stops, including benches, shelters, and better signage to accommodate weather conditions and those differently abled**. One participant said that the **lack of security in the bus system discourages using it with children**. Overall, these responses were largely aligned with results of UVA's Equity Center's "Transportation Equity and Accessibility" study, formerly discussed in Section 2.2.3.

Similar perspectives were also captured by open-ended questions included in our survey, where six respondents commented on the lack of safety associated with CAT's services. Three respondents mentioned the poor quality of CAT bus stops, while one emphasized the need for bike lanes and adequate space for pedestrian traffic. Four survey respondents agreed that CAT's services are not convenient (e.g., not comfortable or not easy to use), while two other respondents discussed the importance of effective real-time tracking.

[10] In July 2021, CAT announced that it will be transitioning to a new real-time information App (ETA Spot App). The former Catch the CAT App will be discontinued on 9/4/2021 (CAT, 2021 a; CAT, 2021 b).

4.2 Routes' Range (Geographic Coverage)

An important topic discussed by our focus groups was routes' range, which addresses the geographic coverage provided by CAT. Participants mentioned that **the bus system does not adequately access places they would like to go, including grocery stores**, Stonefield, Walmart, Target, or other areas further out on the US-29 corridor. Most participants mentioned that additional bus routes along the US-29 corridor would improve access to new housing developments and decrease the amount of commuter traffic in the City of Charlottesville and Albemarle County. Some also mentioned that they would like to have a **rapid transit lane added on the US-29 corridor** as a way to incentivize transit use.

All participants were in agreement that **better coverage is needed for locations such as schools, churches, and hospitals**. Schools must have a nearby and convenient bus stop to ensure children are safe. Participants also mentioned that populations living outside of the greater Charlottesville area are more likely to be affected by a high-cost burden due to their longer commute. A few participants discussed the **need for more Park-&-Rides near large bus connections** to allow for commuters from outside the City to utilize CAT and prevent bottlenecking or too many personal vehicles in the City during rush hour.

Similar perspectives were captured by open-ended questions included in our survey, with three respondents highlighting inefficient route design. Another seven respondents mentioned how CAT services do not succeed in reaching potential riders. One respondent reported that the nearest CAT stop to them is more than a two-mile walk away. Another respondent addressed how CAT does not serve the last mile of their commute.

4.3 System's Frequency and Schedule (Service Hours and Days)

One of the primary topics discussed by our focus groups was CAT's frequency and schedule. Participants mentioned that taking the bus or Trolley to and from work significantly increased their commute time because the system does not run often enough. All participants agreed that service hours' span and infrequency were underlying factors for choosing not to ride the bus. The participants were in agreement that improved frequency would allow commuters to get to their jobs on time, families to pick up children from school on time, and incentivize community members as a whole to utilize CAT more often.

One participant mentioned that the bus schedule is prohibitive to nurses or other working class community members whose work schedules are earlier or later than the bus system runs. The CAT schedule does not operate from the very beginning to the very end of the day. According to some participants, this is an important problem for the Latino community, since many people work in the restaurant sector and leave their job very late. Some participants mentioned that there needs to be extended bus route hours or 24-hour service to allow those who commute to and from work during alternative hours adequate access to transportation.

Similar perspectives were also captured by open-ended questions included in our survey, where three respondents shared that extended service hours are necessary, eight

respondents mentioned their dissatisfaction with the low frequency of routes, six highlighted issues with long travel times, and four discussed inconvenient wait times.

4.4 Preference for Other Travel Modes

A topic surfaced by our focus groups was preference for other modes of travel. Participants mentioned that beginning a family changed their transportation habits, motivating them to commute by car more often. A participant said that people are likely to pay more money if they are able to use more reliable, faster, and customizable options such as scooters to travel instead of waiting for a bus.

Similar perspectives were also captured by open-ended questions included in our survey. Although there seems to be a consensus in our community input that other alternative travel modes are preferred over CAT's services, there is less agreement on which mode is ideal, with seven respondents highlighting the reliability of driving and five discussing the reliability of biking. Four respondents also mentioned the ease of walking; which, however, disagrees with repeated concerns from members of our survey and focus groups regarding the safety and connectivity of Charlottesville's sidewalks.

4.5 Equity/Accessibility

One of the main topics discussed by our focus groups was equity and accessibility. Participants believed that the bus lines were not set up to serve everyone, or reach communities and neighborhoods that are most in need of transportation. Most participants mentioned that they believe lower-income, working class communities and individuals living below the poverty line were more affected by high transportation burden. Other participants mentioned that they believe people of color and the elderly are disproportionately affected by transportation cost burden. People differently abled were also mentioned to have a disproportionate transportation burden, as well as more hardship accessing transportation and being able to travel to necessary destinations, such as doctor appointments or the grocery store.

One participant mentioned that this situation is made more difficult by the high costs of bus passes, and changes in Medicaid/Medicare eligibility that would allow someone to apply for a free or reduced-cost pass. Cultural differences were also mentioned in the focus groups. All of the participants who emigrated from Latin America commented that they do not use CAT frequently at this time, despite having used it as their main mean of transportation when they were recently immigrated. One participant added that in her home country she only traveled by bus. When she came to Charlottesville, she found it confusing to learn that the bus only traversed the City and not its outskirts.

Solutions to equity issues mentioned in the focus groups include a better indication of where the CAT buses go. Sometimes people cannot read or understand the system, such as how to make connections to other routes. Many participants highlighted the need for the **reduction or abolition of bus fare** to make public transport more cost allowable.

Similar perspectives were also captured by open-ended questions included in our survey, where three respondents shared that fare-free service is necessary. Three more respondents emphasized the need for more accessibility in CAT's services.

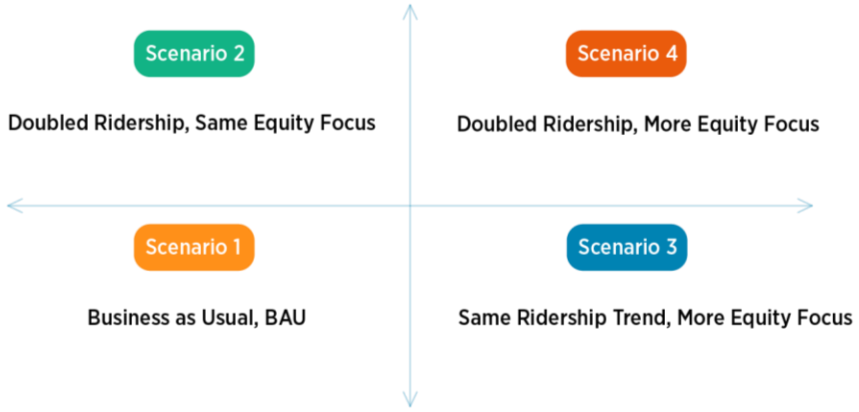
4.6 COVID-19/Other

A topic mentioned by our focus groups was COVID-19. Participants highlighted that as a whole, they have been less comfortable taking public transportation since the pandemic. Similar perspectives were captured by open-ended questions included in our survey, with three respondents sharing that they are afraid of contracting COVID-19 on public transportation.

5 Scenario Analysis

As discussed in the Background Section, investing in robust, equitable, and clean public transportation yields diverse benefits for communities, the economy, and the environment. **This section uses a four-quadrant scenario analysis to illustrate the environmental and social co-benefits of doubling CAT's ridership from 2019 levels by 2024 with an enhanced equity focus.**[11] The diagram below (Figure 15) shows how we considered ridership and equity focus to give us four distinct "what if" scenarios (or pathways).[12]

Figure 15. Scenario Design Illustration



By illustrating the net environmental and social co-benefits of each scenario and presenting them side-by-side, we can better understand how maximizing the benefits of transit depends on thinking holistically about all aspects of transit, including technology, service area, and target market. This analysis also provides additional insight to support transit planners and advocates in forming data-supported positions. The four hypothetical scenarios (pathways) considered in this analysis are:[13]

I. **Business as Usual (BAU):**
   - Ridership declines at pre-pandemic rates, while equity efforts do not improve.

II. **Ridership Growth Alone:**
   - Ridership doubles by 2024, (compared to 2019); equity efforts do not improve.

III. **Increased Equity Focus Alone:**
   - Ridership declines at pre-pandemic rates; however, the enhanced equity focus allows the transit system to better serve historically underserved groups.

IV. **Ridership Growth with an Increased Equity Focus:**
   - Ridership doubles by 2024 (compared to 2019), while the enhanced equity focus allows the transit system better serves historically underserved groups.

[11] Although scenario analyses are not intended to predict or forecast what will happen, they are a useful way to understand what may happen under a given set of circumstances. Therefore, it is a useful tool to help us to weigh the pros and cons of different approaches to the future of transit in the Charlottesville and Albemarle region.

[12] See Annex for a more detailed explanation of the used assumptions, data sources and methodology.

[13] This section will focus primarily on the expected results of each of the four scenarios, not so much on how each of them could be achieved. However, the Recommendations Section of this report sheds light on the factors we consider crucial to doubling the number of CAT passengers and improving its fairness in transit.

Key Takeaways

- For all scenarios, CAT's transit system plays the important role of avoiding millions of car-based trips and hundreds of thousands of dollars in car-fuel costs (with positive impacts in reducing the average transportation burden of local households).
- If CAT ridership levels decline at pre-pandemic rates, bus-occupancy levels would fall and the agency's capacity to avert CO_2 emissions would be impaired.
- If CAT ridership levels double by 2024 (compared to 2019), CAT becomes a net reducer of CO_2 emissions and avoided car-fuel costs are at least twice as big as in 2019. The highest savings are achieved if transit equity is enhanced.
- Regardless of ridership trends, scenarios with enhanced transit equity yielded higher environmental benefits than their less equitable counterparts.
- Bus occupancy level is critical when considering public transportation's climate change impact. There is a threshold (between 6.0 and 9.7 passengers per bus) that only over which transit buses emit less than a car on a per passenger basis.

5.1 Analysis

5.1.1 Scenario I: "Business as Usual" (BAU)

This scenario assumes that transit ridership decreases at a compound annual growth rate (CAGR) of 6% between 2019 and 2024 with no significant changes in service to better serve disadvantaged communities. As former riders continue to choose more expensive car-based forms of transportation, households' average transportation burden in the community would continue to increase at pre-pandemic rates. This more car-based scenario would result in worse environmental and health outcomes.

A possible consequence of this scenario is that captive riders will make up an increasing share of CAT's ridership mix (the demographic composition of all CAT's riders). This could, in turn, lead to lower service quality over the medium-to-long term, as transit agencies can feel less compelled to provide good services to riders that could not realistically opt to not use the system (Perk, et al., 2008).

5.1.2 Scenario II: "Ridership Growth Alone"

Under this scenario, transit ridership doubles by 2024 compared to 2019. However, this increase is not coupled with an enhanced equity focus. The larger share of travelers using the transit system would result in lower community-wide transportation burden as thousands of households start to use CAT's service more regularly.

5.1.3 Scenario III: "Increased Equity Focus Alone"

Like Scenario I, this scenario assumes that transit ridership decreases steeply between 2019 and 2024. However, **under this scenario, CAT enhances its equity focus and improves riders' experience by decreasing waiting times,[14] improving service reliability, constructing weatherproof bus stops, making its mobile App more user friendly and accurate, and providing better sidewalks and crosswalks.**

By meeting previously unmet needs and increasing accessibility, **CAT's service would become more welcoming and respectful of rider's time** (especially to those riders that have longer commutes, are differently abled, face long working hours, and/or that have children and other domestic responsibilities). Under scenarios III and IV, where CAT's equity focus is enhanced, the agency's ridership mix would increasingly have a higher share of historically underserved demographics, yielding more net social and environmental benefits for the average trip made with CAT buses.

As a consequence of riders' lower average income and higher car-fuel cost savings, this unlikely scenario (where CAT's service quality improves, but ridership falls) would result in a larger reduction of riders' average transportation burden than in its less equitable peer scenario where ridership also follows its recent trends (Scenario I).

5.1.4 Scenario IV: "Ridership Growth with an Increased Equity Focus"

This scenario combines the best aspects of Scenario II and Scenario III. CAT enhances its equity focus and improves riders' experience. Both positive changes are followed by an increase in transit ridership, CAT's ridership demographic mix would be more diverse, with important impacts in households' average transportation burden.

5.1.5 Results

Although we use 2019 as our baseline year, environmental and socioeconomic impacts by 2024 are assessed by contrasting the effects of transit use to the same amount of car-based passenger miles traveled (PMT) that would take place.[15] **We chose the following three key variables for making a cross-sectional comparison across the scenarios:**

- **"Avoided Non-transit VMT/year,"** is CAT's annual PMT divided by United States' average car occupancy for 2017 (BTS, 2018);[16]
- **"Net CO2 Emissions ($MtCO_2$)"** is CAT's annual CO2 emissions ($MtCO_2$) minus the emissions that would have taken place if "Avoided Non-transit VMT/year" were to be driven by light-duty vehicles (LDVs);

[14] Waiting times could only be decreased if frequency increases. In accordance with our assumption that CAT's entire fleet's VMT remains unchanged, for selected routes to benefit from lower waiting times reductions in the frequency, loop-lengths and/or service hours of other routes would have to take place.

[15] PMT stands for the product of VMT by the average number of passengers that were carried on each mile.

[16] CAT's annual PMT varies across scenarios only as a consequence of changes in CAT's bus occupancy, given that the agency's VMT is assumed to remain unchanged.

- **"Avoided Car-fuel Costs"** is the cost of the gallons of fuel that would have been used by average LDVs to run a distance equivalent to "Avoided Non-transit VMT/year."

Table 1 shows how CAT's activities impacted each of the three selected variables in the baseline year of 2019 and how it may impact them under each hypothetical scenario. For all scenarios, CAT's transit system plays the important role of avoiding millions of car-based trips and hundreds of thousands of dollars in car-fuel costs (with positive impacts in reducing the average transportation burden of community's households).

Under scenarios I and III, the agency's capacity to avert CO_2 emissions is impaired as ridership experiences a steady decrease (followed by an equally steep fall in bus-occupancy levels). Under these scenarios, the agency becomes a net CO_2 emitter. Avoided car-fuel costs also fall, because of the decrease in avoided non-transit VMT/year and CAT's stable VMT/year.

In scenarios II and IV, where ridership doubles, all three variables improve. Under both scenarios CAT's services remains a net reducer of CO_2 emissions, reducing **3,074 $MtCO_2$/year under Scenario II** and **3,354 $MtCO_2$/year** (a 9% better performance) **if ridership increases with an enhanced equity focus.** Avoided car-fuel costs also increase and are at least twice as big as in 2019 in both scenarios, with the highest savings being gained through a higher equity focus.

In scenarios III and IV (where CAT enhances its equity focus) environmental benefits are higher than in their less equitable counterparts, with more avoided $MtCO_2$. Socio-economic benefits, in the form of avoided car-fuel costs, are higher too.

Table 1. Key Results for Each Scenario

KEY RESULTS FOR EACH SCENARIO	Baseline (2019)	Business as Usual, BAU (2024)	Doubled Ridership, Same Equity Focus (2024)	Same Ridership Trend, More Equity Focus (2024)	Doubled Ridership, More Equity Focus (2024)
Avoided non-transit VMT/year	4,550,438	3,514,486	9,100,875	3,514,486	9,100,875
Net CO_2 emissions ($MtCO_2$)	-109	567	-3,074	459	-3,354
Avoided car-fuel costs	639,066	493,576	1,278,131	516,834	1,338,357
Source	Own elaboration based on multiple sources (refer to Annex).				

One of the key assumptions underlying the results described above is the average occupancy of LDVs. According to the U.S. Bureau of Transportation Statistics (BTS) (2018), the average car-occupancy in the country is 2.22 passengers per trip. However, **if considering only commuting and running family/personal errands,[17] the average vehicle occupancy is 1.36 passengers per trip. In order to best reflect the typical trip purposes of CAT riders, we used the latter average car occupancy in our analysis.**

[17] As defined per the BTS: trips to/from work, shopping, and other family/personal errands.

5.2 Reminder of Bus-occupancy Levels and Battery Electric Buses

When considering the climate change impact of public transportation, bus occupancy is a critical metric because there is a threshold over which transit buses emit less than a car on a per passenger basis. This "break-even" point is **between 6.0 and 9.7 passengers per bus**, when considering CAT's current fleet performance and the assumptions over the average occupancy of LDVs trip's that are being displaced. These findings align generally with estimates from the Federal Transit Administration (FTA, 2010).

Therefore, an important takeaway from our scenario analysis is that increasing bus occupancy is critical to unlocking the environmental benefits of public transit in Charlottesville. **If bus-occupancy does not increase, higher ridership alone would not suffice for CAT to further reduce the community's CO2 emissions; at least, not with its current fossil-fueled fleet.** This issue could be averted if more BEBs were incorporated to the fleet, as observed in Section 2.7 "Electrifying Transit."

When comparing the different scenarios, it should also be considered that enhancing CAT's equity focus might require ridership to grow more slowly in the short-term, as extra planning, investments, and community engagement would be needed**. However, an enhanced equity focus would support more sustainable long-term growth and better serve the needs of those that rely on transit the most.**

Although not quantified in our analysis, increased transit ridership could also provide benefits in the form of **reduced traffic congestion**. Additionally, communities with **reduced VMT levels could see lower concentrations of air pollution and adverse health impacts** (EF & VCCA, 2020; Emissions Analytics, 2020).

6 Recommendations

Learning from the voices of the community and best practices around the country, we have identified key recommendations that the City of Charlottesville, Albemarle County, CAT and any other pertinent authority should move to immediately evaluate and implement.

6.1 Increase equity and affordability

1) Make fare-free transit permanent. In March of 2021, CAT announced that fare-free transit, originally put in place as a COVID relief and safety measure, would be extended until at least 2024. Additionally, CAT has said that they are exploring options for making fare free service permanent; this is a significant step in the right direction.

Case studies of fare-free transit systems in other parts of the country have shown that eliminating fares virtually guarantees rapid increases in ridership, sometimes by as much as 60% in the course of a few months (NASEM, 2012). The more important impact, however, is on the pocketbook of riders, especially captive riders who do not have any other transportation options. For someone who commutes five days a week to a job on a CAT bus, fare free service could save that individual, conservatively, $30 to $50 a month. To some, this may not be much, but to many lower-income households, these savings could be significant.

2) Set a goal to double transit ridership by 2024, with an emphasis on increasing average bus-occupancy levels. As we emerge from the COVID-19 pandemic, ridership will naturally rebound. Fare-free transit will turbo-charge this upward trend as well. To make the most of this momentum, setting a target to double ridership can help focus CAT, the City, and community partners to achieve the goals. Following the findings of Section 5.2 Discussion, in order to maximize its environmental gains, the ridership target should be linked to a verifiable commitment to increasing bus occupancy levels.

3) Set a goal to have no route frequency in excess of 30 minutes intervals. The frequency of buses has a disproportionate impact on whether using public transit is viable for some, particularly those that want to use the service to commute to work and have to arrive at a specific time. Frequency also serves as a buffer against reliability issues. If a bus is late or breaks down, the next bus is not far behind, making it less risky for riders to rely on bus service to reach their destination on time. Finally, frequency allows transit to more closely approximate the freedom that comes from owning a vehicle (but without the cost, which many cannot afford).

4) Restore and expand pre-COVID service hours. Most of CAT's routes operate on a limited schedule (CAT, 2018). While service hours on Sundays or earlier/later in the day might attract less ridership than other hours, expanded service hours serve to attract users that *need* these weekend or very early/late services. In many cases, these will be workers with an early/late shift or families going to parks, churches or doing groceries on Sundays.[18]

[18] Fortunately, CAT has recently announced the intention of expanding service hours to offer a weekday and Saturday service-hours span from 6:00 am to 11:00 pm for major routes (Charlottesville, 2021).

Increasing service hours improves the chances of meeting the full transportation needs of riders, making them more likely to use transit as their primary means of getting around. For a lower-income family, extended service hours could mean the difference between using transit and being forced to purchase a car that they may not be in a position to easily afford.

6.2 Invest in rider experience

With the goal of increasing ridership, transit agencies should pay close attention to rider retention and the fact that transit ridership growth in the U.S. is strongly related to increasing the presence of choice riders (Perk, et al., 2008). In view of this, improving customer satisfaction and nurturing riders' loyalty should be of paramount importance.

If we want to drastically reduce transportation emissions, then we need to get people of all walks to choose transit over personal vehicles. CAT needs to consider what is fundamental for community members to make that choice. Such improvements should include significant increases on each and every route's frequency and go beyond that, benefiting captive riders *and* making the transit service more attractive to all.

5) Relax overly restrictive rules. Our focus groups surfaced a common complaint among CAT riders—rules around eating and drinking are overly restrictive and should be relaxed. No one wants to ride a bus that resembles a poorly tended fast food dining room, but reasonable allowances for eating and drinking should be considered. This is especially important for individuals that spend a lot of time on the bus, such as daily commuters. Additionally, riders in our focus group and survey have also reported unreasonable restrictions on carrying bags on the bus, which negatively impacts those who have no alternative choice but to use the bus to do their shopping.

6) Invest in technology upgrades to improve customer experience. More than ever, people are using smartphones to access mobility services, including public transit. Because of this, the CAT App is often a new potential rider's first interaction with CAT. We all know that first impressions matter, but our survey and focus groups showed that the CAT App has proven be unreliable. Real-time information on the location and on-time status of buses is unavailable, often leading to confusion and eroding trust in the App. Rightfully or not, eroded trust in the App transfers to the service as a whole. We applaud CAT's recent announcement that it will be transitioning to a new real-time information App (ETA Spot App), discontinuing the former Catch the CAT App on 9/4/2021 (CAT, 2021 a; CAT, 2021 b). We hope that this upgrade will address the App-reliability issues identified by our report and we urge CAT to share with the community the steps they will take to implement the new App and frequently monitor, evaluate and report on its performance.

7) Move swiftly to invest in increasing safety at bus stops. If CAT's App is the first impression a rider has of CAT's transit service, the bus stops are the second. In our community survey, 37% of respondents rated bus stops "Unsatisfactory" or "Unacceptable." Over half listed bus stops enhancements as a top priority improvement for CAT services. Bus stops should be comfortable in all types of weather and be well lit at all times of day or night. Additionally, the surrounding area should also be well-lit to ensure the safety of those that walk from the bus stop to their homes.

8) Complement main routes with on-demand mobility services. Although all CAT's routes cost roughly the same to operate per miles-traveled, the average number of passengers carried per miles travelled can vary up to 20x among routes. In order to maximize the full potential of its resources, CAT should study the feasibility of providing (or outsourcing) on-demand mobility services to substitute routes with lower occupancy and nimbly connect less dense neighborhoods with the core routes of the system.

6.3 Increase Collaboration and Coordination

9) Increase collaboration between key advisory boards to ensure that community voices have a role in transportation planning. CAT (working alongside UVA's UTS and the Regional Transit Partnership) should ensure transparency and stakeholder engagement through frequent public hearings, surveys, focus groups, and the creation of a Community Transit Advisory Council. The Council should guide future decision-making and have the participation of a variety of interested parties, representing the Charlottesville and Albemarle community, their households, nonprofits, and businesses.

10) Invest in developing comprehensive regional transit policy through increased collaboration across services. The level of fragmentation across transit services in the greater Charlottesville area is a hindrance to improving service, particularly for those who need it most. As housing continues to get more expensive, lower-income households are forced to live farther from the urban core of Charlottesville and sometimes find themselves outside of the City's limits altogether. If this trend continues, it makes ensuring equitable access a multi-jurisdiction challenge that can only be solved through increased collaboration and planning.

6.4 Invest in zero-carbon transit for Charlottesville

11) Develop a pilot program to introduce BEBs to CAT's system and set a target to transition to a fleet with 50% of its buses being zero emission vehicles by 2030. The City of Charlottesville and the County of Albemarle has set a goal of reducing GHG emissions by 45% by 2030. To maximize the climate and environmental benefits of public transit, Charlottesville should start immediately to lay the groundwork for a zero-emission bus fleet. As discussed previously, electrifying buses also delivers significant cost savings over the life of the vehicle.

6.5 Beyond Transit

Increasing the availability, quality, and affordability of transit is just the beginning. Ensuring a prosperous future for all residents of Charlottesville and doing our part to fight climate change requires wholesale reimagination of how we plan future development in our city. Prioritizing location-efficient zoning and planning practices can be a multiplier effect for the benefits of transit and improve the quality of life for all residents of Charlottesville whether or not they use transit.

12) Double investments in improving pedestrian and bike-friendly infrastructure, with priority placed on areas within one mile of existing and/or planned transit service. For those that rely on transit, walking and biking can also be essential modes of transit to get to and from bus stops. By prioritizing new infrastructure around bus stops to increase walkability and bikeability, the City and the County prioritize the populations with the greatest need for this infrastructure and improve both the safety and attractiveness of using CAT. For improved walkability, specific focus should be placed on better sidewalks, crosswalks and pedestrian bridges. For increased bikeability, bike lanes should be planned to connect neighborhoods with key bus stops, conveniently equipped with bicycle parking.

13) Commit publicly to building affordable housing in the urban core of Charlottesville. Another way to improve equitable access to opportunity, essential services, and amenities for all is to commit to increasing affordable housing availability in Charlottesville's urban core. Doing so will help low-income individuals access housing where transportation options are more affordable and diverse.

14) Lay the groundwork for zoning reform that allows for a denser and more transit-oriented development with affordable housing as a central feature. Zoning reform is no easy undertaking, but car-dependence is largely driven by our land use planning decisions. Reversing the decades-old trend of segregating housing from commercial spaces is critical to building communities that are more walkable, mixed use, and sustainable. Additionally, reducing minimum parking requirements for commercial buildings could simultaneously free up spaces that could be allocated for meeting our local housing needs, while serving as an added incentive for choice riders to choose transit options over cars for their trips (Perk, et al., 2008).

7 Conclusion

The recommendations we outline above are just some of the ingredients in a recipe for a more equitable, sustainable, and prosperous Charlottesville. **Our call to action is for the City of Charlottesville, Albemarle County, CAT and any other pertinent authority to make a public commitment to the actions they intend to take.** First, well-publicized public commitments would signal intention and introduce accountability to the community that our local government institutions serve. Second, a public commitment to ambitious action is also an invitation to potential riders to give the service a try. Finally, a public commitment can also be an invitation to the Charlottesville and Albemarle community to partner with CAT in achieving its goals. **C3 and many of our Charlottesville-based partner organizations stand ready to support CAT in any way we can to achieve a shared vision of equitable transit service in Charlottesville and Albemarle.**

Improving our transportation systems is essential to extending opportunity and access to all members of our community, contributing to breaking the cycle of poverty many low-income households find themselves in, mitigating climate change, and freeing ourselves from the expense, pollution, and hassle of a car-dependent city. Building a strong transit system is not easy, but it's also not a mystery—other cities around the country are leading the way, and it is time for Charlottesville and Albemarle to join that leadership.

8 Annex

8.1 Life Cycle Cost Analysis (LCCA) of Battery Electric Buses (BEBs) vs. Diesel Buses – Assumptions, Methodology, and Sources

Our LCCA is used to assess the total cost of owning four BEBs or diesel buses. The analysis is especially useful as both alternatives are assumed to meet performance necessities but differ with regards to their initial, as well as the operating, costs. The alternatives are compared to find which can maximize savings over time.

The LCCA includes many assumptions, most of which are derived from relevant research and are cited accordingly. Other assumptions are generated by the authors of the report. A few general assumptions across the entire analysis are noted below on Table 2. A more detailed list of assumptions related to BEBs is included on Table 3, while specific assumptions related to diesel buses are listed on Table 4.

Table 2. LCCA - General Parameters and Assumptions

LCCA - GENERAL PARAMETERS AND ASSUMPTIONS		
Average annual mileage per bus (miles)	31,370	CAT
DRPT's grant, share of the investment cost	68%	DRPT 2020
Discount Rate	3.50%	Author decision
Electricity cost ($/kWh)	0.082	EIA
Electricity annual cost escalation	0.029	Author decision
Electricity emission rate ($MtCO_2e$/kWh) for 2019	0.00035	EIA
Electricity CO_2 emission changes	Author decision	Based on Shobe, et. al.2020
Diesel cost ($/gallon)	$2.80	Author decision
Diesel annual cost escalation	5.00%	Author decision
Diesel emissions ($MtCO_2$/gallon)	0.01021	EPA

Table 3. LCCA - BEBs Key Parameters and Assumptions

LCCA - BEBS KEY PARAMETERS AND ASSUMPTIONS		
Battery efficiency (kWh/mile)	1.82	Johnson, et al. 2020
Other operating costs ($/mile)	0.64	Johnson, et al. 2020
Charger efficiency	91.4%	Author decision
Vehicle purchase price ($)	887,308	Johnson, et al. 2020
Depot charger cost, with installation ($)	67,050	Johnson, et al. 2020
Electricity demand charge ($/kW)	3.45	Johnson, et al. 2020
Added peak electricity draw (kW)	280	Based on Johnson, et al. 2020

Table 4. LCCA - Diesel Buses Key Parameters and Assumptions

LCCA - DIESEL BUSES KEY PARAMETERS AND ASSUMPTIONS		
Fuel economy (mpg)	4.04	Based on CAT's specific information
Other operating costs ($/mile)	0.88	Johnson, et al. 2020
Vehicle purchase price ($)	480,000	Johnson, et al. 2020

8.2 Scenario Analysis - Assumptions, Methodology, and Sources

8.2.1 Global Assumptions

Each scenario that we analyzed use the following simplifying assumptions:

- Due to the unclear impacts on transit usage of other alternatives to car-based transportation, such as rideshare or active mobility, we do not assume any relationship between their trends and CAT's ridership growth.

- Changes in "air-pollutant emission levels" are only a result of the expected emissions avoided per reduced non-transit (car-based) VMT; as a consequence of increased CAT's PMT. Average fuel economy levels do not change over the period of analysis.

- Due to the elevated expenses of owning a car, the transportation burden levels of most households would decrease if they used public transit more frequently (AAA, 2020). The transportation burden of historically underserved demographics would be even further reduced as a consequence of their likely lower income levels and/or their less efficient vehicles and/or their longer commuting.[19] Therefore, in order to maximize the reduction of the average household transportation burden in the community, efforts to increase ridership should be paired with an equity focus.

- To estimate the fuel economy of LDVs, we start with the 2019 average fuel economy of short-wheelbase LDVs from the Energy Information Administration (EIA). We then assume a 35% lower than average fuel-economy due to the community's local context of frequent short trips,[20] seasonal exposure to cold or hot weather, and urban driving (at lower speeds and with frequent speed changes) (EIA, 2020; DOE & EPA, n.d. a; DOE & EPA, n.d. b; DOE & c, n.d.).

- Some non-CAT-riders would use CAT's services if they were better served by it. Due to the low-quality transit services, they decide not to ride CAT and keep their higher car-based (direct, monetary) transportation burden in favor of reducing other non-monetary transportation burdens (such as, long-waiting times in bus stops, risk of missing appointments/meetings due to unreliable services, risk of traffic accidents due to lack of sidewalks or crosswalks, exposure to bad weather conditions, long travel times due to inefficient route design).

- Changes in population and income growth or distribution are insignificant between 2019 and 2024.

8.2.2 Assumptions that may drive results

[19] This analysis will not consider other expenses sources that could also affect the car-ownership expenses of these demographics (such as: potentially higher car-loan costs, as a result of higher interest rates, inability to pay loans quicker and/or to meet payment deadlines).

[20] According to Data USA, the average commute in Charlottesville is 16 minutes. We assume that commutes (approximately 10% of total trips) account, on average, for the longest car-based trips done by local residents.

The following additional assumptions are key to our results and may importantly affect the overall socioeconomic and environmental benefits of increasing CAT's ridership, either with an enhanced equity focus or not:

- Every mile traveled by bus by a certain bus passenger implies a one-mile reduction in the passenger's car travels. Therefore, the community's total PMT remains unchanged, as each extra unit of CAT's PMT implies a unit less of non-transit (car-based) PMT.

- CAT's route design, service-hours span and frequency could change. However, the average fuel economy of CAT's buses and the total annual VMT of CAT's fleet are assumed to remain stable. Therefore:
    - Changes in emissions of CO_2 and other pollutants are only a result of reduced car-based transportation.[21]
    - CAT's ridership increases or decreases are only a consequence of changes in bus occupancy levels (also known as bus utilization).[22] [23]

- Historically underserved demographics include populations of color and lower-income households, which are assumed to:
    - Drive cars with 5% lower fuel economy (Timmons, 2016; Ferrell & Reinke, 2015);
    - Make 18% longer bus travels (following the results of our survey).

8.2.3 Extra Assumptions and Sources

A number of additional assumptions were considered, as shown on Table 5.

Table 5 Scenario Analysis - General Parameters and Assumptions

SCENARIO ANALYSIS - GENERAL PARAMETERS AND ASSUMPTIONS		
CAT - Average bus occupancy (passangers), 2019	5.49	Estimations based on CAT's public information
CAT - Average distance travelled per passanger (miles), 2019	4.21	Estimations based on CAT's public information and C3's survey
CAT - Buses average fuel economy (mpg), 2019	4.04	Estimations based on CAT's public information
CAT - Riders' average personal fuel economy (mpg)	15.67	EIA 2020
CAT - Ridership 5-years growth rate (2015-19)	-22.8%	Estimations based on CAT's public information
CAT - Total annual VMT, 2019	1,129,331	Estimations based on CAT's public information
CAT - Total ridership, 2019	1,846,181	Estimations based on CAT's public information
Average personal car occupancy (passangers), 2017	2.22	BTS 2018
Diesel emissions (kg CO_2/gallons)	10.21	EPA
Vehicle Fuel cost per gallon ($), 2019	2.20	Author decision
Targeted average personal car occupancy (passangers), 2017	1.36	BTS 2018

[21] The frequency of selected routes could only be increased, without changing CAT's entire fleet's VMT, if they are compensated by readjustments in other routes' frequency, loop-lengths, and/or service hours.

[22] Between 2015 and 2019, ridership decreased by 25% while routes' design, service hours and frequency remained largely the same; therefore, solely as a consequence of changes in bus-occupancy levels. Doubling ridership levels by 2024, compared to 2019, would require a 50% increase in CAT's bus occupancy compared to 2015.

[23] Alternatively, CAT's ridership growth could have been assumed to be also a consequence of changes in CAT's annual VMT. However, this would have curtailed the effects of ridership changes. For example, if ridership increases by 100% while CAT's VMT increases 50%, then changes in "Avoided Non-transit VMT/year", "Net CO2 Emissions ($MtCO_2$)", and "Avoided Car-fuel Costs" would have been reduced by half.

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