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Factors influencing bikeshare service and usage in a rural college town: A case study of Montgomery County, VA

Cat Woodson[a], Huthaifa I. Ashqar[b], Mohammed Almannaa[c], Mohammed Elhenawy[d], and Ralph Buehler[e]

[a]School of Public and International Affairs, Virginia Tech, Blacksburg, VA, USA; [b]Arab American University, Jenin, Palestine; [c]Civil Engineering Department, King Saud University, Riyadh, Saudi Arabia; [d]CARRS-Q, Queensland University of Technology, Brisbane, Australia; [e]Urban Affairs and Planning, Virginia Tech Research Center, Arlington, VA, USA

ABSTRACT

While much of the bikeshare boom has centered around larger cities, smaller, lower-density, and even some rural communities have also implemented bikeshare systems successfully. Using a bikeshare dataset of more than 14,000 trips that cover the period from July 2018 to December 2021 for both pedal and e-bikes, this paper describes the structure and performance of ROAM NRV, a bikeshare system in Montgomery County, Virginia—which is home to Virginia Tech university and has many areas classified as rural. The paper presents bikeshare users' travel behaviors and usage trends (including during the COVID-19 pandemic). Moreover, compares the usage of the system's pedal bicycles to electric bicycles (e-bikes) that were introduced in 2021. Findings indicated that residents of Blacksburg and Christiansburg regularly use and benefit from bikeshare much like their urban counterparts do. Ridership was noted to likely be more common among university affiliates with trips more likely to start/end on or around campus due to the number of stations located within campus grounds. Trail usage was also high among bikeshare users due to the extensive trail network within and between the towns. As rural bikeshare users tend to travel greater distances and encounter more varying terrains throughout their commutes, considering e-bikes instead of pedal bike systems should increase the utilization of such mobility systems in rural areas. When electric assist bicycles were first introduced to the system, initially replacing some and then all former pedal bicycles, utilization increased significantly compared to pedal bike usage.

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1. Introduction

Transportation options for most rural communities are limited, with residents almost exclusively needing to rely on private motor vehicles to get around. However, those who do not own or have access to a car must find other modes of transportation to meet their needs. Bikesharing systems in rural areas that include college towns in The United States are not studied as often as urban areas (Fukushige et al., 2022), maybe because their population has been shrinking. The latest 2020 Census in The United States updates indicate that 46 million people currently live in rural areas, about a 23% decrease from the 2010 Census (America Counts Staff, 2017; U.S. Census Bureau, 2016b; U.S. Department of Agriculture, 2019). However, the comparatively low number of studies does not mean that transportation challenges do not exist in rural areas. According to the latest American Community Survey, at least 292 (out of 3142) U.S. counties have a minimum of 10% of their households lacking access to a car; 56% of which are rural households (Bellis, 2020; U.S. Department of Agriculture, 2021). The overall importance of mobility for access to jobs, food, healthcare, and other destinations is generally known, and it is particularly important for rural areas. However, while public transportation should be made available to those areas, it is unfortunately almost nonexistent, and other options, such as taxi rides or rideshare are often too expensive for day-to-day needs.

The provision of public transit in rural areas is a multifaceted issue that stems from the inherent challenges posed by sparse population densities, geographical dispersion, and limited resources (Ashqar et al., 2019; Böcker et al., 2020; Rojas-Rueda et al., 2012). Unfortunately, many rural communities are underserved or entirely lacking in viable public transportation options, leaving residents with reduced mobility and limited access to essential services. This deficiency in transit availability often leads to a range of negative consequences, including social isolation, reduced economic opportunities, and increased reliance on private vehicles, contributing to traffic congestion and environmental degradation.

CONTACT Mohammed Elhenawy mohammed.elhenawy@qut.edu.au CARRS-Q, Queensland University of Technology, Brisbane, Australia.

The necessity of making transit available in rural areas is grounded in several compelling factors (Ashqar et al., 2019; Böcker et al., 2020; Rojas-Rueda et al., 2012). From a need's perspective, many individuals in these regions, such as the elderly, low-income populations, and those without access to private vehicles, rely heavily on public transportation to access employment, healthcare, education, and social interactions. Philosophically and ethically, providing equitable access to transportation aligns with principles of social justice and equal opportunity, ensuring that all citizens can fully participate in community life. Policy goals related to sustainability, reduced congestion, and environmental conservation also underscore the importance of transit in rural areas. Furthermore, institutional documents and strategies, such as regional development plans and sustainable transportation initiatives, often emphasize the need to extend transit services to underserved regions to foster balanced growth, enhance quality of life, and mitigate carbon emissions.

Despite these compelling reasons, the unfortunate lack of transit provision in rural areas can be attributed to a variety of challenges (Bieliński et al., 2020; Bruzzone et al., 2021; Galatoulas et al., 2020). Limited financial resources and economies of scale make it more difficult to establish and maintain cost-effective transit services in low-density areas. Inadequate infrastructure, including poorly maintained roads and a lack of transit hubs, can hinder the feasibility of establishing efficient public transportation networks. Additionally, the perception that rural areas do not warrant transit investments due to lower population numbers can result in a self-perpetuating cycle of underinvestment. As a result, finding sustainable and effective transit solutions for rural communities requires innovative strategies that consider local context, integration with other modes of transportation like bikes and demand-responsive systems, and active collaboration among governmental bodies, transportation agencies, and community stakeholders. Potential solutions to this challenge may exist in implementing and supporting more active modes of transportation. Despite the common assumption that active modes like biking and walking are strictly for urban commuters, for many rural communities they are common as well (Bieliński et al., 2020; Bruzzone et al., 2021; Galatoulas et al., 2020).

Bikeshare (or bike sharing) has started becoming a vital part of transportation systems in cities across North America. Historically, bikeshare has been around since the 1960s but did not take off in the U.S. until 2008. Since then, this model has spread across the country, yet not every community has been able to take advantage of it. Urban areas were among the first to adopt this transportation model, and thus bikeshare is more common throughout metropolitan areas compared to suburban or rural areas (Ashqar, 2018; Henning-Smith et al., 2017). Existing bikeshare studies are primarily concentrated around larger cities. Bikeshare in urban areas has been found to be primarily used for shorter distance traveling purposes or fulfilling first and last mile needs, which often leaves rural communities out of the conversation by default.

Some of the key barriers preventing rural communities from partaking in this model include infrastructure, geography, funding, accessibility, political support, public awareness, and finally socio-demographics (Henning-Smith et al., 2017). The combination of low population densities and longer trip distances in most rural communities presents a unique challenge to bikeshare operators—including greater operating costs and fewer possibilities for multimodal integration compared to urbanized areas Longer trip distances in rural areas have also encouraged some systems to consider e-bikes instead of the traditional (pedal) bikes as they are usually easier to ride specifically in complex terrains (Henning-Smith et al., 2017).

Bikeshare systems may also be implemented in a community as part of a larger goal to get people out of their cars and into more active and sustainable modes of transportation. Unfortunately, this goal may end up excluding the needs of residents who cannot drive but are still lacking transportation options. Implementing more bikeshare systems in smaller localities and/or more rural areas could be a way to help bridge some of the existing transportation gaps. Additionally, securing sustainable funding sources, developing and maintaining infrastructure that supports walking and biking, enabling safe access for all users, are essential for increasing active transportation equity in rural areas. This in turn also encourages and increases opportunities to implement bikeshare.

One encouraged practice is the use of e-bike sharing systems, which have emerged as a transformative mode of urban transportation, combining the benefits of cycling with electric assistance (Almannaa et al., 2021; Haustein et al., 2020; Poliziani et al., 2023). E-bikes offer a convenient and energy-efficient solution for covering longer distances and navigating hilly terrains, making cycling more accessible to a broader demographic. In urban environments, e-bike sharing can play a crucial role in reducing traffic congestion, lowering emissions, and promoting sustainable mobility. E-bikes have the potential to attract a wider range of users, including those who may have been deterred by the physical demands of traditional cycling. By incorporating e-bikes into bike-sharing systems, cities can encourage more people to adopt active transportation, leading to improved public health outcomes and reduced reliance on fossil fuels. While e-bike sharing presents numerous advantages, it also comes with its own set of challenges. Infrastructure and charging infrastructure are critical concerns. E-bikes require specialized maintenance and charging stations, which need to be strategically placed to ensure convenient access. Ensuring the security of e-bikes and preventing theft is another challenge. Additionally, regulatory and safety issues related to higher speeds achievable by e-bikes need careful consideration. Balancing the integration of e-bikes with traditional bicycles in bike-sharing systems requires thoughtful planning to ensure a seamless and equitable user experience.

The relationship between bike share usage and the built environment is influenced by various factors (Ashqar et al., 2019; Eren & Uz, 2020; Guo et al., 2022). Firstly, different regions (West Europe, East Asia, North America, and

Oceania) have distinct transportation cultures, affecting how cycling, public transit, and cars are prioritized, leading to unique built environments for cycling. Secondly, docked and dockless bike share systems exhibit variations in user demand and travel characteristics, and the urban surroundings impact them differently. Thirdly, bike share trips are commonly related to work, school, entertainment, recreation, and connecting with public transit, each linked to specific urban features. Fourthly, the layout of areas where bikes are picked up and dropped off is crucial in bike share usage. Lastly, bike share patterns differ between weekdays and weekends due to varying demand, thus influencing the impact of the built environment on bike share usage.

This study focuses on Montgomery County, VA, encompassing the towns of Blacksburg and Christiansburg. About 25% of each town is considered to be rural based on the 2010 Census definitions. This area of study is also unique in that it is dominated demographically and economically by the presence of Virginia Polytechnic Institute and State University (Virginia Tech). Montgomery County, situated in southwestern Virginia and encompassing the towns of Blacksburg and Christiansburg, retains a notable rural character despite the presence of these towns. The county's landscape is characterized by rolling hills, agricultural land uses, and a limited urban density, fostering a genuine rural ambiance. Natural features, such as open spaces, parks, and the New River contribute to this rural identity. Architectural patterns favor low-rise structures and single-family homes, maintaining a visual coherence with rural settings. The region's cultural and historical significance, including preserved traditions and historic structures, further underscore its rural heritage. While the towns offer some urban amenities, the county overall lacks the infrastructure commonly associated with more urbanized areas. Montgomery County's enduring rural charm lies in its natural beauty, scenic views, and a deep connection to the land, all of which collectively create a distinct and authentic rural atmosphere. The New River Valley's regional bikesharing system known as ROAM NRV serves university students, faculty, and staff, as well as the citizens of Blacksburg and Christiansburg. In its 3 years of operations, the systems underwent several changes and experienced external challenges. Year 2019 was the system's first full calendar year as a pedal-bike system. For the year 2020, the system was still entirely made up of pedal bicycles, however a new variable, the COVID pandemic, was introduced. Additionally, the bikeshare vendor underwent a merger with a scooter sharing company. Virginia Tech and the community at Montgomery County followed Virginia State guidelines, which resulted in no classes at Virginia Tech since March 2020. In August 2021, Virginia Tech reinstates in-person classes with hybrid option across campus locations. During 2021, impacts from the pandemic were still being felt, although lockdown restrictions and stay home orders were lifted (Almannaa et al., 2022). However, another new variable, electric-assisted bicycles, were introduced mid-year, replacing the former pedal bicycles. Additionally, the bikeshare vendor underwent yet another company change when they were bought out by another scooter sharing company. That said, this study set out to investigate the bikesharing system in Montgomery County by analyzing bikeshare users' travel behaviors and tracing the introduction of these factors including COVID and electric bikes (e-bikes) instead of pedal ones.

There are some peer-reviewed case studies including (Karpinski, 2021; Scorrano & Danielis, 2021) and various non-peer-reviewed case studies of bikeshare systems that share some characteristics of the Montgomery County, VA bikeshare system including population size and presences of a college or university, its rural geography, and implementing a successful bikesharing system within rural communities. Some examples include *ValloCycle* launched in October of 2011, starting out with 50 bikes, in Montevallo, Alabama. *WE-Cycle* launched as a dock-based bikeshare system in 2013, starting out with 100 bikes and 10 docking stations, and expanding into the following communities: Basalt, El Jebel, Willits, and Snowmass Village in Aspen, Colorado. *Book-a-Bike* in a college of Ohio University (i.e. Athens, Ohio) which launched in 2013 with 16 bikes. *OrangeRide* in another college town of Oklahoma State University (i.e. Stillwater, Oklahoma) that was launched in 2013. The successful implementation of these bikeshare systems were due to stakeholder and community collaboration, sustainable funding efforts, and addressing barriers to biking for their residents including infrastructure and accessibility.

2. Methodology

2.1. Methods

For the purposes of this study, alternative transportation is defined as traveling by other modes than a car. Examples include public transportation, walking, and biking. Active Transportation is defined as traveling by human power, examples primarily include walking and bicycling (U.S. Census Bureau, 2016a). Bikesharing falls within the realm of shared micromobility, typically utilizing on-demand access to bicycles and/or e-bicycles at a variety of origin and destination locations (Ashqar et al., 2022). Traditionally, there are three main types of bikesharing systems, public, closed campus, and peer-to-peer. Public (with docked/stationed and dockless) bikesharing systems are the most common, allowing anyone to access a bicycle for a fee. Closed campuses refer to bikes that are only available for use by campus affiliates, or bikes that may only be utilized within campus boundaries. Peer-to-peer bike sharing uses location services on mobile phones and social networks of existing users/bike owners.

This study aims mainly at studying the impacts of bikeshare in the small, rural communities of Montgomery County, VA. This will include investigating the bikesharing usage, travel behaviors of users, system productivity, and the impact of COVID and replacing pedal bikes with electric ones. The analysis captures trips from 2019 to 2021, covering three periods: before, during-, and post-pandemic were studied. Bike and e-bike trips were also investigated in terms of usage and productivity.

2.2. Dataset

The research utilized a dataset of ROAM NRV. The system covers two towns: Blacksburg and Christiansburg—both part of Montgomery County, VA. It was launched through the efforts of the partnership between these two towns, the county and Virginia Tech. It was initially operated by Gotcha Mobility LLC, which was later acquired by Bolt Mobility in 2021. The system initially kicked off in July 2018, with 12 bike stations and 75 bikes as shown in Figure 1 and although it is a regional program, the system primarily served the Virginia Tech community.

The bikeshare system in Montgomery County, Virginia, reflects a bicycle-friendly environment that fosters safety, encouragement, and infrastructure for cycling. The university and community exhibit a commitment to cycling as a mode of transportation, promoting bike lanes, pathways, and other facilities that enhance safety for riders. While the university and community's specific recognition by the League of American Bicyclists is a silver level Bicycle Friendly Community (BFC), their focus on bike-friendly infrastructure aligns with the league's criteria. The bikeshare system involves user costs, with rates typically varying based on membership plans. While specific details about e-bike *vs.* standard bike rates aren't mentioned, it's common for e-bikes to have slightly higher rates due to the added technology. Additionally, there may be periods of free or discounted use during special events or as part of promotional efforts to encourage more people to utilize the bikeshare system, fostering greater engagement with sustainable transportation options. Bikes can be reserved online or *via* mobile app for a per-ride rate of $1 per 15 min. When the e-bikes were introduced, riders had the option to utilize two membership plans: Pay as you go of $1 to unlock with $0.35 per minute, and annual plan of $99 per year, which includes a waived unlock fee and 30 min of free ride time every time a bike is unlocked then $0.35 per minute after the free 30 min expire.

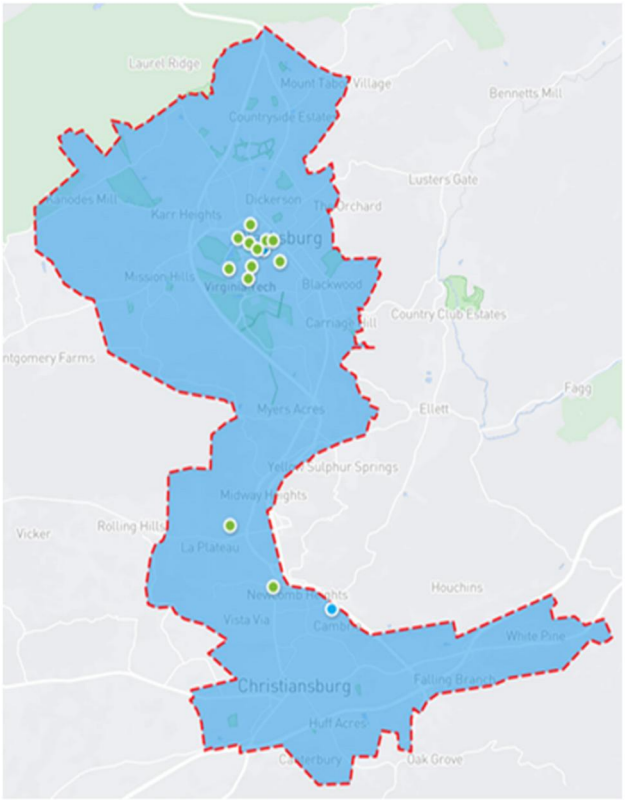

Figure 1. Map of ROAM NRV system.

The dataset covers data from July 2018 to December 2021 for both pedal and e-bikes. More than 14,000 trips were made, with users spending over 11,000 h on bikes, traveling over 45,000 miles during the study period. Since its launch, over 5000 users have taken more than one trip (active users). The dataset records the details of every trip made, namely: the coordinates of the origin and destination of the trip, path of the trip, the date and time of the beginning and ending of the trip, distance traveled in miles, trip length in minutes, estimated calories burned and CO_2 reduced (the calculation method is a proprietary information), types of trips (unique or regular), type of user (active or non-active), and new or returning user. The bike stations were initially distributed in the Town of Blacksburg (2), the Town of Christiansburg (2), and the Virginia Tech Campus (8). The system has grown since then, covering more area in the New River Valley. In June 2021 the system was converted to an electric-assist bikeshare system.

According to the 2020 census, the total population for Montgomery County VA (388 sq miles) was 99,721 residents (1.61% increase from 2019) with 44,826 residing in the Town of Blacksburg (1.18% increase from 2019) and 22,163 residing in the Town of Christiansburg (1.48% increase from 2019). Virginia Tech's student population makes up over 82% of the Town of Blacksburg's community. The university's student body had 37,024 students for the 2020–2021 academic year (0.04% increase from 2019 to 2020). During that same time, the population size dropped by 0.52% for the Town of Blacksburg and increased by 1.15% for the Town of Christiansburg.

3. Results

3.1. Bikesharing usage and trends

About 2100 bikeshare users in Montgomery County, VA took over 6000 trips on 75 bikeshare pedal bikes in 2019. The following year, an estimated 2000 users took over 4100 trips, only about two-thirds of the number of trips taken in 2019. The bikeshare system saw its highest number of users in 2021, surpassing pre-COVID numbers with nearly 2500 users, who collectively took about 4400 trips that year. This section takes a closer look at several trip trends including the average and changes in utilization (trips per bike per day), miles per trip, minutes per trip, weekday and weekend trips, peak trip taking hours, and trip paths based on heat maps that observe riders' origins and destinations and the routes in between them.

In 2019, the average bikeshare bicycle was used for about a quarter of a trip per day. In 2020, that dropped to less than a quarter (0.17 trip/bike/day), however in 2021, average utilization bounced back up to about a quarter of a trip per

bike per day (0.21 trip/bike/day). The average trip length in 2019 was 2.34 miles and in 2020 it nearly doubled to 4.11 miles. However, in 2021 it dropped slightly down to 3.4 miles, but was still higher than the bikeshare's first year. Furthermore, average trips in 2019 lasted for 31.1 min, in 2020 it nearly doubled to 58.15 min. However, in 2021 average trips dropped slightly to 45.51 min.

Peak travel times remained consistent from 2019 to 2021, with the highest number of trips typically occurring in the afternoon, between the hours of 1 and 4 pm Riders were typically active between 7 am – 9:00 pm in 2019, with most of their trip activity taking place between 12 and 6 pm Peak travel time occurred at 3 pm with almost 600 trips total (an average of 12 trips per day during this hour), followed closely by 2 pm with over 500 trips (an average of 10 trips). During the pandemic, bikeshare users were riding later in the day than they had previously. While riders were still typically active in the same time range as they were in 2019, the total number of trips being taken saw a considerable decrease. This was likely due to the Stay-at-Home orders placed early on during the pandemic, resulting in many residents having to work from home and students attending classes online. Peak travel time occurred at 4 pm with nearly 500 trips total (an average of 8.5 trips per day during this hour), followed by 1 pm with around 400 trips total (an average of 8 trips). As restrictions were lifted and the campus returned to an in-person class environment with a hybrid option, trip activity began to rebound slightly, although the system had not reached its pre-pandemic levels of activity. Peak travel time returned to 3 pm with 439 trips total (an average of 8.5 trips per day during this hour), followed closely by 1 pm with 424 trips total (an average of 8 trips). These trends are illustrated in Figure 2.

Peak travel days also remained consistent from 2019 to 2021, with the highest number of trips typically occurring over the weekends. Riders were most active on Saturdays in 2019, with over 1000 trips total (an average of 20 trips per day), followed by Wednesday with over 900 trips total (an average of 17 trips). During the pandemic, bikeshare users were predominantly riding on the weekends with just under 1000 trips total occurring on Saturdays (an average of 19 trips per day) and over 900 trips total occurring on Sundays (an average of 17.5 trips). This peak trip travel trend

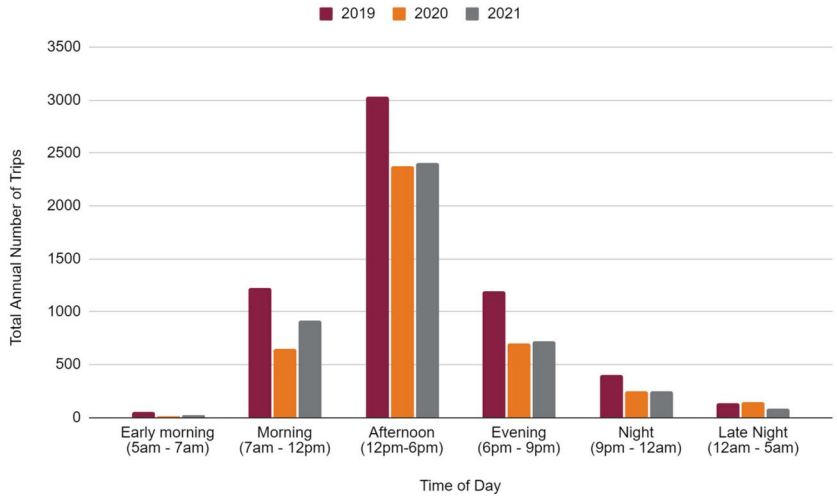

Figure 2. Total annual number of trips by time of day, 2019–2021.

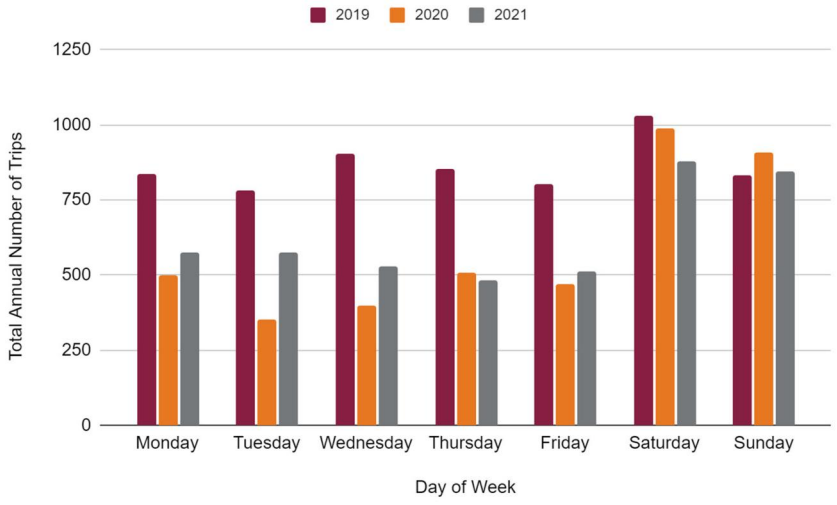

Figure 3. Total annual number of trips by day of the week, 2019–2021.

continued throughout 2021, with just under 900 trips total occurring on Saturdays (an average of 17 trips per day) and Sundays (an average of 16 trips per day). These trends are illustrated in Figure 3.

Over the time between 2019 and 2021, more trips were taking place over weekends, as many as 2–4 times more trips per day than seen during the week. Overall, the average number of trips per day taken during the week saw a declining trend from 2019 to 2021, with the number of trips per day being cut in half. Despite this decline, the average distance of those trips saw a steady inclining trend, increasing from 2–4 to about 5.5 miles per trip. Likewise, the average duration of those trips saw an inclining trend, from 30 to 60 min spent on a bike to over 1.5 h. Note that due to the unique geographic terrain and extensive trail network of this system, typical commutes are farther than for urban-based bikeshares, which leads to spending more time on a bike by default. A further breakdown of 2021 specific trips between the pedal bikes and e-bikes can be seen later in the study.

Moreover, it is noticed that the average number of trips taken remained constant during the first couple of years after the system launched, including during the pandemic, only seeing a slight drop in 2021. The average distance of those trips remained steady at about 3–4 miles long (see orange line). The average duration of those trips saw a similar trend as the average trips/day in that there was an initial increase from 42 min per ride in 2019 to over an hour in 2020, but then a drop to 50 min in 2021. Despite this decline in time spent on a bike in 2021, bikeshare users were still spending more time on a bike than in pre-pandemic times. These trends are likely a result of the transition over to e-bikes mid-2021, a further breakdown of this can be seen later in the section.

3.2. Trip paths and users' behavior

The trip path or route of the bikeshare's users was observed using data provided by the system's software and GPS. Data were pulled for the month of June to understand the effect of bikeshare being in a rural area as the university is off during June. Ridership was about the same across each year, with a gradual incline from year to year. Two predominant patterns in trip paths were noticed: (1) most trips took place on or around Virginia Tech's campus, and (2) most trips also took place utilizing the market's trail network: The Huckleberry Trail. This trail is about 15 miles in length with several additional regional natural surface trails bringing the entire network of connected trails to over 60 miles. Additionally, the Huckleberry Trail provides an important and useful connection between the two towns of Montgomery County, as well as many connection points from residential areas to campus.

Campus-based routes were likely made by students who account for over 2/3rds of the area's population as well as a disproportionate number (∼70%) of the bikeshare system's stations being located right on the university's campus. These routes remained common even during the early stages of lockdown orders resulting from the pandemic; most labor force working from home and students moving off campus. This means that users were most likely to start (originate) and/or end (destination) on or near campus. The increase in trail use occurring during 2020 may likely have been due to folks taking advantage of working from home and wanting to be outside during the pandemic restrictions and lockdowns. Trail use continued and even increased in 2021, with many folks continuing to work from home, the bikeshare system expanding, adding more stations to its network, as well as converting its fleet to electric assist bikes. We examined many paths during the different days of the week and for different purposes. We found that they tend to be similar throughout the different days of the week and they differ based on the trip's purpose.

3.3. Comparisons by vehicle type

Given the emerging trend of electric vehicles seen over recent years, the bikeshare industry has been evolving their systems to include more electric options. The percentage of bikesharing systems deploying e-bikes in North America increased by 28–44% in 2019–2020 (Rails to Trails, 2012; Ratcliffe et al., 2016). Trips made by e-bikes also increased by 7 million–10 million in this time (Rails to Trails, 2012; Ratcliffe et al., 2016). As the use and acceptance of e-bikes become more evident, planners and developers have an opportunity to take advantage of this trend to address some of the transportation challenges rural communities face, providing more equitable transportation to residents and visitors as it provides an easier-to-ride option, especially for older people. The number of bikes in the ROAM NRV bikeshare remained the same throughout this study's timeline, however, the number of stations did increase from 12 to 16 and the fleet was completely replaced by e-bikes. Once the system had re-launched with its fleet of exclusively electric-assist vehicles, the number of trips doubled and continued to increase until the cooler seasons (see Figure 4).

3.3.1. Pedal vs. electric bikes

One important note is the system is the effect of introducing e-bikes. Weekday (Figure 5) and weekend (Figure 6) trips in 2021 were further analyzed to compare the trends of pedal bicycles to electric assist bicycles. Before introducing e-bikes, the trend in average trips per day from 2019 to 2021 was a decline. However, when looking at 2021 separately, it was noticed that weekday trips had only decreased for pedal bikes, compared to after the e-bikes had replaced the pedal bikes when weekday trips doubled from 6.5 to 13 trips per day. A similar trend was observed for trip distances, those using pedal bikes were biking <4 miles per trip, but e-bike trip lengths had nearly doubled with users biking an average of about 7 miles per trip. Finally, trip duration was noticed to have gone down after the e-bikes launched. Users were initially spending about an hour and a half on the pedal bikes, whereas users were spending about 50 min on the electric assist bikes. This indicates that after the bikeshare system converted its fleet to an exclusively electric assisted

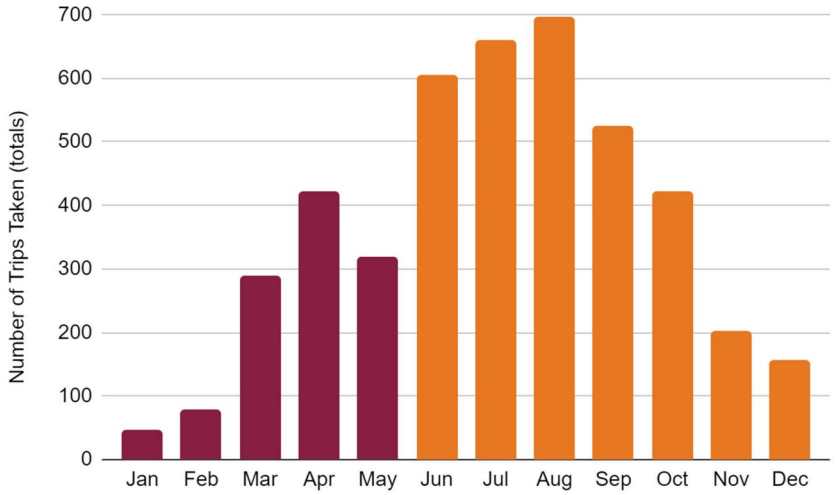

Figure 4. 2021 Monthly trip activity: Jan–May—pedal bikes (maroon) and Jun–December—e-bikes (orange).

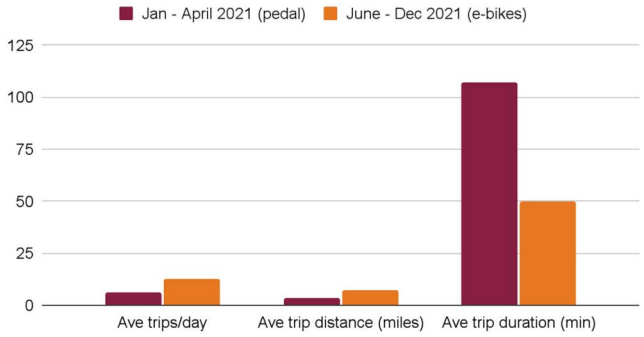

Figure 5. 2021 Weekday trip trends: pedal bikes *vs.* e-bikes.

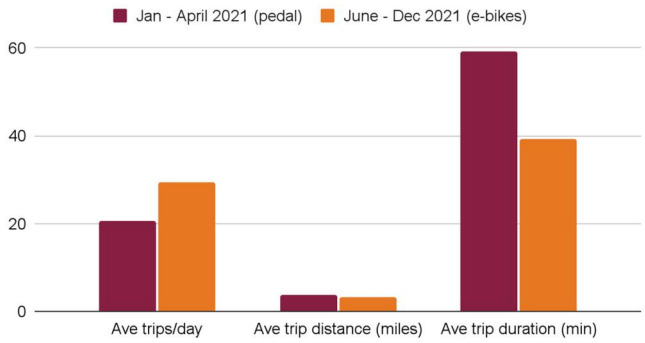

Figure 6. 2021 Weekend trip trends: pedal bikes *vs.* e-bikes.

system, users started taking more trips per day and were traveling further distances in shorter amounts of time. This illustrates a positive correlation between travel distances and duration on the pedal bikes and a negative correlation between travel distances and duration on the electric assist bikes. The relationship between travel time distance and duration is likely primarily impacted by whether the bicycle was strictly human powered or had a motor that assisted users' efforts, allowing them to cover more ground in shorter amounts of time, which also likely encouraged users to take more trips, or not.

To further understand the effect, when analyzing weekend-based trips for 2021, it was noticed that the total number of trips per day had been decreasing when users were riding the pedal bikes, however when users were riding the e-bikes, trips had increased from 21 to 30 trips per day just as they had for weekday trips. Of interesting note though was that the distance traveled per trip had shortened for weekend trips when switching from pedal to an electric assist system. Users riding the pedal bikes were traveling nearly 4 miles per trip compared to 3 miles traveled on e-bikes. Similar to weekday trip duration, weekend trip duration had decreased, with users spending about an hour on a bike per trip on the pedal bikes compared to about 40 min per trip on an e-bike.

E-bikes, leveraging their electric assist capabilities, effectively address the hurdles associated with rural commuting by alleviating the physical strain often posed by extended distances and undulating terrains. Notably, results indicate that the transition from conventional pedal bicycles to e-bikes has yielded a marked surge in the utilization of the bikeshare system, a clear testament to the positive influence of this technological transition on ridership trends. Furthermore, the successful pivot toward e-bikes in rural settings, leading to heightened levels of engagement with the bikeshare system, showcases the transformative potential embedded within electric bicycles. This potential goes beyond the convenience of urban settings and extends to rural landscapes, effectively expanding the scope and accessibility of bikeshare initiatives. The integration of e-bikes not only accommodates the distinct challenges posed by rural terrains but also extends the allure of bikeshare systems to a broader demographic, ultimately enhancing the sustainability of these programs in regions traditionally characterized by sprawling landscapes.

3.4. System productivity and operating characteristics

Bikesharing systems may exhibit different characteristics depending on the size of the city they serve. According to the North American Bikeshare Association's 2019 Industry Report, larger cities tend to have more vehicles per system but fewer per capita, higher bikeshare utilization, and typically more than one operator. However, in the updated 2020 Report, larger cities had both, more vehicles per system and

Table 1. Comparison of small/medium (<500,000 people) and large (more than 500,000 people) city bikeshare characteristics to the ROAM NRV bikeshare system.

Systems	Number of systems	Vehicles per system	Vehicles per 1000 people	Vehicles per square mile	Trips per vehicle per service day	Median number of operators
ROAM NRV	1	75	0.00075	0.19	0.2075	1
Sm/Med cities	126	197	1.2	4.5	0.4	2
Large cities	43	1725	1.6	11.6	1.8	3

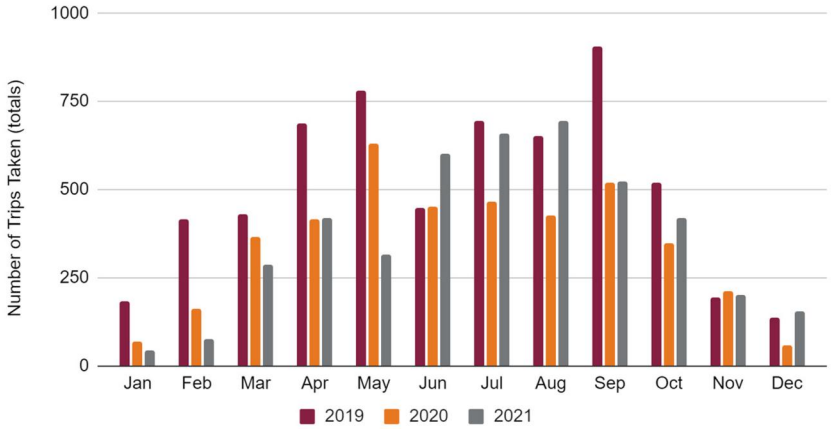

Figure 7. Monthly trip activity, 2019–2021.

per capita; vehicle densities were also shown to be higher in larger cities. Unfortunately, this report does not showcase more rural localities. Table 1 highlights the characteristics of bikeshares, as noted in the industry reports, for Montgomery County, VA.

Bikeshares across the U.S. experienced major declines in ridership, with many having to temporarily suspend their operations and others permanently closing (Bureau of Transportation Statistics, 2020; Bureau of Transportation Statistics, 2021a). During the height of the pandemic, many bikeshare systems had to make the tough decision to suspend service or fully shutdown for many reasons including health concerns. Approximately 14% of bikeshare services were suspended during the pandemic (Ratcliffe et al., 2016). Fortunately, 75% of those suspended systems were successfully reopened by the end of 2020 (Bureau of Transportation Statistics, 2021b, 2021c, 2022). Despite the statewide lockdown orders and restrictions in place, the ROAM NRV bikeshare remained fully operational in the Montgomery County area, maintaining its pre-COVID service and bike fleet availability standards.

While the ROAM NRV bikeshare maintained uninterrupted service during this time, it did experience a similar, albeit to a lesser degree, disruption to its ridership (see Figure 7). There was a slight drop in 2019–2020 (down 3.56%), this decline was short lived as ridership experienced an upward trend in 2021 (up 11.39%). This system also underwent a complete system change in 2021, converting its entire bike fleet from pedal bikes to electric pedal assist bikes, as well as changing the app platform, users' interface with. These dynamic changes were additional factors that impacted ridership. As indicated by the notable drop in overall ridership during break periods, such as summer and winter, university students likely make up the bulk of the bikeshare's ridership. Based on this observation it is also likely then, that the most notable impact on the bikeshare system's ridership was seen when the university pivoted its classroom environment to a virtual one with many faculty and staff shifting to work from home as well. Additionally, residential halls were closed, and students moved off campus either into the surrounding community or returning to their parents' homes.

Given the warm climate of Virginia, biking season can begin as early as April and last as late as October for those who commute primarily during fair weather conditions. The weather and climate in Virginia play a significant role in shaping both COVID-19 dynamics and the productivity of the bikesharing system. Virginia experiences a humid subtropical climate, characterized by distinct seasons. The mild winters and warm, humid summers may have implications for the spread of respiratory viruses like COVID-19. Additionally, the territorial characteristics of Virginia, including its mix of urban and rural areas, could influence the virus's transmission patterns. Concerning bikesharing productivity, the climate affects ridership patterns. While spring and fall tend to see higher usage due to the pleasant weather, summer heat, and winter cold might discourage bike usage. Moreover, regional variations in weather within Virginia can impact bikesharing differently across the state. Urban areas like Richmond and Northern Virginia, with higher population density and more favorable biking conditions, might experience more consistent bikesharing activity compared to rural regions with less developed infrastructure. Understanding the interplay between climate, territorial features, and COVID-19 dynamics is crucial for effective public health and transportation planning in Virginia.

Upon examining the monthly ridership data, May–September were the busiest months overall. May is the last month of the spring semester when students start leaving and September is the first full month of the fall semester

after students have returned. July and August are right around when students start to come back and move into their dorms before the semester begins. The busiest month during 2019 was September with over 900 total trips taken (averaging about 30 trips per day), followed by May with nearly 800 total trips taken (averaging 26 trips per day). That flipped around in 2020, with May being the busiest month with over 600 total trips taken (averaging around 21 trips per day), followed by September with over 500 total trips taken (averaging about 17 trips per day). The busiest month during 2021 was August with nearly 700 total trips taken (averaging around 22 trips per day), followed by July with 658 total trips taken (averaging nearly 22 trips per day).

4. Conclusion

Rural Americans face unique transportation challenges, however new mobility options, like bikesharing, can offer cost-effective solutions to help address concerns, such as safe and affordable transportation, changing rural populations, and higher health risk concerns. Bikeshare can offer a complementary option to traditional public transit services, by expanding the reach of these fixed routes with first-last mile connections. In addition to that, introducing e-bikes in rural areas can offer a relatively easier-to-ride option. In this study, we investigated implementations of bikesharing in small and rural towns. We analyzed the bikeshare system's characteristics, bikeshare user trip trends, and changes in vehicle types throughout our study's location: Montgomery County, VA. We utilized a three-year dataset of bikeshare trips from July 2018 until December 2021. Initial findings did indicate that small town residents and rural communities do use and benefit from bikeshare just like urban based communities do.

The ROAM NRV bikeshare was implemented through a partnership between the two towns, the county, and the university, and an initial startup grant. Despite this partnership, the university's dominating presence—in population and economically—meant that more stations and therefore more bikes were located on campus with only a few stations and less bikes to spread out between the two town boundaries. It also meant that users were more likely to be students or somehow afflicted with the university. Results illustrated that ridership and travel behaviors varied around on three main factors: the availability and accessibility of pedal bikes or e-bikes, whether the university's semesters were in session or if students were on break, and impacts of the pandemic. Overall annual trips and trips per day saw a significant decline in 2020 during the pandemic but started increasing again after e-bikes replaced the pedal bikes in 2021. Weekends were the busiest days for ridership and afternoons (12–6 pm) were the busiest time of day for ridership to occur. Overall, trips were also farther with users spending more time on the bikes compared to the typical urban-based trip. Trip routes predominantly occurred on or around the university campus and/or on the trails, particularly the Huckleberry Trail.

The findings underscore a notable trend in the utilization and benefits of the bikeshare system by residents of both Blacksburg and Christiansburg, resembling the patterns often observed in more urbanized regions. Notably, the usage of the bikeshare system appears to be more concentrated among university affiliates, a trend likely attributed to the strategic placement of stations within and around the campus environment. The inherent convenience of these locations encourages more frequent trips originating or concluding on campus grounds. This aligns with the observation that the extensive trail network that crisscrosses the towns contributes to the high usage of the bikeshare system, as trails often serve as efficient and enjoyable pathways for commuting. Interestingly, the study highlights a unique aspect of rural bikeshare usage—the tendency for rural users to cover longer distances and traverse varied terrains during their journeys. Given the rural landscape's potential challenges, such as increased distances and terrain fluctuations, the integration of e-bikes has emerged as a transformative solution. E-bikes, with their electric assist capabilities, mitigate the challenges associated with rural commuting by reducing the physical strain of longer distances and hilly terrains. The study suggests that this transition to e-bikes from traditional pedal bicycles led to a significant upswing in system utilization, signifying the positive impact of this technological shift on ridership.

It should be mentioned that this study would be enhanced if we have demographic information about the users of the bikes and have the geometric data of some trips. However, in essence, the study highlights the seamless integration of bikeshare systems into the daily lives of Blacksburg and Christiansburg residents, with a particular emphasis on the influence of university affiliations and the availability of trails. Moreover, the successful transition to e-bikes in rural contexts, resulting in increased utilization rates, speaks to the transformative potential of electric bicycles in extending the reach of bikeshare systems and addressing the unique challenges posed by rural landscapes.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Huthaifa I. Ashqar http://orcid.org/0000-0002-6835-8338
Mohammed Almannaa http://orcid.org/0000-0002-5893-3052

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