Case Study

Bus Stop Amenity Policy and Practice: A Multiagency, Multijurisdictional Evaluation

Rachel Inman[1]; Sophie Spiliotopoulos[2]; and Xavier J. Harmony[3]

Abstract: Bus stop amenities are an important but underresearched topic. While recent work has provided some insight into bus stop amenity decisions, this paper adds to recent work by focusing on a different geography, over multiple time periods, and a more complex bus operating environment. Specifically, this study evaluates how and why bus stop amenities are distributed in Northern Virginia, an area served by seven bus operators. The paper begins the evaluation by exploring bus stop amenity policies across the region to understand how they might help explain amenity decisions. The paper then uses a mix of Google Street View data, contextual data, and statistical methods, to demonstrate that bus stop amenity distribution is correlated with factors such as adjacent land use, the location of bus stops in cities or adjacent to local roads, and demographics. While local transit policies do not directly address the complicated operating environment in Northern Virginia, in practice, bus stop amenity priorities are strongly correlated with shared transit relationships. Shared bus stops were consistently found to be a predictor for bus shelters and benches across years and modeling strategies. When bus stops are shared between agencies, bus stop amenities likely follow the most detailed guidance from the agencies. When bus stops are not shared, there is some evidence that jurisdictions may play more of a role in the distribution of amenities than agencies. Finally, this paper demonstrates how bus amenities change over time with accessibility-related amenities and seating seeing the greatest change over the last decade.
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Introduction and Background

Bus stops are the starting and ending points of many transit commutes. However, most bus stops do not have more than a sign. The availability and condition of amenities at bus stops can greatly impact the quality of one's commute as well as perceptions of bus service providers. For example, bus amenities can increase rider comfort (Easter Seals Project Action 2016; NACTO 2016; Texas Transportation Institute 1996), reduce the perception of wait times (Lagune-Reutler et al. 2016), and contribute to rider safety and security (Easter Seals Project Action 2016; Texas Transportation Institute 1996). If perceptions of bus stops are negative, ridership may decrease. Previous work has demonstrated better bus stop amenities may increase ridership (Brown et al. 2006; Kim et al. 2020; Raida et al. 2023; Texas Transportation Institute 1996) with improved amenities also reducing the demand for more expensive services such as paratransit (Kim et al. 2020). Further, as bus riders are disproportionately lower income people and people of color (Wang and Renne 2023), these groups may also be disproportionately impacted by a lack of bus stop amenities. Lack of coverage and protection from natural elements and passing traffic as well as stop inaccessibility may deter bus ridership and make riding the bus a less comfortable experience. Bus stop amenities may also help accommodate various groups with special needs including people with disabilities, older adults, and those traveling with strollers or equipment. Not only will improving bus stops potentially increase ridership, but it may also make riders feel more valued and represented in the planning process (Kim et al. 2020).

While bus stop amenities are important, research on the distribution of bus stop amenities is scant. As Moran (2022) has highlighted, transit literature has not included much work analyzing bus stop amenities. Recent work has helped fill these gaps, evaluating bus stop amenities using a variety of data collection methods. Moran (2022) collected amenity data in person while others used computer vision methods, either on imagery gathered using camera-on-vehicles (Shameli et al. 2023; Shameli and Azar 2022) or Google Street View (Kim et al. 2024). This paper furthers previous work in three important ways. First, previous work had focused on areas with a strong transit focus. For example, Moran (2022) partly chose to focus on San Francisco because of its transit first policy directive while Kim et al. (2024) purposely chose cities with a higher proportion of bus commutes. Consequently, an evaluation of bus stop amenities in a more varied geography may produce different conclusions. Second, previous work (Kim et al. 2024; Moran 2022; Shameli et al. 2023; Shameli and Azar 2022) uses cross-sectional methods, providing a snapshot from 1 year. While this has allowed for some novel spatial insights, especially regarding equity in amenity distribution (Kim et al. 2024; Moran 2022), cross-sectional evaluation cannot provide insight into how amenities may change over time, an important aspect for understanding decision-making around bus stop amenities. Finally, previous work focused only on stops from one agency even though bus stop amenity policy and practice can vary greatly between agencies (Project for Public Spaces and MultiSystems 1999; Texas Transportation Institute 1996) and may conflict when service areas overlap. For example, while there are many bus operators in the San Fransico Bay area, Moran (2022) only visited bus stops that

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belonged to the San Francisco Municipal Transportation Agency (SFMTA), the city's primary bus operator. This allowed for an evaluation of SFMTA's bus stop policies but does not account for the complexities that arise when bus agencies share service areas and amenities. While Kim et al. (2024) briefly discusses transit agency guidelines for bus stop amenities, more depth is needed to understand how decision factors might vary or conflict between agencies.

This paper adds to the existing literature by evaluating bus stop amenities in a different geography, over multiple time periods, and in a more complex transit operating environment. This study specifically evaluates bus stop amenities across Northern Virginia, examining why differences might exist as well as possible inequities surrounding the allocation of bus stop amenities. Northern Virginia provides a good case for evaluating these questions as there are a mix of jurisdictions and multiple bus transit operators, proving a variety of geographic and institutional factors to consider within a relatively small geographic context. While parts of the region like Arlington County and the City of Alexandria have higher transit use, like Moran (2022) and Kim et al. (2024) focused on, other parts have lower transit use, with just 6% and 2% of commuters using transit in Fairfax County and Loudoun County, respectively (NVTC 2024). In addition, while this paper uses Google Street View data like Kim et al. (2024), the analysis goes beyond previous work by collecting amenity data over multiple years, allowing more insight into how much bus stop amenities change over time. Finally, Northern Virginia is served by seven bus operators with overlapping service areas and many shared bus stops. Consequently, unlike previous work, this paper explicitly explores how bus amenity decisions may be affected by overlapping service areas, providing a richer understanding of the complexities around bus stop amenity decision-making. This is achieved by both evaluating the spatial distribution of bus stops as well as differences in transit agency and regional policies that help shape and influence bus stop amenity decisions.

Section "Bus in Northern Virginia" of this study provides regional context; section "Policy Context" synthesizes relevant policies that may affect bus amenity distribution; section "Data and Methods" describes the methodology and data used for evaluating existing bus stop amenities; section "Results" provides the results; and section "Discussion and Conclusions" presents a discussion of the findings before concluding.

Bus in Northern Virginia

Northern Virginia is defined as the counties of Arlington, Fairfax, Loudoun, and Prince William as well as the cities of Alexandria, Falls Church, Fairfax, Manassas, and Manassas Park. The region covers 1,327 mi^2 and has approximately 2.5 million residents. Bus service in this area is provided by seven different bus agencies serving more than 7,500 stops across 251 routes (NVTC 2024). The bus agencies include Arlington Transit, City of Fairfax's City-University Energysaver (CUE), City of Alexandria's DASH, Loudoun County Transit, the Potomac and Rappahannock Transportation Commission's OmniRide, Fairfax Connector, and Washington Metropolitan Area Transit Authority's (WMATA) Metrobus. The latter two are the largest providers, serving over two-thirds of the region's bus stops. Bus transit accounts for almost 40% of the region's public transit ridership, serving over 31 million riders in 2023 alone (NVTC 2024). Because of the sheer number of bus trips taking place, investing in bus stop improvements could make a large difference in retaining and attracting riders, a particular concern given the Washington, DC, region, which includes Northern Virginia, was one of the areas in the US where transit was most impacted by the COVID-19 pandemic (Ziedan et al. 2023). Bus service makes up over 80% of fixed-route transit service in the region with rail making up the remaining share (NVTC 2024). Although buses carry fewer riders per trip compared to rail services, they are crucial in connecting residents of outlying communities to other transit and urban centers and are especially important for the region's essential workers.

As these statistics have demonstrated, bus transit is important to the region. However, bus service in Northern Virginia is very different to other regions studied in recent bus amenity research. While there are dense areas in the region, like Alexandria and Arlington, there are also suburban parts, like in the counties of Fairfax, Loudoun, and Prince William. Bus operations also look different. While SFMTA, for example, predominately operates local bus services, Northern Virginia has a mix of local and commuter services. Finally, while previous work (Kim et al. 2024; Moran 2022) focused on just stops from a single agency in each city, Northern Virginia has a more complex operating environment with nine jurisdictions, seven bus operators, and a lot of overlap. In some cases, up to six operators serve the same location and a single bus stop can serve three different operators. This makes bus stop amenity decisions much more complicated. With many bus services overlapping, Northern Virginia presents some unique opportunities to evaluate how transit agency policies interact in a regional context.

Policy Context

The design and placement of bus stop amenities is the outcome of policy decisions. With limited funds available for bus infrastructure, transit agencies and jurisdictions must prioritize which bus amenities to install and where they should be placed. This section explains the policy context that may provide some insight for the results, including national and state guidance that may influence bus stop amenities as well as each agency's bus stop amenities policy.

To start, the Civil Rights Act has direct implications for transit amenities. Title VI of the Civil Rights Act ensures federal funds are not used to discriminate based on race, color, or national origin. The United States Department of Transportation (USDOT) Federal Transit Administration (FTA) requires transit agencies report how transit amenities are distributed through their service areas to ensure there are no Title VI violations (DOT Federal Transit Administration 2012). FTA does not set criteria for bus stop amenities but requires transit agencies to establish their own policies when they are able to do so. FTA acknowledges that in some cases a jurisdiction may have control over bus stop amenity polices instead of a transit agency. This is particularly relevant in Northern Virginia where service areas overlap. The US Access Board *Public Rights-of-Way Accessibility Guidelines* have additional guidance affecting accessibility. While these guidelines focus on amenity design rather than placement, the requirements can increase the time and cost of installing bus stop amenities and can prohibit amenities in locations with insufficient space.

In addition to the federal regulations, there are state guidelines and policies for bus stop amenities in Virginia including building and roadway design guidelines. Additional process steps are triggered when state right-of-way is affected, like when a bus stop is located on a Virginia Department of Transportation (VDOT) road. When a bus stop on a VDOT road is to be improved, both the Virginia Department of General Services (DGS) and VDOT have processes that can complicate amenity installation (Gordon

2023). VDOT's multiphase process could mean it might take years to add new bus stop amenities (Gordon 2023). However, the Virginia Department of Rail and Public Transportation has been working on improving outcomes by trying to "map out the VDOT and DGS process, remove red tape, and shepherd essential infrastructure projects through" (Gordon 2023).

Agency Policies

Northern Virginia transit agencies have specific requirements and standards for approving bus stop improvements. Publicly available bus amenity policies of each agency were evaluated to determine where there may be similarities and differences. DASH did not have a publicly available policy describing their standards for different bus stop amenities.

Several transit agencies apply different decision rules depending on the type of stop. Table 1 summarizes the different tiers or categories Northern Virginia agencies use to classify their bus stops. Some stops are categorized based on their function, like commuter stops or bus stops that serve transit stations, while other stops are categorized based on the amount of service or ridership. These categories serve as a way for transit agencies to prioritize their bus stop improvements. This is demonstrated by the fact many agencies describe their bus stop improvement policies in their transit development plans (TDPs), a strategic document that details an agency's planned transit improvements. Tier classification standards vary between transit agency policies. For example, while both Arlington Transit and CUE use daily boardings to describe stop tiers, the thresholds are different. Across transit agencies, modal shifts are the most consistent criterion for bus stops with more amenities. Whether for car to bus, like with Loudoun County Transit and OmniRide, or bus to train, like Arlington Transit and WMATA, shifting modes is the commonality. However, this focus may implicitly result in better bus stop amenities for wealthier transit riders or transit riders that are less reliant on transit services. Both commuter bus services and rail transit are disproportionately used by wealthier transit riders (Garrett and Taylor 1999; Wang and Renne 2023).

Fig. 1 shows how different types of amenities vary by transit agency and bus stop tier. The most detailed guidelines come from Arlington Transit and WMATA, likely because both agencies have a specific document dedicated to defining guidelines and standards for bus stops. As mentioned previously, other agencies typically just include their policies as part of their TDPs. Bus shelters were the most frequently mentioned stop amenity across agencies, explicitly included in every publicly available policy, followed by seating. Lighting and static system maps were both mentioned third most. Bus stop amenity policies are also used very differently between agencies. While Arlington Transit, WMATA, and Loudoun County Transit had several required amenities for bus stops, agencies such as CUE and Fairfax Connector only stated that amenities should be considered, giving the agencies latitude to *not* install an amenity.

Transit agencies also varied in their justification for whether to improve a bus stop or not. Table 2 summarizes the different criteria transit agencies cited in their policies when considering improving their bus stops. Evidently, decision-making factors vary considerably by agency. The only consistent measure was passenger demand. No other decision-making criteria were used by more than four transit agencies. However, there are still observable trends. For example, some transit agencies considered adjacent land-use types in their decision-making while others took advantage of changes near a stop, such as road reconstruction or a new development, to improve a stop's amenities. Few agencies had policies against improving stops. The primary exception was when it was not physically possible to install an amenity due to an obstruction or right-of-way limitations. Fairfax Connector was the only agency with additional criteria for not improving a stop. Specifically, a bus stop's proximity to an existing stop with a shelter can be used to rule out its eligibility for also receiving a shelter. This policy makes it more difficult to build shelters in urban areas where bus stop spacing is typically smaller.

Overall, there is little consistency in the region's bus amenity policies. This presents a challenge because in Northern Virginia bus agencies have overlapping transit service and stops serving multiple agencies. This makes it more difficult to determine which standards to follow. None of the public guidelines for Northern Virginia transit agencies directly acknowledge this. DASH (2023) acknowledges that in some cases their bus stops can be shared by up to three bus operators but provides no guidance on which standard to follow when this occurs.

Data and Methods

A primary focus of this study is to gain a better understanding of how and why bus stop amenities are distributed across Northern Virginia. To do this, both bus stop amenity and contextual data were collected. These data were evaluated using a variety of spatial and statistical methods described as follows.

Table 1. Northern Virginia bus stop tier definitions

Tier level	Arlington transit	CUE	DASH	Fairfax connector	Loudoun county transit	OmniRide	WMATA
Tier 1 (highest)	Transit Station	20 + boardings per day	—	—	Park-and-ride lots	Commuter stops	Transit center
Tier 2 (middle)	40 + boardings per day	15–19 boardings per day	—	—	Transfer points, commuter bus stops, and other stops with higher boarding concentrations	Local stops	Enhanced service stop (e.g., express or limited stop service)
Tier 3 (lowest)	0–40 boardings per day	< 15 boardings per day	—	—	Not defined	—	Basic stop
Other	—	—	No specifics	Up to 11 different categories for different amenities	—	—	—

Sources: Data from DASH 2023; Arlington County 2020; KFH Group 2017; Loudoun County Transit 2018; OmniRide 2020; TranSystems and Foursquare Integrated Transportation Planning 2016; WMATA 2009.

Bus Stop Amenities		Arlington Transit			CUE			DASH	Fairfax Connector	Loudoun County Transit		OmniRide		WMATA		
Tier^		1	2	3	1	2	3	-	-	1	2	1	2	1	2	3
Category	**Amenity**															
Information	Bus stop sign/marker	●	●	●	-	-	-	-	-	-	-	-	-	●	●	●
	Schedule (static)	-	-	-	-	-	-	-	◗	◗	◗	-	-	●	●	●
	System map (static)	●	◗	◗	-	-	-	-	◗	-	-	●	-	●	●	◗
	Real-time information	●	◗	○	-	-	-	-	-	-	-	-	-	●	●	◗
Accessibility	Concrete boarding area/landing pad	●	●	●	-	-	-	-	-	-	-	-	●	●	●	●
	Adjacent sidewalk	●	●	●	◗	◗	○	-	-	-	-	-	-	●	●	●
	Connection from boarding area to sidewalk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Curb cut/ramp	●	●	●	◗	◗	○	-	-	-	-	-	-	●	●	●
	Marked crossing to other side of street	-	-	-	-	-	-	-	-	-	-	-	-	●	●	●
	Tactile curb warning strip	●	◗	○	-	-	-	-	-	-	-	-	-	-	-	-
Infrastructure	Lighting	●	●	●	◗	◗	○	-	-	●	-	-	-	●	●	◗
	Seating	●	◗	◗	◗	◗	○	-	◗	-	-	●	◗	●	●	◗
	Shelter	●	◗	○	◗	◗	○	-	◗	●	●	●	◗	●	●	◗
	Lean bars	◗	◗	◗	-	-	-	-	-	-	-	-	-	-	-	-
Other	Trash cans	●	●	◗	-	-	-	-	-	●	-	-	-	●	●	◗
	Bicycle racks	-	-	-	◗	◗	○	-	-	●	-	-	-	-	-	-
	Newspaper vending boxes	-	-	-	-	-	-	-	-	-	-	-	-	○	○	○

^Tier 1 is the highest; ●*Required;* ◗*Considered;* ○*Not required;* - *Not mentioned*

Fig. 1. Northern Virginia bus stop amenity policies. [Data from Alexandria Transit Company (DASH) 2023; Arlington County 2020; KFH Group 2017; Loudoun County Transit 2018; OmniRide 2020; TranSystems and Foursquare Integrated Transportation Planning 2016; WMATA 2009.]

Table 2. Northern Virginia bus stop amenity decision-making considerations

Category	Criteria	Arlington Transit	CUE	DASH	Fairfax Connector	Loudoun County Transit	OmniRide	WMATA
Ridership	Daily boardings; average ridership at stop	X	X	X	X	X	X	X
	Trip generators with greater accessibility needs (e.g., percentage of children, elderly, or disabled)	X	—	—	—	—	—	X
	Trip generators that support transit use	—	X	X	X	—	—	X
Service type	Evening service	—	—	—	—	—	—	X
	Number of bus routes serving stop	X	—	X	—	—	—	X
	Bus headways	—	—	—	—	—	—	X
	Commuter bus service	—	—	—	—	X	X	—
Connections	Transit centers	X	—	—	X	—	—	X
	Transfer points	—	—	X	—	X	—	X
	Park-and-ride lot	—	—	—	X	X	—	—
Physical characteristics	Available right of way	X	X	X	X	—	—	—
	Sight distance	X	—	—	—	—	—	—
	Obstructions (poles, structures, trees)	X	X	X	—	—	—	X
	Proximity to other bus stops with amenities	—	—	—	X	—	—	—
	Proximity to fast food restaurants or convenience stores	—	—	—	—	—	—	X
	Adjacent road type (e.g., arterial street)	—	—	—	X	—	—	—
Other	New development	—	X	—	—	—	X	—
	Road reconstruction	—	—	—	—	—	X	—
	Potential for stop sponsorship	—	—	—	—	—	—	X
	Safety	—	—	—	X	—	—	—
	High potential advertising revenue	—	—	—	X	—	—	—
	Nearby pedestrian activity	—	—	—	—	—	—	X
	Stakeholder requests	—	X	—	—	—	—	—

Sources: Data from DASH 2023; Arlington County 2020; KFH Group 2017; Loudoun County Transit 2018; OmniRide 2020; TranSystems and Foursquare Integrated Transportation Planning 2016; WMATA 2009.

Data

The population of bus stops was generated using June 2023 general transit feed specification (GTFS) data for the seven agencies that serve Northern Virginia. The geographic boundary for Northern Virginia was used to remove any stops that were not physically located in the region, resulting in a total of 7,528 bus stops. Shared bus stops are recounted for every agency that uses the stop. If a stop serves two transit agencies, it is listed twice. Pooled GTFS data do not identify shared stops, but shared stops are identified later. Due to the large number of stops, a sampling strategy was developed to create a manageable workload. As Northern Virginia transit agencies do not have an equal number of bus stops, a simple systematic sampling strategy risks not including bus stops from all agencies. Consequently, a stratified random sampling strategy was deemed most appropriate. This strategy allows all transit agencies to be represented in the sample while ensuring our findings are likely still representative of the bus stop population. First, a minimum sample size was estimated. A confidence level of 95% and margin of error of 5% were used to calculate a statistically valid minimum sample size of 366, rounded to 401 for increased accuracy. The authors initially aimed for 400 but used 401 due to rounding resulting from the proportioned sampling strategy. Second, proportionate weighting was used to determine how many of the sample needed to correspond with each transit agency, the strata. If one agency's bus stops made up 10% of the bus stop population, they would also make up 10% of the sample. Finally, a random number generator was used to select the required number of stops for each agency. Fig. 2 shows the population of Northern Virginia bus stops as well as the sample evaluated in this study.

The paper's authors manually viewed the sample bus stops in Google Street View to identify and record a variety of amenity data for each stop. Amenities were defined based on both previous research and professional judgment. Table 3 summarizes the bus stop amenities included in the data and their operationalization. While computer vision methods have provided more comprehensive ways to gather bus stop amenity data (Kim et al. 2024; Shameli et al. 2023; Shameli and Azar 2022), these methods do not reliably capture all amenities, especially when there are no shelters (Shameli et al. 2023), and do not capture all the amenities presented in Table 3. Fig. 3 provides an example of many of these amenities at a bus stop shared by three Northern Virginia transit agencies. Google Street View was used to allow for the collection of multiple years of data which were used to identify trends over time (Fig. 4 shows some examples). A test subsample revealed bus stop data were most commonly available for 2014, 2018, and 2022.

As the review of local policies highlighted, there are a variety of geographic and other contextual factors that could help explain the inclusion of different amenities at a stop. First, some local policies considered demographics and population concentration in their bus stop amenity decision-making. Consequently, population and demographic characteristics were estimated for areas around a bus stop. This was done by first acquiring 2017–2021 American Community Survey (ACS) 5-year estimates at the block group level for

Fig. 2. All Northern Virginia bus stops and sampled bus stops. (Sources: County of Prince William, Fairfax County, VA, VGIN, Esri, TomTom, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS, USFWS.)

Table 3. Bus stop amenities identified for data collection

Category	Amenity	Definition	References
Accessibility	Boarding/alighting area	A flat, paved area that extends to the curb and does not reduce walkable space on a sidewalk	Brown et al. (2006), Easter Seals Project Action (2016), Kim et al. (2020), and NACTO (2016)
	Sidewalk	A paved path that supports pedestrian travel to and from the bus stop	Brown et al. (2006), Easter Seals Project Action (2016), Fan et al. (2016), Kim et al. (2020), and NACTO (2016)
	Connection to sidewalk/path	A direct connection between the boarding area and sidewalk	Easter Seals Project Action (2016) and NACTO (2016)
	Proximity to crosswalk	A marked pedestrian crossing that connects two sides of a street within 200 ft of bus stop	WMATA (2009)
	Curb cut/ramp	A ramp that allows for pedestrians to transition to and from the road to a sidewalk at the nearest point where the sidewalk ends	Arlington County (2020), NACTO (2016), Texas Transportation Institute (1996), and WMATA (2009)
	Hostile architecture	Designs that restrict the use of public space and amenities (divided benches, spikes, etc.)	WMATA (2009)[a]
Information	Bus stop sign/marker	A pole, flag, or other designated marking that identifies a bus stop	Arlington County (2020), Brown et al. (2006), Easter Seals Project Action (2016), Kim et al. (2020), Moran (2022), NACTO (2016), and WMATA (2009)
	Real-time transit information	Electronic real-time service information	Easter Seals Project Action (2016), Fan et al. (2016), Moran (2022), and NACTO (2016)
	Schedule (static)	Static schedule sign, poster, or brochure	Easter Seals Project Action (2016), Fan et al. (2016), and WMATA (2009)
	System map (static)	Static system map sign, poster, or brochure	Brown et al. (2006), Easter Seals Project Action (2016), Fan et al. (2016), Moran (2022), and WMATA (2009)
Infrastructure	Lighting	Streetlight, shelter light, or designated bus stop light within 20 ft of the bus stop	Brown et al. (2006), Easter Seals Project Action (2016), Fan et al. (2016), KFH Group (2017), and NACTO (2016)
	Seating	Designated seating provided by the transit agency	Brown et al. (2006), Easter Seals Project Action (2016), Fan et al. (2016), Kim et al. (2020), Lagune-Reutler et al. (2016), Moran (2022), and NACTO (2016)
	Shelter	Designated shelter provided by the transit agency, advertising contractor, or other responsible entity	Arlington County (2020), Easter Seals Project Action (2016), Kim et al. (2020), Lagune-Reutler et al. (2016), Loudoun County Transit (2018), Moran (2022), NACTO (2016), TranSystems and Foursquare Integrated Transportation Planning (2016), and WMATA (2009)
Other	Alternative shelter	Shelter not provided by the transit agency (awning, overhang, underpass, etc. excluding trees)	Easter Seals Project Action (2016)
	Alternative seating	Informal seating	Fan et al. (2016)
	Bicycle racks	Bicycle racks or other bicycle storage within 100 ft	Easter Seals Project Action (2016), KFH Group (2017), Loudoun County Transit (2018), and NACTO (2016)
	Newspaper vending boxes	Boxes or displays for newspapers and magazines within 50 ft of the bus stop	Easter Seals Project Action (2016) and WMATA (2009)
	Trash can	Trash receptacles within 50 ft of bus stop	Arlington County (2020), Brown et al. (2006), Easter Seals Project Action (2016), Kim et al. (2020), NACTO (2016), and WMATA (2009)
	Tree coverage	Tree coverage accessible to the public within 20 ft of the public right of way	Brown et al. (2006), Easter Seals Project Action (2016), Kim et al. (2020), and Lagune-Reutler et al. (2016)

[a]While WMATA does not explicitly mention hostile architecture, their policy says benches should be designed to "discourage people from sleeping on the bench."

the region. Next, areal weighting was used to estimate the demographics and population within a quarter mile of each bus stop. The demographic data included total population, zero car households, transit commuters, low-income population [defined as people below 200% of federal poverty level, a threshold used by the region's metropolitan planning organization (Metropolitan Washington Council of Governments 2018)], nonwhite population, and jobs. Jobs data were obtained from the Metropolitan Washington Council of Governments. Only 2015 and 2020 data were available so straight-line interpolation was used to estimate 2014, 2018, and 2022 data.

Transit boardings were the most ubiquitous metric used by agencies in their decision-making. Consequently, average daily boarding and alighting data were requested from each agency for the three data collection years. Not all stops in the sample were in operation for all 3 years and some agencies did not have ridership data available. These data gaps may affect some of the results.

Multiple transit agencies also noted they used service characteristics in bus stop amenity decision-making. Consequently, GTFS data were used to determine the number of routes and the average weekly number of bus trips that served the stop. Bus stop IDs and spatial proximity analysis were used to determine if a bus stop served more than one transit agency (approximately 23.9% of sample bus stops are shared).

Finally, differences in jurisdiction and right-of-way must be considered. In Virginia, independent cities manage their own roads while county roads are typically controlled by VDOT (Gordon 2023; Reich 2018). However, some county roads are also managed by the county, developers, or other groups. The different ownership rules mean it is easier to build bus stop amenities in

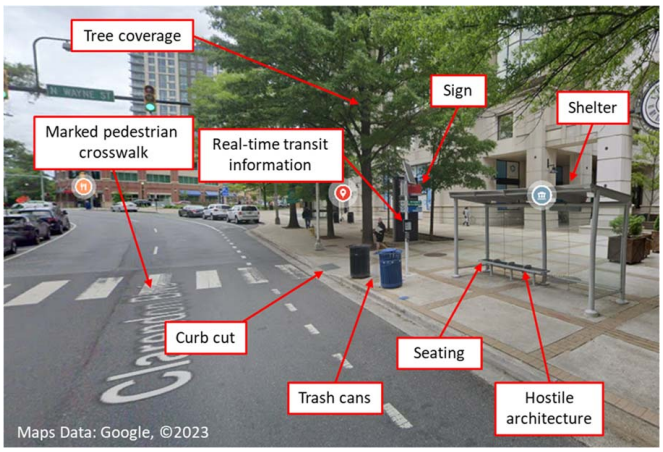

Fig. 3. Example of amenities at a bus stop served by three transit agencies. (Map data ©2023 Google.)

some places than others. In addition, as previously noted, transit agencies may have different amenity distribution policies to jurisdictions (DOT Federal Transit Administration 2012), which can make installing bus amenities more complicated for agencies that are not governed by the jurisdiction. Consequently, differences in adjacent road ownership were obtained from city and county geographic information system data.

Bus Stop Data Quality

Although there are several advantages to using Google Street View data, including the ability to collect data for multiple years and the reduced data collection time per stop, there are some limitations, such as missing data. Google does not collect street view data for every street every year, meaning some bus stop data are unavailable for this study. Approximately 91% of sample stops have at least one observation; 45% of stops have data for every year, 31% have data for 2 years, and 15% of stops have data for 1 year. The data quality is correlated with the jurisdiction type where the stop is located. Almost two-thirds of stops in cities have all 3 years of data while only 38% of stops in counties have data for all 3 years. Some bus stops had no data at all. This occurs if a stop sign is missing or if the GTFS coordinates for the stop are incorrect. In some cases, this was because the stop was in a location that was inaccessible to a Google car, such as in a rail station bus loop. About 9% of stops had no data. Stops with missing data were negatively correlated with population density. Bus stops with street view data average approximately 1,520 people with access to a stop (defined within a quarter mile), regardless of whether there is 1 or 3 years of data. Conversely, stops with no data average about 970 people near a stop, a 36% reduction.

The accuracy of the data was vetted by comparing the collected sample data to data provided by transit agencies in their TDPs (or similar documents). Only shelter data were evaluated as it was the only consistent amenity cited across agencies. In performing this check, a regional average for TDPs was estimated by weighting an agency's percentage of bus stops with shelters by the total number of stops operated by the agency. According to this process, 17.3% of bus stops in the region have bus shelters. In comparison, 18.6% of the most recent year of bus stops in our sample had shelters, a 1.3% difference. Considering some of the TDP shelter data are older and the number of shelters may have since increased, the small difference suggests the sample is likely representative of the region, even with gaps in street view data.

Methodology

Bus stop data were analyzed using four different methods. First, graphs were created to help identify trends or patterns in the data. Different bus stop amenities were plotted based on their frequency of observation. These graphics were supported by statistical tests including chi-squared tests and *t*-tests. The chi-squared tests

Fig. 4. Examples of bus stop improvements. (Map data ©2023 Google.)

provide insight into whether the percentages of stops with each amenity were statistically different to percentages of stops without the amenity for variations in land use, road ownership, jurisdiction type, or shared status. For the *t*-tests, areal weighting was used to estimate different demographics or population types around bus stops with an amenity as well as bus stops without the amenity. The *t*-tests were then calculated for these two numbers to determine whether there was a statistically significant difference between the two, which might suggest a potential correlation between the population statistic and the bus stop amenity. As the split calculation might create unequal variances, Welch's *t*-test was assumed to be the most appropriate for this study. Welch's *t*-tests have been used in previous bus stop research incorporating Google Street View (Hara et al. 2015).

After calculating basic statistics, bus stop amenities were plotted spatially to observe spatial patterns or trends. Finally, binary logistic regression models were developed to identify any correlations between bus stop amenities and other bus stop characteristics. The models were used to estimate the probability of whether a bus stop had an amenity or not while controlling for a variety of contextual variables. Models were only produced for seating and shelters as these amenities were most often included in bus stop amenity guidelines and policies (Fig. 1). Three model variations were developed. First, 2022 data were modeled as they were the most recent data available. Second, because the pandemic may have affected the effect of ridership, 2018 data were modeled. Finally, because of data gaps for ridership, 2022 data were modeled without ridership data to allow for a larger sample size. The four employed methods evaluated bus stops both spatially as well as temporally to both see what factors may affect the distribution of stop amenities as well as how bus stops are improved over time.

Results

As noted, Google Street View data were not available for all stops for all years. A total of 356 unique bus stops were included in at least one of the data collection years. Each of the 3 years averaged approximately 265 unique stops with the most observations in 2022. Fig. 5 shows the proportion of stops with each amenity type for each year of data. Even though the observed stops change somewhat between years, the proportions of amenities are similar with a gradual increase as time progresses, which is what would be expected if more amenities were installed over

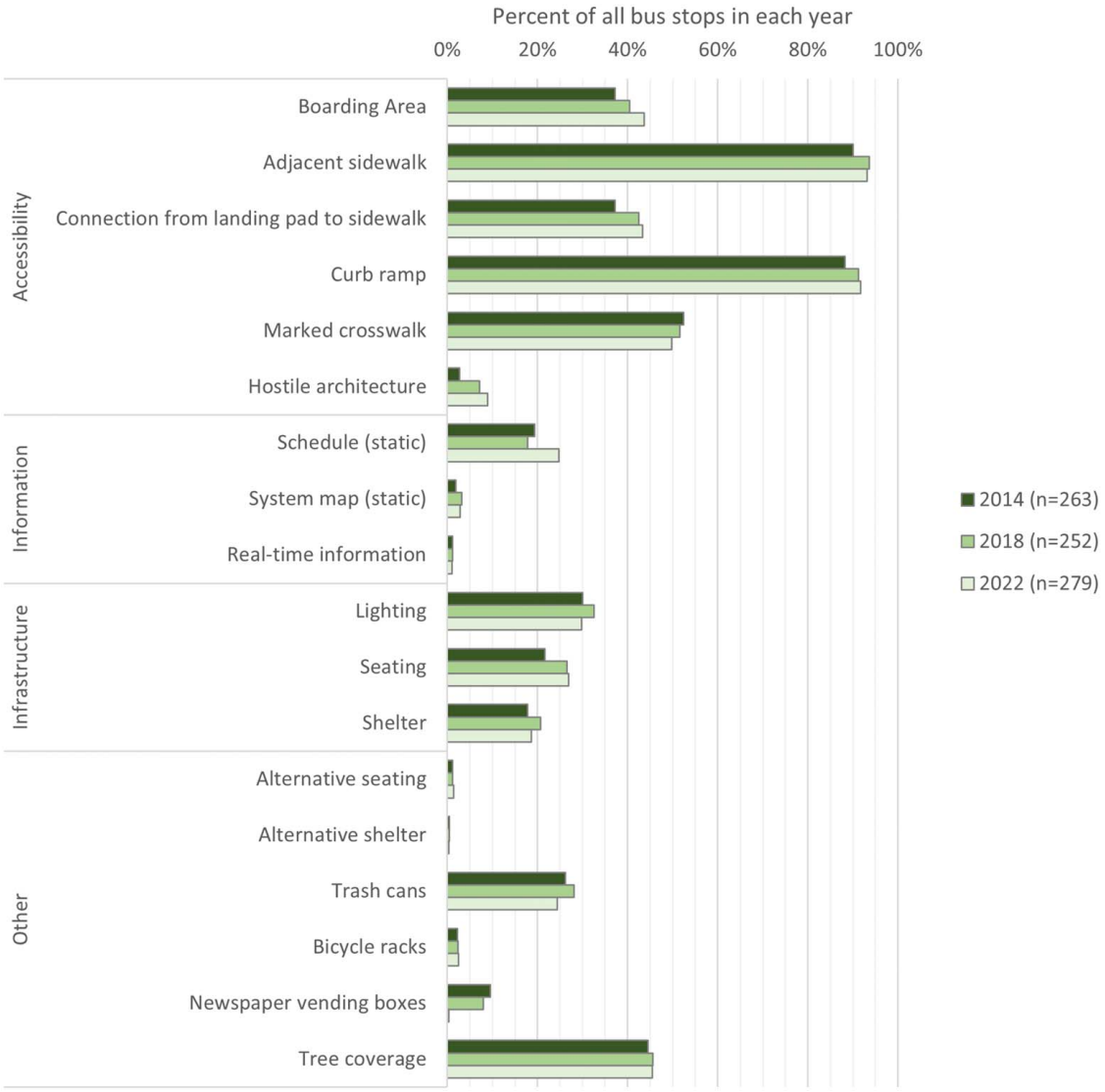

Fig. 5. Northern Virginia bus stop amenities.

	Boarding Area	Adjacent sidewalk	Connection from landing pad to sidewalk	Curb ramp	Marked crosswalk	Hostile architecture	Schedule (static)	System map (static)	Real-time information	Lighting	Seating	Shelter	Trash cans	Bicycle racks	Tree coverage
Boarding Area stops with…		94%	94%	95%	61%	20%	35%	5%	2%	35%	56%	42%	52%	6%	43%
Adjacent sidewalk stops with…	44%		47%	98%	51%	10%	24%	3%	1%	31%	28%	20%	26%	3%	46%
Connection from landing pad to sidewalk stops with…	95%	100%		99%	63%	21%	35%	6%	2%	36%	58%	42%	53%	6%	43%
Curb ramp stops with…	45%	99%	47%		53%	10%	25%	3%	1%	32%	29%	20%	27%	3%	45%
Marked crosswalk stops with…	53%	96%	55%	97%		16%	37%	5%	2%	40%	37%	26%	35%	5%	45%
Hostile architecture stops with…	100%	100%	100%	100%	88%		64%	4%	4%	64%	100%	88%	76%	4%	24%
Schedule (static) stops with…	62%	91%	61%	93%	74%	23%		10%	4%	43%	41%	30%	38%	6%	48%
System map (static) stops with…	75%	100%	88%	100%	88%	13%	88%		0%	63%	63%	50%	50%	13%	50%
Real-time information stops with…	67%	100%	100%	100%	100%	33%	100%	0%		67%	33%	33%	67%	0%	0%
Lighting stops with…	52%	98%	52%	98%	67%	19%	36%	6%	2%		43%	34%	41%	6%	45%
Seating stops with…	91%	99%	93%	97%	69%	33%	37%	7%	1%	48%		69%	76%	7%	41%
Shelter stops with…	98%	98%	98%	98%	69%	42%	40%	8%	2%	54%	100%		87%	6%	40%
Trash cans stops with…	94%	99%	94%	100%	71%	28%	38%	6%	3%	50%	84%	66%		9%	47%
Bicycle racks stops with…	100%	100%	100%	100%	100%	14%	57%	14%	0%	71%	71%	43%	86%		57%
Tree coverage stops with…	41%	94%	41%	91%	50%	5%	26%	3%	0%	29%	24%	17%	25%	3%	

Fig. 6. Bus stop amenity crosstabulation (2022 only; $n = 279$).

time. Accessibility-orientated amenities are better represented than other amenity categories. The most prevalent amenities, sidewalks and curb ramps, are also those that are more likely to be under a jurisdiction's control than a transit agency's. Northern Virginia also shows some differences to other regions. While approximately one-quarter of Northern Virginia stops had seating and one-fifth had a shelter, these numbers are noticeably lower than San Francisco where 34% of stops had seating and 31% had shelters (Moran 2022). Both San Francisco and Northern Virginia are considerably lower than the 20 cities covered in Kim et al. (2024) where, on average, 41.5% of bus stops had shelters. Finally, transit information was poorly provided at Northern Virginia stops.

Bus stop amenities are rarely implemented in isolation. Consequently, a cross tabulation was created to see how bus stop amenities were associated with each other. Fig. 6 summarizes the results and shows some clear patterns. First, sidewalks and curb ramps are almost always present for other types of bus stop amenities. Bus stops with shelters were often clustered with several other amenities. In the 2022 data, all shelters had seats, with a majority also having lighting, hostile architecture, and trash cans. Further, while amenities providing information were generally not broadly observed, they were most often seen at stops with shelters. Compared to San Francisco (Moran 2022), Northern Virginia is more likely to have seating without shelters (only 69% of stops with seating have shelters while 90% of stops with seating have shelters in San Francisco), and much less likely to have static or real-time information at stops.

Demographic characteristics were also associated with bus stop amenities, but patterns differed to previous work. Moran (2022) found that census tracts with higher-than-average share of white residents were more likely to have bus stops with seating or shelters than census tracts with an above average share of people of color. Conversely, Kim et al. (2024) found mixed results. In the cities evaluated, Kim et al. found 11 cities with positive correlations between racial minority populations and bus shelters with a further 4 cities having negative correlations, suggesting inequality. Northern Virginia tells a more complex story around bus stop amenities and race. As Table 4 presents, while people of color are less likely to have their bus stop close to a crosswalk or with schedule information, bus stops with shelters are adjacent to a higher share of residents of color than those without shelters. The populations with access to bus stops with shelters are, on average, 46% people of color while stops without shelters are accessed, on average, by 40% people of color. There was no statistically significant difference in race for seating. In addition, while Moran (2022) found no relationships with income, in Northern Virginia, every statistically significant relationship between bus stop amenities and income showed lower-income populations were more likely to have amenities. However, Northern Virginia and San Francisco also shared some similarities. Moran (2022) noted less dense areas were less likely to have amenities and the same is true in Northern Virginia. Bus stops with amenities typically have a higher number of residents who can access a stop, indicating higher population density. Job density was not as reliable with no statistically significant difference for seating or shelters. Finally, higher ridership was associated with stop amenities, especially seating and shelters. This was expected given the policy decision-making criteria described in Table 2.

As some variables may be clouding the effect of others, binomial logistic regression was used to establish which variables were the strongest predictors of bus stop amenities. All model results are provided in Table 5. Some of the variables from Table 4 were not included because of correlation or sample size issues. One consistency across all three model variations is bus stops shared among transit agencies or with more transit services are the most likely to have seats or shelters. Bus ridership was not statistically significant in either year; however, when ridership was removed from the 2022 model, the strength of the retail variable increased. This suggests there may be a relationship between stops with seating/shelter, retail land use, and bus ridership. Finally, while nonwhite populations were statistically significant for shelters in 2022, the effect size is small and not consistent between years.

Table 4. Tests for statistical significance

			Amenity									
Variable	Description	*N*	Boarding area	Side-walk	Curb cut	Proximity to crosswalk	Hostile arch.	Schedule (static)	Lighting	Seating	Shelter	Trash can
Chi-squared analysis: Percentage of stops with each amenity												
Land use	Bus stops adj. to retail	354	54.5%*	98.0%*	97.0%*	56.6%	12.1%	28.3%	39.4%*	42.4%***	29.3%**	41.4%***
	Bus stops adj. to residential		42.3%*	91.8%*	90.5%*	49.1%	8.2%	26.8%	26.4%*	25.0%***	17.7%**	22.7%***
	Bus stops adj. to office		54.3%*	97.1%*	97.1%*	45.7%	2.9%	20.0%	31.4%*	14.3%***	14.3%**	17.1%***
Adjacent road owner	Bus stops on a local road	279	49.7%	97.3%**	94.6%	56.4%*	10.1%	30.2%**	37.6%***	31.5%	20.1%	31.5%**
	Bus stops on a state road		36.5%	87.8%**	87.8%	41.9%*	8.1%	23.0%**	14.9%***	20.3%	17.6%	16.2%**
	Bus stops on other roads		37.5%	89.3%**	89.3%	42.9%*	7.1%	12.5%**	28.6%***	23.2%	16.1%	16.1%**
Jurisdiction type	Bus stops in a county	279	40.5%**	91.4%	90.5%	47.3%	10.9%**	28.6%***	26.4%**	23.6%**	17.7%	19.1%***
	Bus stops in a city		55.9%**	100.0%	96.6%	59.3%	1.7%**	10.2%***	42.4%**	39.0%**	22.0%	44.1%***
Multiple agencies at stop	Bus stops shared	279	64.9%***	94.6%	93.2%	60.8%**	18.9%***	37.8%***	43.2%***	52.7%***	36.5%***	43.2%***
	Bus stops not shared		36.1%***	92.7%	91.2%	45.9%**	5.4%***	20.0%***	24.9%***	17.6%***	12.2%***	17.6%***
Welch's *t*-test (*unequal variances t-test*): Average demographic and population values with and without a specific amenity												
Population	Avg. for stops with amenity	279	1,746.0***	1,540.6**	1,533.9	1,769.9***	2,025.9**	1,847.7***	1,810.8***	1,916.6***	1,963.9***	1,934.2***
	Avg. for stops without amenity		1,316.3***	1,006.7**	1,173.7	1,240.4***	1,452.8**	1,391.3***	1,374.3***	1,352.6***	1,398.9***	1,365.6***
Zero car households (%)	Avg. for stops with amenity	279	7.6%***	6.4%**	6.4%**	7.6%***	9.0%*	8.3%***	7.9%***	8.7%***	8.6%***	8.2%***
	Avg. for stops without amenity		5.1%***	4.0%**	3.8%**	4.9%***	5.9%*	5.6%***	5.5%***	5.3%***	5.7%***	5.6%***
Transit commuters (%)	Avg. for stops with amenity	279	12.2%***	10.2%**	10.2%*	11.7%***	14.6%***	13.3%***	12.1%***	12.9%***	13.2%***	12.5%***
	Avg. for stops without amenity		8.2%***	6.3%**	7.5%*	8.2%***	9.5%***	8.8%***	9.0%***	8.9%***	9.2%***	9.1%***
Nonwhite population (%)	Avg. for stops with amenity	279	41.5%	41.2%	41.1%	37.3%***	39.8%	36.2%***	38.9%	41.9%	45.9%**	41.4%
	Avg. for stops without amenity		40.4%	36.5%	38.5%	44.5%***	41.0%	42.4%***	41.7%	40.5%	39.8%**	40.7%
Low-income population (%)	Avg. for stops with amenity	279	17.7%***	16.0%***	16.2%***	14.5%	16.9%	14.7%	15.2%	18.8%**	20.7%***	20.1%***
	Avg. for stops without amenity		14.0%***	10.1%***	9.5%***	16.7%	15.5%	15.9%	15.8%	14.5%**	14.4%***	14.2%***
Jobs	Avg. for stops with amenity	279	1,383.7	1,270.7**	1,272.4**	1,491.8**	1,603.2	1,487.6	1,690.6**	1,505.2	1,489.1	1,308.4
	Avg. for stops without amenity		1,096.0	546.0**	653.0**	952.8**	1,183.8	1,133.9	1,022.6**	1,117.0	1,160.0	1,193.3
Average bus trips per week	Avg. for stops with amenity	274	313.4***	244.7	245.7	276.0**	383.0**	290.1*	283.7**	345.6***	341.5***	314.8***
	Avg. for stops without amenity		192.1***	267.8	251.3	216.0**	232.4**	231.6*	229.8**	208.6***	223.8***	223.4***
Average number of bus routes	Avg. for stops with amenity	274	2.4***	1.9	1.9	2.1**	2.5	2.2	2.1	2.4**	2.5**	2.3**
	Avg. for stops without amenity		1.6***	2.5	2.0	1.8**	1.9	1.8	1.9	1.8**	1.8**	1.8**
Average daily ridership[a]	Avg. for stops with amenity	176	36.6**	26.9***	24.4	31.8	45.3	41.0**	30.6	53.7***	62.1***	43.0***
	Avg. for stops without amenity		17.1**	10.6***	42.6	20.4	23.9	21.9**	23.7	15.1***	17.1***	19.7***

Note: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

[a]Loudoun County Transit and Arlington Transit data were unavailable.

Table 5. Binomial logistic regression log likelihoods for seating and shelters

	2018		2022		2022 (excluding ridership)	
Independent variable	Seating	Shelter	Seating	Shelter	Seating	Shelter
Average daily ridership (log)	1.352* (0.160)	1.179 (0.158)	1.196 (0.149)	1.122 (0.156)	—	—
Weekly bus trips (log)	2.055** (0.299)	2.241*** (0.311)	2.405*** (0.304)	2.081** (0.323)	2.158*** (0.207)	1.632** (0.213)
Population (log)	0.912 (0.289)	0.768 (0.305)	2.616** (0.398)	1.752 (0.416)	1.614* (0.274)	1.483 (0.292)
Nonwhite population %	0.037 (2.189)	0.672 (2.162)	1.012 (0.020)	1.049** (0.022)	1.014 (0.013)	1.032** (0.015)
Low-income population % (log)	1.976 (0.501)	1.800 (0.530)	1.036 (0.384)	1.197 (0.424)	0.997 (0.285)	1.150 (0.310)
Jobs (log)	1.372 (0.224)	1.299 (0.228)	1.024 (0.219)	1.330 (0.237)	1.080 (0.153)	1.057 (0.167)
Stop shared by multiple agencies	3.284** (0.527)	2.974** (0.524)	5.753*** (0.496)	4.128*** (0.526)	6.224*** (0.357)	4.989*** (0.378)
City stop	1.380 (0.590)	0.472 (0.602)	0.983 (0.628)	0.700 (0.653)	1.525 (0.441)	1.149 (0.482)
Bus stop adjacent to local road	1.584 (0.577)	2.393 (0.557)	0.941 (0.601)	1.147 (0.627)	0.727 (0.402)	0.716 (0.432)
Bus stop adjacent to homes	1.471 (0.601)	2.409 (0.663)	0.929 (0.592)	1.658 (0.644)	1.185 (0.452)	1.172 (0.489)
Bus stop adjacent to retail	1.100 (0.509)	0.856 (0.531)	3.012** (0.512)	2.234 (0.559)	3.024*** (0.368)	2.732** (0.397)
Constant	0.004 (3.395)	0.003 (3.587)	<0.001*** (3.312)	<0.001*** (3.645)	<0.001*** (2.170)	<0.001*** (2.300)
Observations	142	142	174	174	274	274
Log Likelihood	−66.94	−63.245	−71.039	−61.922	−121.404	−106.833
Akaike Inf. Crit.	157.879	150.49	166.078	147.844	264.808	235.666
McFadden's Pseudo-R^2	0.231	0.191	0.313	0.280	0.245	0.198

Note: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

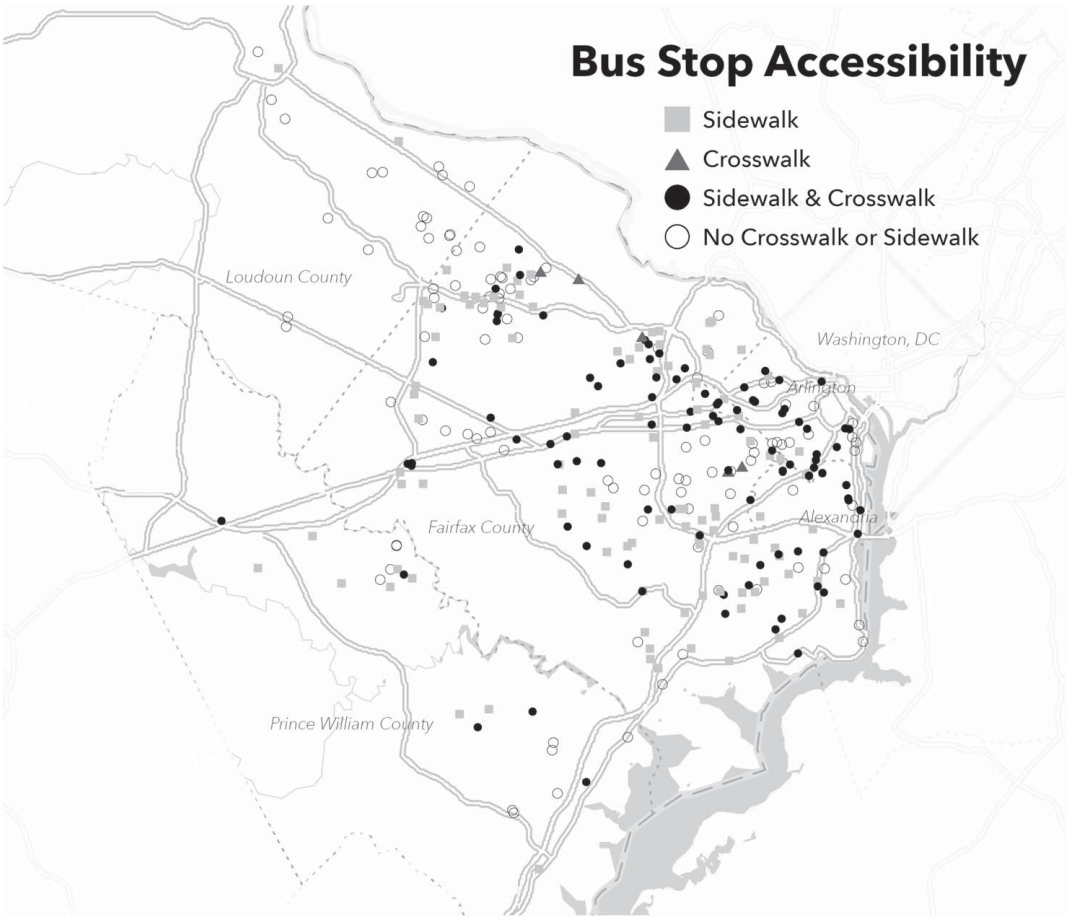

Fig. 7. Distribution of Northern Virginia accessibility amenities (2022 data only). (Sources: County of Prince William, Fairfax County, VA, VGIN, Esri, TomTom, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS, USFWS.)

Some of the key amenities were plotted on maps to observe spatial patterns for bus stop amenities. Accessibility and infrastructure amenities are displayed in Figs. 7 and 8, respectively. As Fig. 7 shows, sidewalks are present throughout the region. However, sidewalks with crosswalks are more heavily concentrated closer to Washington, DC. Bus stop infrastructure shows an even more concentrated pattern. The closer to Washington, DC, the greater the concentration of bus infrastructure amenities. More suburban

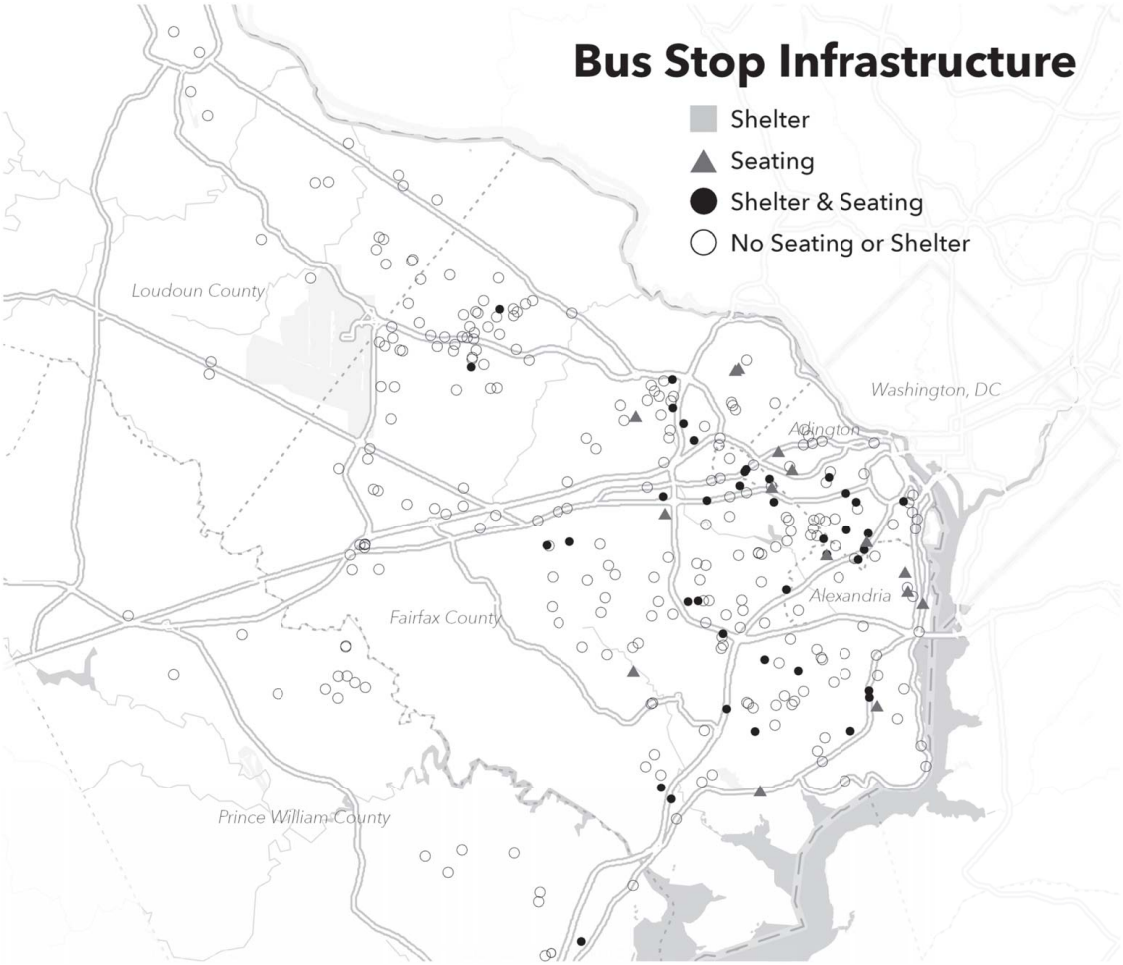

Fig. 8. Distribution of Northern Virginia infrastructure amenities (2022 data only). (Sources: County of Prince William, Fairfax County, VA, VGIN, Esri, TomTom, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS, USFWS.)

areas in the west have fewer infrastructure amenities. These patterns correlate with where transit is most used in the region. As mentioned previously, the jurisdictions closest to Washington, DC, Arlington County, and the City of Alexandria have some of the highest transit use in the region while Loudoun and Fairfax counties to the west have some of the lowest transit use (NVTC 2024).

Interestingly, there is some evidence jurisdictions play a stronger role in amenity type than agency. For example, the proportion of stops with seating varies less between different agencies operating within one jurisdiction than within one agency's stops in different jurisdictions. For example, WMATA operates buses in five jurisdictions and has a coefficient of variation of 0.41. Alexandria, Arlington, and Fairfax County each have at least three bus operators with an average coefficient of variation of 0.25. This also makes intuitive sense when considering jurisdictions, not transit agencies, typically manage bus stop right-of-way.

The final evaluation considered how bus stop amenities changed over time. To do this, bus stops that had two or more observation years were identified. Next, stops were counted if they did not have an amenity for one observation and then did for the subsequent data year. Finally, the stop count was expressed as a percentage of all stops with multiple observations to track the proportion of stops that have added amenities across the sample. Because data were unavailable for all stops and all years, these calculations are likely an underestimation of the change in the region's bus stop amenities. Fig. 9 shows the result.

Accessibility-related amenities were the largest category of growth. However, this includes hostile architecture, which hurts accessibility. Increases in hostile architecture are likely related to the almost 10% increase in seating over the 8-year period. As Fig. 6 shows, hostile architecture was always observed at bus stops with seating. In addition, although information has generally been lacking at Northern Virginia bus stops, static schedule information was added to over 5% of stops over the study period. Conversely, real-time information saw the smallest change, suggesting it was not a regional priority. Finally, policy context in section "Policy Context" suggested there were many challenges around improving resource-intensive amenities such as shelters. Over the 8-year study period, $<3.5\%$ of bus stops gained shelter. Change is evidently slow; however, more work needs to be done to identify causal mechanisms. Changes between 2014–2018 and 2018–2022, in each of the 4-year periods, were comparable, suggesting no real difference in the rate of bus stop amenity additions.

A binomial logistic regression was also developed with the dependent variable being the likelihood of a bus shelter or bench being added to a stop. In this model, the independent variables include the same categorical variables as those in Table 5 as well as changes to the numerical values (e.g., change in population). However, the small sample size of changed variables, missing years of data, and data noise made it difficult to establish factors that were associated with changes in bus stop amenity infrastructure. Shared stop status was the only statistically significant variable.

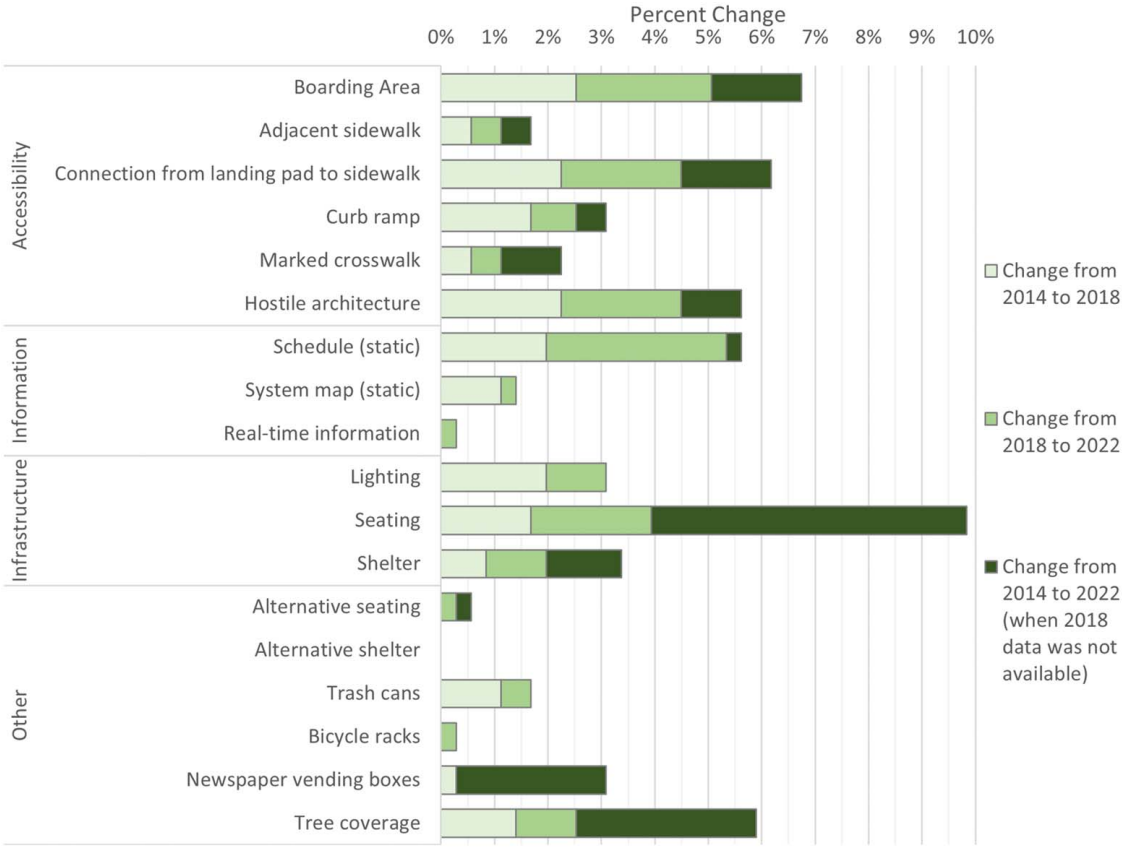

Fig. 9. Cumulative changes in Northern Virginia bus stop amenities over time ($n = 356$).

Discussion and Conclusions

This study sets out to further the field's understanding of bus stop amenities. Specifically, building on recent work, bus stops were evaluated over a new geography in Northern Virginia, a more complex transit operating environment with seven bus operators, and with multiple years of amenity data. The study demonstrated that, unsurprisingly, a different geography has differences in bus stop amenity availability and distribution. Northern Virginia has many fewer bus stops with seats or shelter compared to San Francisco. Both Northern Virginia and San Francisco have a smaller proportion of bus stops with shelters than the cities evaluated by Kim et al. (2024). This may be because Kim et al. purposely chose cities with higher-than-average bus commutes, meaning additional bus infrastructure investment may be easier to justify. Some of the other differences between San Francisco and Northern Virginia highlight San Francisco's transit first policy may be having an impact on bus stop quality. For example, in San Francisco, over 20% of stops have real-time information and 30% have a route map. Only a small fraction of Northern Virginia stops also offer this information. Finally, although amenities in Northern Virginia were generally less available than in San Francisco, there did not appear to be any inequity concerns around race like Moran (2022) observed. Kim et al. (2024) also found mixed results comparing bus stop amenities and the distribution of racial minorities.

An important characteristic of Northern Virginia transit is its complex transit environment. With many jurisdictions, transit agencies, and overlapping service areas, it can be confusing for transit professionals to understand the network, let alone the general public. While local transit policies do not appear to directly address these complicated operating issues, in practice, bus stop amenity priorities appear to be decided based on shared relationships. Shared bus stops were consistently found to be a predictor for bus shelters and benches across years and modeling strategies. Looking more in-depth at the data revealed that 97% of shared stops were used by WMATA in both 2022 and 2018 (ART and Fairfax Connector were next highest at about 40% each in both years). As section "Agency Policies" demonstrated, WMATA has the most extensive bus stop amenity guidance. Consequently, the significance of shared stops may indicate that, when stops are shared, bus stop amenity policies yield to the highest, most detailed guidance, which is typically WMATA's in Northern Virginia. When stops are not shared, there is some evidence that jurisdictions may play more of a role in the distribution of amenities than agencies. Overall, it might be useful if transit agencies and jurisdictions were more transparent with how their bus stop policies consider situations where bus stops are shared by multiple bus service providers or how amenities are decided when transit agency and jurisdiction policies may conflict. This additional policy guidance could reduce ambiguity for transit professionals, reduce potential regional conflict, and help develop a more consistent rider experience. Alternatively, bus agencies in a shared region should consider developing bus amenity guidance as a region rather than by individual agency.

Finally, this paper demonstrated how bus amenities changed over time. While the calculations are likely an underestimation, the sample demonstrated almost 10% of bus stops gained a bench over the 8-year study period with almost all amenities increasing over time. However, there is a region-wide gap in real-time information at stops and the current increases in real-time information amenities suggests this will not change any time soon.

Overall, this work has built on previous bus amenity research in several ways. However, there are some limitations to the study. While Moran (2022) and Kim et al. (2024) used the full population

of stops in their analyses, this paper used a sample. The sample was justified given the scope of bus stops in Northern Virginia, but it does limit the types of analyses that could be performed. In addition, while Google Street View data enabled multiple years of data collection with relative ease, the gaps in the imagery make a comprehensive analysis more difficult. Further work could explore why these data gaps exist and the implications of these gaps in research that use Google Street View data. Studies of bus stop amenities could also benefit from new geographies, especially outside of the United States, and increases in sample size and years of analysis to observe how trends may change over time. Finally, given some of the data gaps, future work could try leveraging clustering or other missing data methods to help predict some of the missing data values.

Data Availability Statement

Some or all data, models, or codes that support the findings of this study are available from the corresponding author upon reasonable request.

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