

Long-Term Maintenance Needs and Costs of Green-Colored Pavement Markings and Flexible Post Delineators

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16. Abstract: In recent years, Virginia localities have expressed interest in installing two specific bicycle infrastructure elements: green-colored pavement markings (GCPMs) on bicycle facilities and flexible post delineators (referred to as flexposts) along separated bike lanes to improve conspicuity and safety. In some cases, these elements were pursued as part of quick-build safety improvements. Flexposts, in particular, were often incorporated into quick-build interim treatments that could remain in place for many years. The Virginia Department of Transportation (VDOT) lacked information on the long-term maintenance costs for these infrastructure elements. Using examples from Virginia, this study investigated the long-term maintenance costs and needs of both GCPMs on bicycle facilities and flexposts used for separated bicycle lanes or pedestrian facilities. The study included a screening survey to identify locations of either infrastructure element on both VDOT-maintained and non-VDOT-maintained roads, in-depth interviews regarding the materials used, maintenance costs and frequency, and labor and equipment needs. Case studies present specific cost information for the infrastructure elements of interest. Of the 57 agencies that responded to the screening survey, 16 reported having GCPMs, 10 reported having flexposts for bicycle applications, and 12 reported having flexposts for pedestrian applications. In-depth interviews regarding maintenance were conducted with 11 agencies with GCPMs and 11 agencies with flexposts. Overall, interviewees indicated that the presence of GCPMs did not affect sweeping or snowplowing operations and that more frequent replacement was required for GCPMs in areas with high vehicular traffic, within the wheel path for turning movements, exposed to higher rates of heavy-vehicle traffic, and extended through intersections. Actual or anticipated GCPM replacement timelines were 7 years for thermoplastic, 5 to 7 years for methyl methacrylate, and 2 years for traffic paint. For bicycle and pedestrian facilities with flexposts, sweeping and snow removal were not major issues due to the ability to use equipment the agency already owned and the relative infrequency of snowfall within Virginia. Flexpost replacement frequency varied but was generally less than twice per year. Four case studies were examined to provide additional support to the survey findings. These case studies include a bicycle lane in Danville with preformed thermoplastic GCPMs at the beginning of each block, a flexpost-separated bicycle and pedestrian lane in Front Royal, a flexpost-separated pedestrian lane in Halifax County, and a flexpost-separated bicycle lane with preformed thermoplastic GCPMs in Arlington County. Overall, localities did not report incurring annual maintenance costs from GCPMs. For flexpost-separated lanes, the estimated cost of maintenance activities in the first year ranged from approximately 3% to 27% of the installation costs. Transportation agencies can use this information in planning for maintenance needs. This report recommends that VDOT include attributes indicating the presence of flexposts and GCPMs in its active transportation facility inventory, consider maintenance implications when incorporating GCPMs and flexposts into agency procedures and guidance materials, and explore partnerships to maintain flexpost-related infrastructure. The benefits of taking these actions are roughly \$600,000 during a 5-year period.			
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FINAL REPORT

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VTRC 27-R07

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ABSTRACT

In recent years, Virginia localities have expressed interest in installing two specific bicycle infrastructure elements: green-colored pavement markings (GCPMs) on bicycle facilities and flexible post delineators (referred to as flexposts) along separated bike lanes to improve conspicuity and safety. In some cases, these elements were pursued as part of quick-build safety improvements. Flexposts, in particular, were often incorporated into quick-build interim treatments that could remain in place for many years. The Virginia Department of Transportation (VDOT) lacked information on the long-term maintenance costs for these infrastructure elements. Using examples from Virginia, this study investigated the long-term maintenance costs and needs of both GCPMs on bicycle facilities and flexposts used for separated bicycle lanes or pedestrian facilities. The study included a screening survey to identify locations of either infrastructure element on both VDOT-maintained and non-VDOT-maintained roads, in-depth interviews regarding the materials used, maintenance costs and frequency, and labor and equipment needs. Case studies present specific cost information for the infrastructure elements of interest.

Of the 57 agencies that responded to the screening survey, 16 reported having GCPMs, 10 reported having flexposts for bicycle applications, and 12 reported having flexposts for pedestrian applications. In-depth interviews regarding maintenance were conducted with 11 agencies with GCPMs and 11 agencies with flexposts. Overall, interviewees indicated that the presence of GCPMs did not affect sweeping or snowplowing operations and that more frequent replacement was required for GCPMs in areas with high vehicular traffic, within the wheel path for turning movements, exposed to higher rates of heavy-vehicle traffic, and extended through intersections. Actual or anticipated GCPM replacement timelines were 7 years for thermoplastic, 5 to 7 years for methyl methacrylate, and 2 years for traffic paint. For bicycle and pedestrian facilities with flexposts, sweeping and snow removal were not major issues due to the ability to use equipment the agency already owned and the relative infrequency of snowfall within Virginia. Flexpost replacement frequency varied but was generally less than twice per year.

Four case studies were examined to provide additional support to the survey findings. These case studies include a bicycle lane in Danville with preformed thermoplastic GCPMs at the beginning of each block, a flexpost-separated bicycle and pedestrian lane in Front Royal, a flexpost-separated pedestrian lane in Halifax County, and a flexpost-separated bicycle lane with preformed thermoplastic GCPMs in Arlington County. Overall, localities did not report incurring annual maintenance costs from GCPMs. For flexpost-separated lanes, the estimated cost of maintenance activities in the first year ranged from approximately 3% to 27% of the installation costs. Transportation agencies can use this information in planning for maintenance needs.

This report recommends that VDOT include attributes indicating the presence of flexposts and GCPMs in its active transportation facility inventory, consider maintenance implications when incorporating GCPMs and flexposts into agency procedures and guidance materials, and explore partnerships to maintain flexpost-related infrastructure. The benefits of taking these actions are roughly \$600,000 during a 5-year period.

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INTRODUCTION

For two decades, the Virginia Department of Transportation (VDOT) has operated under the 2004 Commonwealth Transportation Board policy that the agency “will initiate all highway construction projects with the presumption that the projects shall accommodate bicycling and walking” (VDOT, 2024). Often, accommodating bicycling requires bicycle facilities, which take so many different forms that multiple entities have produced design guides (e.g., Federal Highway Administration [FHWA], 2015, 2024a; American Association of State Highway and Transportation Officials [AASHTO], 2024; National Association of City Transportation Officials [NACTO], 2016, 2020, 2025). In recent years, localities in Virginia expressed increased interest in installing two specific elements of bicycle infrastructure: green-colored pavement markings (GCPMs) on bicycle facilities (e.g., at conflict points such as intersections) and flexible post delineators (also called tubular markers and referred to hereafter as flexposts) along separated bike lanes and pedestrian facilities, such as curb extensions and pedestrian lanes, to improve visibility and safety.

In some cases, these elements were pursued as part of quick-build programs, which allow public agencies to implement transportation improvements that the public can use for years without the long planning process and time-consuming preconstruction activities of larger capital projects (e.g., acquisition of right of way, utility impacts, or design of stormwater management systems). These projects are typically installed within a year from the start of the planning process and are anticipated to be tweaked after installation (People for Bikes, 2016). As such, quick-build projects are constructed with low-cost materials that are relatively easy to obtain and alter, such as flexposts and roadway markings, rather than materials typically used for capital projects, such as concrete (Alta Planning + Design and California Bicycle Coalition, 2020). Quick-build projects are a relatively new and evolving tool for public agencies, and although they can be a crucial tool in allowing agencies to implement transportation improvements on

demand, questions arise regarding the long-term maintenance costs and needs of these improvements.

Whether for quick builds or traditional projects, localities that independently maintain their roadways (cities, larger towns, and two counties) can make installation and maintenance decisions regarding these elements. Those with VDOT-maintained roadways (smaller towns and most counties) must defer to VDOT, which did not have a policy on installing these features (a policy remained in development as of June 2026). Concerns included a lack of information on long-term maintenance costs for both GCPMs and flexposts. Prior to January 2026, when VDOT adopted the *Virginia Manual on Uniform Traffic Control Devices* (MUTCD) version 11.0 (VDOT, 2026a), formal provisions for GCPMs were not provided in the federal MUTCD or the Virginia Supplement. In the spring 2024 research prioritization process, VDOT's Transportation Planning Research Advisory Committee ranked a study of the maintenance needs and costs for these roadway elements in Virginia third of nine topics.

This study assessed the use of GCPMs and flexposts across Virginia. For GCPMs, it included obtaining examples of lifecycle costs, labor time and costs, factors affecting installation such as weather conditions, and the lifespan of different marking materials. For flexposts, the study obtained examples of maintenance costs, frequency, labor, and required equipment.

Green-Colored Pavement Markings

GCPMs are often used to denote the roadway space where bicycles operate. The use of green coloring enhances the conspicuity of this roadway space and is intended to prevent motorists from encroaching on bicycle facilities. In addition, GCPMs may deter drivers from parking in bike lanes and help decrease motorist obstructions in bicycle facilities (New York City Department of Transportation, 2011). A wide variety of marking types using green-colored materials has been used to designate bicycle facilities (Figure 1).

As the standard for traffic control devices in the United States, the 11th edition of the FHWA (2023a) MUTCD was the first to include guidance on GCPMs. Before January 2026, VDOT followed the 10th edition and a Virginia supplement, neither of which contained provisions for GCPMs. However, Virginia was included in an interim approval for green-colored pavement that required each installation to be tracked and potentially removed if the interim approval were rescinded (FHWA, 2013).

Although the 11th edition of the FHWA MUTCD did not require the use of GCPMs for bicycle lanes, the VDOT Traffic Operations Division (TOD) identified GCPMs as an aspect of the manual with potential fiscal effects because of the installation, maintenance, and long-term lifecycle costs. Per Section 3H.06, GCPMs are intended to “enhance the conspicuity of locations where bicyclists are expected to operate, and areas where bicyclists and other traffic might have potentially conflicting, weaving, or crossing movements” (FHWA, 2023a). Lists of acceptable and unacceptable uses of GCPMs were also included (FHWA, 2023a).



Figure 1. Green-Colored Pavement Markings in Virginia Take a Variety of Forms: (a) a separated bike lane at a bus boarding island in Arlington; (b) bicycle lane extension markings through an intersection in Blacksburg; (c) green included in the bikeway portion of a modular bus boarding island in Fairfax County; (d) a bicycle turn box in Charlottesville

Acceptable applications of GCPMs (some shown in Figure 2) are:

- Bicycle lanes.
- Extensions of bicycle lanes through intersections.
- Extensions of bicycle lanes through areas where motor vehicles enter a mandatory turn lane in which motor vehicles must weave across bicycle lanes.
- Two-stage bicycle turn boxes.
- Bicycle boxes.
- The use as a background for bicycle detector symbols.

Figure 9E-7. Examples of Lane Markings for Separated Bicycle Lanes (Sheet 2 of 2)

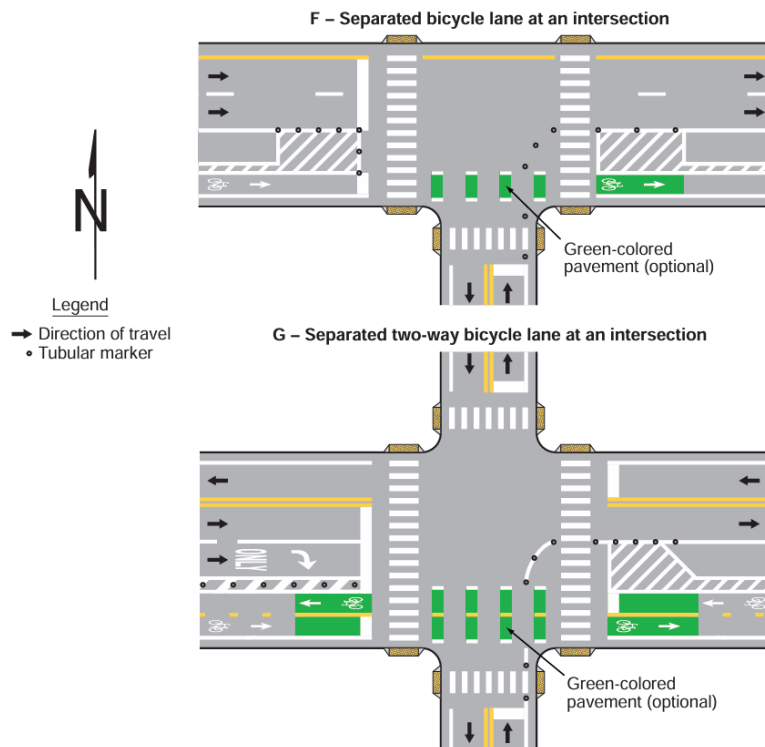


Figure 2. Examples of Acceptable Uses of Green-Colored Pavement Markings per the *Virginia Manual on Uniform Traffic Control Devices, 11th Edition* (VDOT, 2026a: Figure 9E-7)

Unacceptable applications of GCPMs are:

- GCPMs incorporated into electric-vehicle parking stations or parking stalls.
- GCPMs incorporated into crosswalks.
- GCPMs as a background for shared-lane markings, although a black background is permitted.
- GCPMs instead of the required markings for bicycle facilities.

The 11th edition of the MUTCD was the first edition to include GCPMs as an option for bicycle lanes, but standards and guidance have existed for several years. Virginia’s version of the newest MUTCD matches the federal MUTCD’s provisions for GCPMs except in two-stage turn boxes. The federal version states that GCPMs “may” be used in two-stage turn boxes, whereas the Virginia supplement states that GCPMs “should” be used in two-stage turn boxes (FHWA, 2023a; VDOT, 2026a). Still, the Virginia MUTCD does not explicitly require GCPMs but indicates acceptable uses based on operational or safety benefits.

In the same year as FHWA’s (2013) interim approval, NACTO (2011) published the first edition of its *Urban Bikeway Design Guide* (UBDG), which recommended three requirements for GCPMs:

1. The color green shall be used to minimize confusion with other standard traffic control markings.

2. Color shall be applied to the road surface to delineate space, increase visibility, and emphasize proper vehicle priority.
3. Normal white bike lane lines shall be provided along the edges of the colored lane to provide consistency with other facilities and to enhance night-time visibility.

Different GCPM materials have varying maintenance costs. The UBDG outlined the associated benefits and drawbacks of different lane-marking materials, alongside required and recommended features to include in the construction of green-colored bikeways. The UBDG also recommended the use of skid-resistant and retroreflective surfaces to enhance safety and visibility, the inclusion of signs to supplement pavement markings for clearer guidance, and a consistent configuration of color application throughout bikeway corridors to improve continuity and reduce confusion for both cyclists and motorists (NACTO, 2011). The *Colored Pavement Material Guide* covered a variety of pavement-coloring methods for bicycle facilities by summarizing each method's benefits and drawbacks for both spot and corridor treatments (NACTO, 2016).

Some localities in Virginia that independently maintain their roads have used these guidelines to implement GCPMs that denote bicycle facilities at conflict points and intersections. Figure 3 shows an example of a solid green bicycle lane at a skewed intersection in Charlottesville.



Figure 3. Solid Green-Colored Pavement Markings in a Bicycle Lane Along Monticello Avenue at Tufton Avenue in Charlottesville, Virginia

Flexible Post Delineators

Bicycle and Pedestrian Applications for Flexposts

Flexposts are used in several different roadway applications to delineate lanes and channelize traffic. This study examined flexposts in the context of separated bicycle lanes (primarily) and pedestrian facilities, and a concurrent technical assistance effort examined their durability in quick-build projects for traffic calming and safety improvements (Cottrell, 2026).

Also known as cycle tracks or protected bike lanes, separated bicycle lanes have some form of vertical physical separation from motor-vehicle traffic, in contrast to standard or buffered bike lanes that utilize striping alone to demarcate the bicycle lane. The 11th edition of the MUTCD includes standards and guidance for “tubular markers” and other channelizing devices (FHWA, 2023a). Separated bicycle lanes have been shown to improve safety (FHWA, 2024a) and are defined in guidance and standards from NACTO, FHWA, and VDOT. A study evaluating the conversion of a traditional bicycle lane to a separated bicycle lane with flexposts found a resulting crash modification factor of 0.50, suggesting that flexposts used in this way may contribute to decreasing bicycle crashes by up to 50 percent (FHWA, 2023b).

Flexposts have a relatively low cost, small footprint, and easy and quick installation. Although they provide minimal crash protection, flexposts are highly visible and can guide driving behavior (Figure 4; FHWA, 2024b). Flexposts have also been employed in pedestrian facility applications such as curb extensions and interim pedestrian lane facilities, where they offer a low-cost solution for enhancing pedestrian visibility and safety in interim facilities or constrained environments (Figure 5).

FORM OF SEPARATION	KEY THINGS TO KNOW
Delineator Posts  Source: Virginia Department of Transportation (VDOT)	• Common separators due to low cost, visibility, ease of installation • Modify driver behavior • Do not provide crash protection • Less durable than other separators • Consider converting these types of buffers to a more permanent style when design and budgets allow • May need to change barrier type as speed increases to increase bicyclist comfort

Figure 4. Flexposts Are One Form of Bicycle Lane Separation (FHWA, 2024b). Reprinted with permission.



Figure 5. Flexposts Used for a Pedestrian Lane Along Sinai Road in Halifax County

Because of their low up-front cost compared with other forms of bicycle lane separators, flexposts are a popular choice for localities that maintain their roads and are seeking quick and cost-effective implementation of separated bicycle lanes. Furthermore, FHWA recommends installing flexposts as part of pilot programs to test the feasibility of any bicycle lane separator at a given location before committing to a more expensive upgrade, such as installing barriers or raised curbs (FHWA, 2024a). AASHTO (2024: section 7.4.2.4) lists several benefits, including removability to facilitate maintenance, low initial cost, a small footprint, and frangibility (i.e., the tendency to give way easily on impact, making them suitable on roadways regardless of posted speeds). Although flexposts can be cost effective and quick to implement for interim or pilot treatments, the long-term use of flexposts raises concerns about maintenance and lifecycle costs that differ in nature from those of hard infrastructure, such as raised curbs or concrete separators. FHWA (2024a) specifically cites concerns about flexposts' durability and the potential for frequent maintenance and replacement. AASHTO (2024) cites these challenges and adds that flexposts are often considered unattractive and that damaged posts can create a crash hazard for bicyclists.

Along with monetary costs, a particular concern for VDOT was the staff time required to monitor and replace flexposts, because increasing staffing levels can be difficult or, in some cases, impossible. This study of maintenance costs for flexposts provides important data for localities and VDOT to consider regarding the installation of any kind of physical divider.

Maintenance of Flexposts Used for Bicycle and Pedestrian Infrastructure

In October 2024, FHWA released *A Guide for Maintaining Active Transportation Infrastructure for Enhanced Safety*, which expanded the focus of the previous 2013 guide to address the maintenance of bicycle facilities (FHWA, 2024a). The guide provided information on the maintenance of quick-build facilities, incorporating maintenance considerations at the beginning of the design process, and emphasized the importance of considering the capacity to

maintain when selecting facility materials. The variable maintenance costs and frequency associated with different weather conditions and different facility designs make it difficult for transportation agencies to accurately estimate the total lifecycle cost of flexpost installations. Developing more precise cost-estimation methods can help agencies allocate resources and plan for long-term maintenance costs for bicycle and pedestrian infrastructure (FHWA, 2024a).

PURPOSE AND SCOPE

This study aimed to determine the costs, frequency, and necessary labor and equipment for maintaining two elements of bicycle and pedestrian infrastructure within Virginia: GCPMs and flexposts. The scope included various contexts (i.e., large metropolitan, small metropolitan, and rural areas). Applications of flexposts for channelizing motor vehicle traffic were outside the scope of this study but see Cottrell (2026). This study reviewed the effect of facility design on maintenance needs and costs, but crash analysis was outside the scope.

METHODS

Overview

This study included a literature review, a screening survey of the nine VDOT districts and Virginia localities that maintain their roads to identify locations of GCPMs and flexposts used in bicycle or pedestrian infrastructure, and in-depth interviews regarding the materials used and their applications, along with maintenance costs, frequency, labor, and equipment. Five tasks were performed, including:

1. Documenting maintenance considerations for GCPMs and flexposts.
2. Identifying localities and VDOT districts with GCPMs and flexposts through a screening survey.
3. Interviewing survey respondents to discuss materials and maintenance considerations and identifying potential case studies.
4. Collecting data for case studies.
5. Synthesizing the case study data.

Documentation of Maintenance Considerations for GCPMs and Flexposts

Literature on maintenance practices and material considerations for GCPMs and flexposts in the context of bicycle and pedestrian infrastructure was sought via the Transportation Research International Documentation database. Primary search terms included “flexible post delineator,” “flexpost,” “bike lane maintenance,” “bicycle lane maintenance,” “separated bike lane,” “green-colored pavement marking,” “green bike lane,” and “green paint.” Search results were filtered to include documents published since 2015, and abstracts were reviewed for relevance to the study.

Survey to Identify Localities and VDOT Districts with GCPMs and Flexposts

VDOT maintains the Statewide Active Transportation Map Hub (VDOT, n.d.), which includes on-street bike facilities and shared-use paths under the jurisdiction of VDOT and Virginia localities. It classifies each facility for display purposes as either a designated bike lane, a shared lane, or a shared-use path. In the first facility type, some bike lanes have the tag “Bike Lane - Separated” within a Detailed Facility Type attribute. Although this type of facility indicates likely locations of flexpost-separated bike lanes, the type of separation (e.g., flexposts) is not displayed.

The Map Hub does not display information about GCPMs or flexposts used for pedestrian facilities. To obtain this information and confirm the locations of flexpost-separated bike lanes, a brief online screening survey was designed and disseminated to identify locations of GCPMs or flexposts used for bicycle and pedestrian facilities in Virginia. A link to the survey was sent via email to public works directors, town managers, or engineers at 75 Virginia localities that maintain their roadways, and the bike and pedestrian coordinators for all nine VDOT districts. The survey included an overview of the study and descriptions and examples of the infrastructure of interest. Respondents were asked whether the infrastructure existed on roadways within their jurisdiction, the number of instances, and whether methods of tracking the location of these infrastructure elements were available. Branching and skip logic ensured that respondents were presented only with questions relevant to the infrastructure elements they reported having in their jurisdiction. The survey requested contact information for someone with access to detailed infrastructure maintenance information. The Appendix includes the survey overview and the survey questions within a flowchart of the survey logic.

Duplicate responses and incomplete responses (less than 35% of questions answered) were not included in the results. Survey responses were revised if a “yes” response was entered, but the respondent entered a note indicating the response was in error.

Arlington County was known to have numerous examples of GCPMs and flexposts. Although a survey response was not received, its staff participated in an in-depth interview that provided answers to the questions included in the survey, and the resulting responses were included with other survey responses. The City of Richmond submitted an incomplete survey response, but its staff participated in an in-depth interview, and the survey responses were updated to reflect the information provided in the interview about known infrastructure. In addition, two VDOT districts reported infrastructure elements within cities that maintained their roadways. As such, the survey responses from the VDOT districts were revised to reflect the infrastructure on roadways that they maintain. In addition, Fairfax County responded to the screening survey but does not maintain its roadways and was not included in the summary of responses.

Interviews of Survey Respondents

From the screening survey, 19 agencies were identified as having at least one of the infrastructure elements of interest on roadways within their jurisdiction. Requests for in-depth interviews were sent to these 19 agencies. Interviews were conducted with 13 localities and one

VDOT district that responded that they were willing to participate in an in-depth interview on GCPMs and flexposts, as well as Fairfax County—which, as noted previously, does not maintain independently its roadways and is not included in this summary of responses. Figure 6 shows the locations of the agencies that were interviewed, and Table 1 lists the interview topics and interviewees. Written interview summaries were provided to each interviewee and are available from the authors.

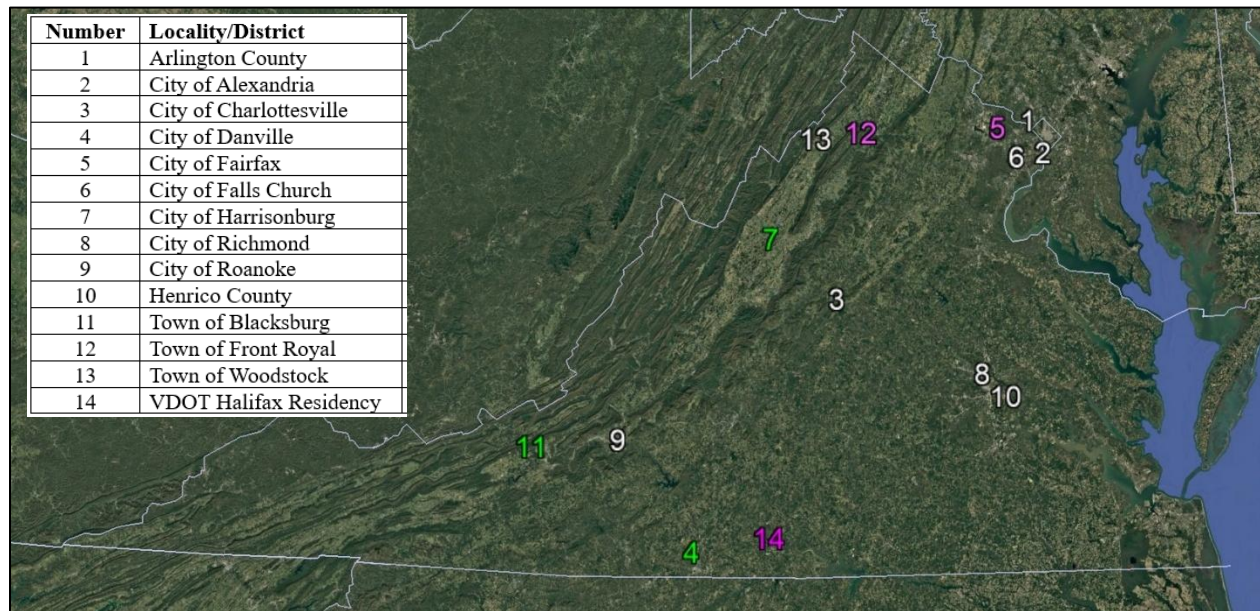


Figure 6. Map of Virginia Showing the Locations of Agencies that Participated in Interviews Regarding Green-Colored Pavement Markings (Green Numbers), Flexposts (Purple Numbers), or Both (White Numbers). Image capture: December 2020, © 2026 Google.

Table 1. Jurisdictions Interviewed, Interview Topics, and Interviewees

#	Locality/District	Topics	Interviewees	Titles
1	Arlington County	GCPMs & Flexposts	Dan Nabors, David Patton	Bureau Chief, Bicycle and Pedestrian Planner
2	City of Alexandria	GCPMs & Flexposts	Bob Garbacz	Traffic Management Division Chief
3	City of Charlottesville	GCPMs & Flexposts	Jonathan Dean, Mike Harlow, Shawn Morris, Tommy Safranek, Caleb Smith	Public Service Manager, Traffic Supervisor, Operations Supervisor, Bicycle and Pedestrian Coordinator, Traffic Engineer
4	City of Danville	GCPMs	Brian Dunevant	Assistant Director of Public Works/City Engineer
5	City of Fairfax	Flexposts	Lucian Stoica	Traffic Signal Superintendent
6	City of Falls Church	GCPMs & Flexposts	Patrick Legler	Senior Crew Leader
7	City of Harrisonburg	GCPMs	Tom Hartman	Director of Public Works
8	City of Richmond	GCPMs & Flexposts	Kenny Horak, Andy Boenau, Michael Sawyer	Paving Engineer, Engineering Program Manager, City Transportation Engineer
9	City of Roanoke	GCPMs & Flexposts	Mason Handke, Rob Issem	Traffic Engineering Technician, Complete Streets and Vision Zero Coordinator
10	Henrico County	GCPMs & Flexposts	Mohammed Rafay	Traffic Division's Bike Lane and Plan Review Engineer

#	Locality/District	Topics	Interviewees	Titles
11	Town of Blacksburg	GCPMs	John Boyer, Kali Casper, Danny Smith	Director of Public Works, Senior Planner, Traffic Engineering Technician
12	Town of Front Royal	Flexposts	Steve Scheulen	Manager of Infrastructure
13	Town of Woodstock	GCPMs & Flexposts	Jill Jefferson, Jamie Givens	Deputy Director of Public Works, Streets Crew Leader
14	VDOT Halifax Residency	Flexposts	Jay Craddock	Residency Administrator

GCPMs = green-colored pavement markings.

The follow-up interviews included in-depth questions regarding the materials used and their applications, along with maintenance operations, costs, frequency, and equipment. The interview questions were sent to interviewees in advance, divided into sections on GCPMs and flexposts, each with subsections on installation, monitoring, maintenance, and replacement activities. Interviewees were reminded that the questions on flexposts pertained specifically to flexposts used for bicycle and pedestrian infrastructure, but the questions did not distinguish between the two applications. Interviews concluded with a discussion of potential case study sites in each locality.

For GCPMs, installation questions addressed materials used, the application process, temperature considerations, surface preparation, the curing process, labor, and pavement type and condition. Monitoring questions covered the method and frequency of monitoring, the determination of the need for intervention, skid resistance, and pavement durability surrounding and beneath GCPMs. Maintenance operations questions addressed sweeping and winter maintenance (plowing and de-icing), including any operational differences from bike lanes without GCPMs and any damage resulting from maintenance activities. Questions regarding replacement addressed the frequency, removal, labor, cost, equipment, areas of increased need for replacement, and coordination with other projects, such as utility work (Figure 7).



Figure 7. Example of Utility Work Having Removed a Section of Dashed Green-Colored Pavement Markings Without Replacing Them: (left) before utility work; (right) after utility work.

For flexposts, installation questions included the type of flexposts, consistency throughout a jurisdiction, the mechanical connection to the roadway, and the installation process. Monitoring questions covered the method and frequency of monitoring, labor requirements, how the need for replacement was determined, and factors potentially leading to an increased frequency of replacement. Maintenance operations questions addressed both sweeping

(frequency, specialized equipment, flexpost removal versus design to accommodate sweeping equipment, and labor) and winter maintenance (flexpost removal, labor, specialized equipment, salt and brining effects, and snowplow damage to flexposts). Replacement questions covered frequency, labor, and maintenance of traffic.

Interviews were conducted with appropriate staff members (titles varied by locality, but examples included Director of Public Works, Bike and Pedestrian Coordinator, Crew Leader, and Traffic Engineer) who were knowledgeable on the installation, design, and maintenance of the infrastructure of interest, although not all interviewees were familiar with all topics covered in the interviews. Of the 14 interviews conducted, eight agency representatives responded to questions on both GCPMs and flexposts for bicycle and pedestrian infrastructure. Three agency representatives responded only to questions on GCPMs, and three responded only to questions on flexposts. Overall, 11 agencies were interviewed on the use of GCPMs, and 11 agencies were interviewed on the use of flexposts for bicycle and pedestrian infrastructure.

Data Collection for Case Studies

Based on interview responses, 10 candidate case study agencies were identified to reflect a variety of facility types and geographic diversity: Arlington, Alexandria, Blacksburg, Charlottesville, Danville, Halifax County (VDOT Halifax Residency), Henrico County, Front Royal, Richmond, and Roanoke. Site visits were conducted in the summer and fall of 2025 to evaluate the current condition of the infrastructure in eight candidate case study localities. A 2025 site visit was not conducted in Front Royal because the flexposts on its bicycle and pedestrian lanes had been removed for the late fall and winter seasons, but it was retained as a case study. A site visit was not conducted in Henrico County because this study's technical review panel suggested removing its two-way separated bike lane from the case study candidate list due to the facility's atypical design. Before this study's completion, the county had removed the flexposts.

To document the current condition of the infrastructure at each site, video recordings were made using an action camera mounted on either a vehicle or a bicycle helmet (Figure 8). For sites with GCPMs, observations were made regarding roadway conditions, the condition of markings and marking materials, the presence of friction materials, and the presence of multiple layers of marking. Staff from VDOT's Materials Division evaluated the GCPM color using a colorimeter and surface friction using a British Pendulum Tester (Figure 9). Materials testing was not part of this study's scope, so this report does not include testing methods and results. However, the testing methods and results contributed to the Materials Division's ongoing field evaluations. For sites with flexposts, researchers observed and documented the type of flexpost and base, the connection to the roadway, the general condition of the roadway and flexposts, spacing between flexposts, and the number of missing posts and bases.



Figure 8. Collection of Video Recordings of Infrastructure Using an Action Camera: (left) mounted on a VDOT vehicle; (right) mounted on a bicycle helmet



Figure 9. Collection of Green-Colored Pavement Marking Color Readings Using a Colorimeter (left) and Skid Resistance Data Using the British Pendulum Tester (right)

Following the site visits to candidate case study locations, localities were contacted to request detailed information regarding site installation and maintenance. Requested information included but was not limited to installation costs, methods, and equipment; maintenance practices, costs, and equipment; and public feedback.

Detailed installation and maintenance information was collected from four localities with case study sites: Front Royal, Danville, Halifax County, and Arlington County. These locations were selected based on the following:

- Availability of installation information (costs and year) and maintenance information (costs and frequency).
- Combination of infrastructure present (GCPMs, flexposts, or both).
- Land use context (e.g., urban, suburban, or rural).

- Traffic volume of roadway.
- Need for specialized maintenance equipment.

Action camera video recordings were reviewed to evaluate the condition of GCPMs based on the estimated areal percentage of damaged and missing markings. GCPMs were classified as “fair” if more than 65% of the marking was present and in good condition and “good” if more than 90% of the marking was present and in good condition. GCPMs were classified as “poor” if less than 65% of the marking was present and in good condition.

Locality-provided cost information was adjusted to 2025 dollars using National Highway Construction Cost Index (NHCCI) values because 2026 NHCCI values had not yet been published (FHWA, 2024c). Yearly cost estimates were calculated for each case study location, and the provided cost information was adjusted using NHCCI values, when available. Cost projections for 2026 and later were based on a 5% annual increase in costs. For Arlington County, preformed thermoplastic GCPMs were assumed to need replacement every 7 years based on input from interviewees. For Danville, preformed thermoplastic GCPMs were assumed to need replacement every 8 years because existing markings had already been installed for more than 7 years.

For example, for the flexpost-separated bicycle and pedestrian lane in Front Royal, a contractor had installed the recessed delineator base in April 2024 at a total cost of \$14,342.31. NHCCI was 3.161 in the second quarter of 2024 and 3.163 in the third quarter of 2025. The ratio of these values (3.163/3.161) was multiplied by the 2024 cost of \$14,342.31 to obtain \$14,351.38 in 2025 dollars.

RESULTS AND DISCUSSION

Documentation of Maintenance Considerations for GCPMs and Flexposts

The following sections summarize the literature in terms of (1) maintenance practices for separated bike lanes with flexposts and (2) considerations for GCPM materials.

Maintenance Practices for Separated Bike Lanes with Flexposts

Because a Minnesota DOT 2021 study regarding the planning and operation of separated bike lanes included a comprehensive literature review of documents related to their maintenance (Hourdos et al., 2021), the authors first summarize these findings and then describe the relevant studies since 2021. Of the 20 guides reviewed in the Minnesota study, only four included specific guidance for the maintenance of separated bike lanes, although the study noted that maintenance considerations can also inform design choices. Maintenance activities were divided into three categories: winter maintenance, debris removal, and facility monitoring. For winter maintenance activities, considerations included methods of removal (i.e., whether specialized equipment was required), snow storage, and ice accumulation. Debris removal considerations included sweeping (i.e., the use of specialized equipment and designs to accommodate standard-sized sweepers). The facility monitoring was described as essential to ensure proper and safe

function. The Minnesota study also conducted interviews, and respondents emphasized the importance of proper maintenance for separated bike lanes, especially during winter. Rather than preferred or best practices, the study enumerated the tradeoffs of each design and maintenance approach (Hourdos et al., 2021).

As the Introduction section noted, FHWA (2024a) provided information on the maintenance of quick-build facilities, incorporating maintenance considerations at the beginning of the design process, and emphasized the importance of considering maintenance capacity when selecting facility materials. For bicycle facilities, maintenance considerations included pavement surface condition, pavement markings, and physical separation features. Maintenance, including sweeping and snow removal operations, was noted as a key consideration for flexposts because clearing facilities with flexposts could require either narrow vehicles (street sweepers or snowplows) or removing flexposts to use standard-width maintenance vehicles. Removing debris and snow and ice was noted as two of the most pressing safety-related maintenance concerns for bicycle infrastructure. Debris and sediment within bicycle facilities could pose a hazard to bicyclists by decreasing roadway traction or obstructing drainage, and snowfall events were a maintenance challenge for bicycle lanes because snow storage for roadways often falls within the curb zone where bicycle facilities are typically located (FHWA, 2024a).

AASHTO's *Guide for the Development of Bicycle Facilities* detailed maintenance and operations for bikeways, emphasizing the need to remove debris, snow, and ice and to provide a usable bike network in all conditions (AASHTO, 2024: Chapter 15). The guide highlighted the cost-effectiveness of designing bicycle infrastructure to accommodate standard-sized equipment and mentioned the removal of flexposts during winter for easier snow removal.

NACTO's third edition of the UBDG noted that facility monitoring and identifying maintenance needs cannot rely solely on public reporting platforms (NACTO, 2025). The guide reported that flexposts require high maintenance frequency but low maintenance intensity and advised that they should be retroreflective and visible in all weather conditions to reduce vehicle strikes.

The 11th edition of the MUTCD did not provide specific guidance on the maintenance of separated bike lanes (FHWA, 2023a).

Considerations for Green-Colored Pavement Marking Materials

Three main GCPM materials were identified in the literature: thermoplastic, methyl methacrylate (MMA), and waterborne paint. Figure 10 shows thermoplastic and MMA. Some state departments of transportation and researchers have performed studies to evaluate the performance and durability of different types of GCPMs (Anderson, 2018; Bao et al., 2024; Fanijo et al., 2022; Kassem et al., 2021; Nyamuhokya and Wilson, 2023). These studies were generally limited in scope regarding the number of sites evaluated and the length of time between GCPM installation and evaluation.



Figure 10. Thermoplastic and Methyl Methacrylate Green-Colored Pavement Markings: (left) preformed thermoplastic; (right) methyl methacrylate

A Vermont study included visual observations of GCPMs made of preformed thermoplastic and two different brands of MMA (Anderson, 2018). After 2 years, most of the GCPMs remained in functioning condition, and MMA GCPMs were observed to outperform the thermoplastic markings. The study concluded that MMA should be explored for future bike lane markings when permitted, given cost and environmental factors.

Nyamuhokya and Wilson (2023) studied the causes of premature failure of GCPMs to develop a GCPM guidelines document for the Florida Department of Transportation. They identified friction materials (e.g., corundum aggregate of varying grain sizes) and performed field evaluations and laboratory testing but did not evaluate the cost-effectiveness of different GCPM materials or application systems. The study concluded that causes for premature failure varied, ranging from “poor installation methods, moisture movement, shrinkage, thermal incompatibility, susceptibility to UV [ultraviolet] light, and traffic abrasion.”

Fanijo et al. (2022) conducted a laboratory-based performance evaluation of retroreflectivity, color changes, and surface friction for three types of GCPMs: MMA, thermoplastic, and waterborne paint. The study concluded that thermoplastic paint experienced a significant drop in retroreflectivity, waterborne paint had the poorest durability performance (resistance to delamination), and MMA surfaces maintained the highest friction. As such, MMA was recommended for use in GCPMs.

Survey to Identify Localities and VDOT Districts with GCPMs or Flexposts

The screening survey received 57 responses (68%), 51 from localities and six from VDOT districts. Of the 57 responding agencies, 16 reported having GCPMs in their jurisdiction, 10 reported having flexposts for bicycle applications, and 12 reported having flexposts for pedestrian applications. Seven agencies reported having flexposts for both bicycle and pedestrian applications. Thirty-eight agencies reported having none of the infrastructure elements of interest on roadways within their jurisdiction (Table 2). In addition, Fairfax County responded to the screening survey but does not maintain its roadways and is not included in the summary of responses.

Table 2. Screening Survey Responses

Locality	GCPMs	Flexposts	
		Bicycle	Pedestrian
Alexandria	X	X	X
Arlington	X	X	X
Charlottesville	X	X	X
City of Richmond	X	X	X
City of Roanoke	X	X	X
Woodstock	X	X	X
City of Fairfax	X	-	X
Falls Church	X	-	X
Harrisonburg	X	-	X
Henrico County	X	X	-
Norfolk	X	X	-
Northern Virginia District	X	X	-
Front Royal	-	X	X
Blacksburg	X	-	-
Danville	X	-	-
Herndon	X	-	-
Williamsburg	X	-	-
Town of Culpeper	-	-	X
Wytheville	-	-	X
Respondents reporting neither GCPMs nor flexposts: Abingdon, Ashland, Bedford, Berryville, Big Stone Gap, Bluefield, Bridgewater, Bristol City, Buena Vista, Christiansburg, Clifton Forge, Colonial Heights, Covington, Culpeper District, Emporia, Farmville, Franklin, City of Fredericksburg, Fredericksburg District, Leesburg, Lexington, City of Lynchburg, Lynchburg District, Manassas, Martinsville, Poquoson, Radford, City of Salem, Salem District, South Boston, South Hill, Staunton District, Strasburg, Suffolk, Tazewell, Vienna, Vinton, and Virginia Beach			

- = respondent indicated that infrastructure was not present; GCPMs = green-colored pavement markings; X = respondent indicated that infrastructure was present.

Survey Respondent Interviews

Of the 19 agencies that indicated in the screening survey that they had either of the infrastructure elements of interest, 13 localities and one VDOT district participated in interviews on GCPMs and flexposts. The following sections summarize the information discussed in these interviews.

Green-Colored Pavement Markings

Installation and Materials

MMA was the most reported material used for GCPMs in Virginia, followed by thermoplastic and traffic paint (Figure 11). Agencies consistently noted that the material used for other pavement markings throughout their jurisdictions influenced their choice of material for GCPMs. Agencies that had installed GCPMs on older pavement indicated durability concerns and issues over time, specifically with thermoplastic markings, and one agency with thermoplastic markings installed on older pavement noted that it may have damaged the micro-surfacing beneath. All agencies reported some surface preparation (cleaning) prior to installation,

and some agencies emphasized the importance of proper surface preparation for markings installed on older pavement.

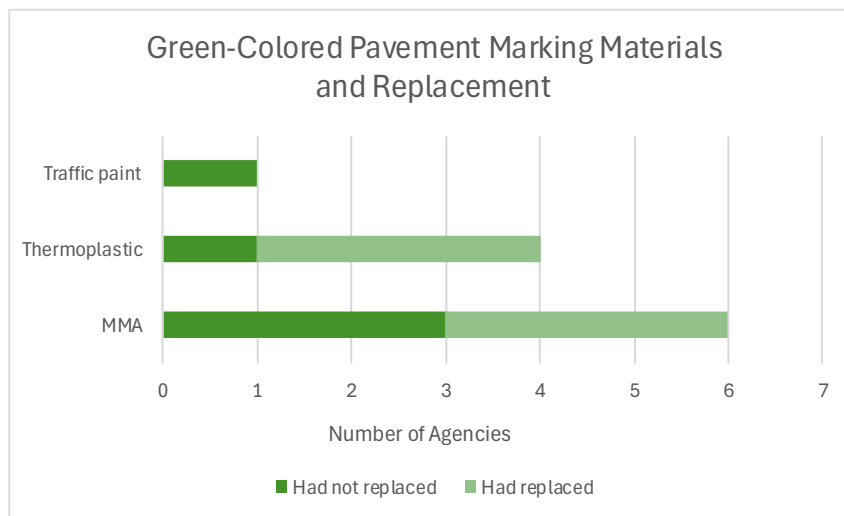


Figure 11. Types of Green-Colored Pavement Marking Materials Used by Virginia Agencies Interviewed in this Study and Whether any Replacements Had Occurred. Arlington had replaced both thermoplastic and MMA. MMA = methyl methacrylate.

Of the 11 localities interviewed regarding the GCPMs within their jurisdictions, six reported using MMA, four reported using preformed thermoplastic, and one reported using traffic paint. Most installations were on new asphalt (less than 1 year old, typically installed within 1 month). Basic surface preparation methods included sweeping, blasting the surface with compressed air, or using a leaf blower to remove debris. Seven agencies had installed GCPMs on new pavement only. Of the four agencies that had installed GCPMs on pavement more than 1 year old, Charlottesville and Arlington reported issues with the markings over time. Arlington noted that GCPMs had been installed on older pavement as part of roadway reconfigurations using cold-rolled micro-surfacing and that preformed thermoplastic installed on top of the micro-surfacing appeared to damage the material underneath, possibly because of a difference in material strength. Charlottesville, utilizing preformed thermoplastic GCPMs, observed a decrease in the longevity of markings installed on older pavement compared with new pavement because of the material not adhering as well to pavement that was 4 or 5 years old. Charlottesville also had a site with thermoplastic GCPMs that were more than 10 years old but observed durability problems at a newer site with solid green thermoplastic that a contractor had installed on new pavement in the wheel path of turning vehicles (Figure 12). The interviewee indicated that installation might have been an issue, possibly moisture related, but was unsure of the details. Harrisonburg reported that installation crews pay special attention to the edge of MMA markings to ensure they are flat and do not have a lip that could be damaged by plowing. Overall, the mix of installations performed by contractors only, locality staff only, and both was even.



Figure 12. A Site in Charlottesville with Solid Green Thermoplastic: (left) shortly after installation; (center) from the opposite angle, wear after 1 year; (right) additional wear after 5 years

Monitoring

Monitoring GCPMs was not reported to be labor intensive and was included either under the umbrella of jurisdictions' existing monitoring of other pavement markings or conducted through a public reporting system. Seven agencies reported that existing staff monitored GCPMs as part of typical pavement-marking monitoring. Richmond reported using a third party for asset management services. Although three agencies reported that staff did not actively monitor their GCPMs, two of these agencies had a reporting system allowing members of the public to submit requests for marking maintenance. Eight agencies reported identifying the need for intervention based on visual inspection for damage, chipping, or delamination. Two agencies reported evaluating GCPMs for retroreflectivity.

In terms of the skid resistance of GCPMs, 10 of the 11 agencies had not received reports of slippery GCPMs and had not observed a decrease in skid resistance over time. Blacksburg, with preformed thermoplastic markings, reported that large areas of GCPMs were observed to be slick for a few weeks after installation, but skid resistance improved over time. Materials Division staff advised that although they had not identified a skid-resistance threshold for GCPMs, the skid-resistance values collected during site visits did not suggest a widespread issue. One exception was a site with 1-month-old GCPMs without any visible friction material, suggesting that skid resistance might be more about product specification and less about maintenance.

Maintenance Activities

None of the 11 agencies with GCPMs reported changing their sweeping operations because of the GCPMs or damage to the markings due to sweeping, and nine agencies reported regularly sweeping over GCPMs.

The same nine agencies reported snowplowing over GCPMs with no change in operations due to the markings. Blacksburg noted the use of polycarbonate plow blades throughout the jurisdiction to avoid damage to all thermoplastic markings. Roanoke reported damage to MMA GCPMs that may or may not have been due to snow plowing; interviewees had observed the damage but were unsure if plowing was the reason. As noted previously, installation of markings without a lip susceptible to snowplows may play a role in preventing

damage. Richmond reported that snowplows sometimes catch the edges of pavement markings and rip up the material. Overall, six of the agencies reported no damage to GCPMs due to snowplowing, one reported possible damage, one reported damage, and one was unknown. None of the agencies reported damage to GCPMs from the application of salt or brine.

Replacement

Only five of the 11 agencies with GCPMs reported having replaced them, limiting the available information on GCPM replacement activities in Virginia.

Frequency. Two agencies using preformed thermoplastic (Blacksburg and Charlottesville) noted that they anticipated replacement would be needed every 7 years. Blacksburg noted that replacement may be needed more frequently if markings were installed on older pavement. Richmond reported a more frequent replacement timeline for preformed thermoplastic markings of every 3 to 5 years. Alexandria, using MMA, reported that replacement was needed every 5 to 7 years, depending on the vehicular traffic passing over the markings. Woodstock, using traffic paint, noted that GCPMs were to be replaced every 2 years as part of the typical marking maintenance schedule but had not yet replaced any GCPMs. Overall, agencies reported that GCPMs required replacement at a frequency similar to that of other pavement markings.

Eradication. Two agencies using MMA replaced markings without eradicating existing markings (Arlington and Alexandria). One agency using preformed thermoplastic (Richmond) replaced markings without eradicating the existing markings, after removing the existing debris. Blacksburg, using preformed thermoplastic, reported that one round of “touch-up” replacement had been conducted by placing preformed thermoplastic on top of existing green preformed thermoplastic (Figure 13), but that for any additional work, eradication was performed before replacement; staff advised that large areas had not been replaced but would be eradicated on the first replacement. It was unclear if Charlottesville had eradicated existing markings before installing the new ones.

Cost. All agencies that reported replacing GCPMs noted that the replacement cost was similar to the initial installation cost. However, it was noted that higher labor costs for eradication and contractor mobilization costs would cause spot work to have a higher unit cost than larger jobs.

Utility Work. Most agencies with GCPMs reported no interaction with utility work affecting GCPMs. Five of the agencies noted that utility companies were required by contract to restore the roadway to its original state, including replacing any damaged or removed GCPMs. However, Alexandria reported dissatisfaction with the quality of replacement markings the utility companies had installed and that the city re-installed GCPMs put in place by utility companies.



Figure 13. Examples of Marking “Touch-up” Work in Blacksburg with Preformed Green Thermoplastic Placed on Top of Existing Green-Colored Pavement Markings that Had Deteriorated

Susceptibility to Wear or Damage. Agencies using both MMA and thermoplastic reported that areas with increased vehicular traffic volumes, especially turning movements across GCPMs, required more frequent replacement. Blacksburg reported that thermoplastic installed on older pavement fared worse in high-traffic areas and turning wheel paths than thermoplastic installed on new pavement. The thermoplastic markings applied over existing thermoplastic markings also exhibited reduced durability. Overall, respondents reported quicker degradation of GCPMs with high volumes of vehicular turning movements and heavy vehicles. In addition, bike boxes, which are in the path of motor vehicle traffic by design, and other GCPMs in intersection areas were reported to be more susceptible to wear.

Flexposts Used for Bicycle and Pedestrian Applications

Installation and Materials

Flexposts may be installed individually or as part of a curb base, and the connection to the roadway surface can be made with an adhesive (epoxy) or bolts (Figure 14). Individual flexposts bolted into the pavement appeared to be the most frequently used type across the agencies interviewed. It was common for agencies to use two bolts instead of four to fasten flexposts to the pavement, although this practice may negatively affect the flexposts’ longevity.

Of the 11 agencies interviewed, eight reported using only individual flexposts, one reported using only flexposts attached to a plastic curb base (VDOT Halifax Residency), and two reported using both (Roanoke and Charlottesville). Of the 10 agencies using individual flexposts, one (Roanoke) used only epoxy for installation, three had used only bolts, and six had used both installation methods. Arlington and the City of Fairfax had used epoxy in the past but switched to using bolts, and Richmond had used bolts in the past but switched to using epoxy. Henrico County reported that flexposts attached with epoxy were used only on concrete bridge decks; flexposts on asphalt were bolted down. The two agencies with flexposts mounted on curb bases reported that the curb bases were bolted down. Although individual bolt-style flexpost bases

have four bolt holes, five agencies reported sometimes using two bolts rather than four to attach flexposts to the pavement. Interviewees who mentioned using this practice typically said it saved time during installation and that two bolts were sufficient for securing the flexpost to the pavement. One agency noted that using only two bolts facilitated reinstallation of a downed flexpost in the same location.



Figure 14. Examples of Flexpost Installations: (left) on a curb base; (center) individually mounted using epoxy; (right) individually mounted using two of four bolt holes

Front Royal used removable flexposts on recessed, plowable bases to create a separated bicycle and pedestrian lane along a roadway shoulder. Installing each flexpost required specialized equipment to grind a divot into the asphalt. A metal base was then epoxied into the divot so that its top was flush with the roadway surface, a plastic delineator base was attached to the recessed metal base via four lug bolts, and a delineator tube was fastened to the plastic base via a locking pin (Figure 15). The agency noted that this product had previously been used on VDOT roadways but was no longer on VDOT's approved products list for roadway delineation. Because this application was on the shoulder rather than within the traveled way for vehicles and on a town-maintained roadway, the town chose to use removable flexposts with recessed bases for easier snow removal.

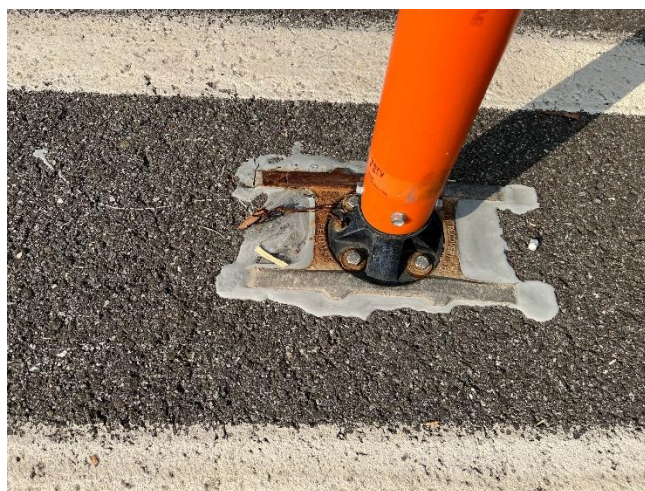


Figure 15. Flexpost with Recessed Plowable Metal Base

Flexpost spacing ranged from 5 feet to more than 100 feet, depending on local context. The pedestrian lane installed by VDOT's Halifax Residency had varying flexpost spacing, with flexposts every 5 feet in some sections but other sections with curb bases and no flexposts for sight distance from driveways. Woodstock used a spacing of about 6 feet to prevent vehicular intrusion at the beginning of its facility and a much wider spacing after that to reduce visual clutter. Arlington indicated using a typical maximum spacing of 20 feet to prevent vehicles from parking or standing between flexposts, and in some cases, it used longer flexpost spacing with wheel stops or modular concrete "pills" between the flexposts to accomplish the same goal. A two-way, separated bike lane in Roanoke had flexposts spaced roughly every 40 feet, with varied spacing near driveways. Henrico County had a separated bicycle lane with flexposts originally placed every 50 feet, which were later spaced at 150 feet after feedback from a local homeowners' association and elected officials. Other respondents indicated that they had consulted the MUTCD for guidance or that they did not know who determined the spacing.

Monitoring

Overall, monitoring the flexposts used for bicycle and pedestrian applications was not a substantial concern for interviewees. Most of the interviewees reported that existing staff monitored flexposts either passively or as part of existing routine oversight of signs and markings. Six of the 11 agencies also reported relying on public reporting to monitor flexposts.

No clear consensus emerged regarding how agencies determined if flexposts needed replacement or repair. All 11 agencies reported performing maintenance activities when flexposts were missing or down (i.e., entirely knocked over), and six agencies reported evaluating flexposts for retroreflectivity when considering repair or replacement. Five agencies reported completing maintenance activities when flexposts were damaged but not missing.

Maintenance Activities

Because flexposts were used for a variety of bicycle and pedestrian infrastructure, including separated bicycle lanes, pedestrian walkways, and curb extensions, maintenance activities varied by application and by agency.

For most applications, sweeping required small equipment, such as leaf blowers or walk-behind brooms, which an agency's public works department already owned. Six agencies, of which five had bicycle lanes and one had a pedestrian lane, reported sweeping infrastructure elements, including flexposts. Arlington reported that a mini sweeper was used to clear bicycle lanes with flexposts on an as-needed basis, depending on staff observations and public requests for sweeping. Woodstock reported using a leaf blower to clear debris, which is estimated at 6 to 8 person-hours of labor per year for a 0.1-mile-long separated bike and pedestrian lane. The City of Richmond reported using a mini sweeper to clear the lanes approximately four times per year. That machine, dubbed MF Broom, cost about \$80,000, and in 2026, the city added a ride-on litter vacuum, dubbed Baby Broom, at a cost of about \$60,000 (Moreno, 2026a). Meanwhile, a volunteer group raised about \$6,000 to purchase a bike-towed sweeper with an electrically powered brush and began using it to clear separated bike lanes (Moreno, 2026b). Front Royal

reported using a walk-behind 4-foot broom to sweep debris from its shoulder bike and pedestrian lane. The town had already owned this broom and used it to sweep sidewalks. In addition, the town noted that although the lane was not specifically designed to accommodate sweeping, they had been aware that the existing equipment would be compatible. Roanoke reported that the bicycle lane was designed to accommodate a standard sweeper so that no specialized equipment was needed for sweeping.

Agencies that reported performing snow removal used specialized equipment, including a snowblower on a small skid-steer loader, a small truck, or an all-terrain vehicle (ATV), often already agency owned. Overall, snow removal was not reported to be a problem regarding cost or labor due to the relative infrequency of snowfall in Virginia and the ability to use equipment agencies already owned. Of the 11 agencies interviewed, four reported removing snow from bicycle and pedestrian infrastructure with flexposts. Three reported having specialized equipment for snow removal, and one reported removing flexposts for the winter season. The City of Fairfax reported using a snowblower on a small skid-steer loader to remove snow. Roanoke reported using a small truck and ATV for snow removal, both of which the city already owned and used for other purposes. Two agencies reported that salt was applied to facilities indirectly by the spreader when treating the adjacent roadway. Falls Church reported not sweeping or removing snow because its areas enclosed by flexposts were not designated walking or biking areas.

The one agency with recessed, plowable bases, Front Royal, reported removing flexposts for the winter season to accommodate plowing. Although no specialized equipment was needed for snow removal, labor was needed for the removal and reinstallation of flexposts, typically in early November and early April, respectively. The town reported that removal of the flexposts took two people less than 1 working day. Reinstallation also involved two people but took approximately twice as long because of the need to clear debris that had accumulated in the metal base during the winter season.

Replacement

Frequency. Generally, flexposts need replacement less than twice per year but could need more frequent replacement shortly after a new traffic pattern is created in higher-traffic areas, including intersections or in areas along a roadway with frequent access points. Ten of the 11 agencies reported having replaced at least one flexpost used for bicycle and pedestrian applications. All 10 of these agencies reported that replacement was performed on demand, with typical replacement frequencies shown in Figure 16.

Labor. Seven agencies indicated that two people could perform replacement, and two agencies used four people. Most agencies reported that replacement took less than 30 minutes per flexpost. VDOT's Northern Virginia District noted that this time estimate was reasonable for a simple swap, but if bolts needed to be removed or ground down and new holes drilled, it could take two people 30 to 60 minutes. Most agencies indicated that the need for maintenance of traffic was determined on a case-by-case basis but was typically not used.

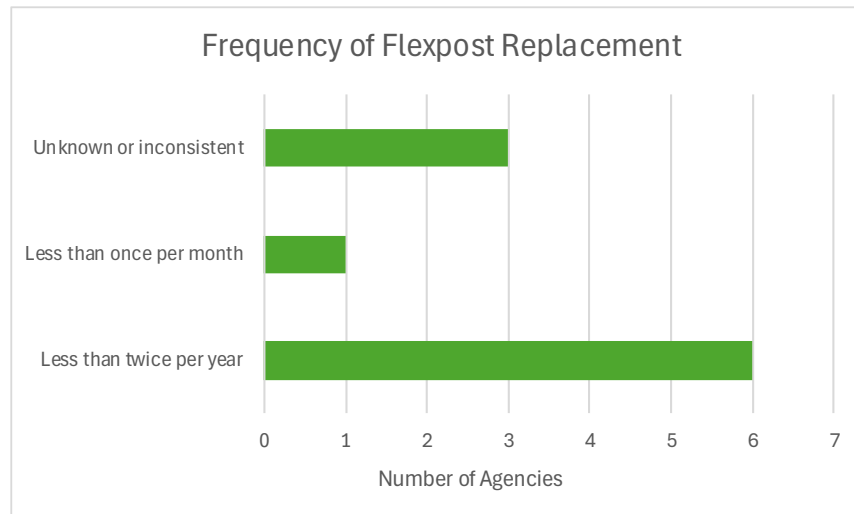


Figure 16. Flexpost Replacement Frequency Reported by Virginia Agencies

Susceptibility to Wear or Damage. Substantial risk of damage to flexposts appears to be posed by snowplowing the adjacent roadway. Seven of the 11 agencies reported damage to flexposts from snowplows. Henrico County reported that snowplows more frequently damaged flexposts attached via epoxy than those attached via bolts. Richmond reported that flexposts closest to intersections and in areas desirable for delivery-truck parking required more frequent replacement.

Falls Church noted that flexposts in new locations required relatively frequent replacement immediately after installation, but the frequency of replacement decreased over time. The City of Fairfax noted that, anecdotally, chevron pavement markings at the beginning of a lane delineated by flexposts might help protect them from damage.

Case Studies

Population figures for case study localities are the official 2025 Virginia estimates for cities and counties and 2024 U.S. Census Bureau estimates for towns (Weldon Cooper Center for Public Service, 2026). Speed limit and average daily traffic (ADT) volumes were obtained from VDOT's Pathways for Planning tool (VDOT, 2026b).

Danville

The City of Danville, with a population of 43,204, is near the North Carolina border about 45 miles northeast of Greensboro in an otherwise rural area. The case study site is a bicycle lane with GCPMs on West Main Street in a suburban context adjacent to Averett University.

Facility Overview

The bicycle lanes along a 1-mile stretch of West Main Street from Holbrook Street to Blackwell Drive include 24 preformed thermoplastic GCPMs, typically at the beginning of each block. West Main Street is a two-lane minor arterial with a posted speed limit of 25 mph and

ADT of 7,400 vehicles per day. GCPMs were installed between late 2018 and 2020. Each GCPM consists of two preformed thermoplastic sections: the arrow and the bicycle symbol (Figure 17). The markings are not in conflict zones and are not exposed to high volumes of motor vehicle traffic.



Figure 17. West Main Street Green-Colored Pavement Markings in the City of Danville

Installation Information

GCPMs along West Main Street were installed on relatively new pavement—likely within 1 year of repaving. The markings were installed following the manufacturer’s instructions, and a sealant was applied to the pavement prior to the markings. The markings include ViziGrip, which the vendor describes as a “unique pattern of surface beads and anti-skid elements that ensure maximized skid resistance and retroreflectivity” (Traffic Safety Supply Company, 2021). Table 3 summarizes the estimated installation costs.

Maintenance Information and Present Condition

GCPMs along West Main Street have been exposed to regular maintenance activities, including sweeping and snow plowing. None of the markings has been replaced since installation, although Danville staff stated that they had considered touching up some of the markings with paint. Of the 24 GCPMs along West Main Street, 22 were evaluated as being in good condition. Two showed mild signs of delamination and are in fair condition. Given that the markings have not required replacement or repair, their maintenance cost was \$0 during approximately 6 years.

Table 3. Estimated Installation Costs for Green-Colored Pavement Markings in Danville

Materials				
Item	Quantity	Unit Cost (2018)	Total Cost (2018)	Total Cost (2025)
Preformed thermoplastic bicycle symbol	24	\$244.80	\$5,875.20	\$9,921.65
Preformed thermoplastic arrow	24	\$244.80	\$5,875.20	\$9,921.65
<i>Total Cost (Materials)</i>			<i>\$11,750.40</i>	<i>\$19,843.31</i>
Labor				
Item	Quantity	Unit Cost (2018)	Total Estimated Cost (2018)	Total Cost (2025)
GCPM Installation	144 hours	\$26.86 ^a	\$3,867.89 ^a	\$6,531.84 ^b
<i>Total Estimated Cost (Labor)</i>			<i>\$3,867.89^a</i>	<i>\$6,531.84</i>
<i>Total Estimated Cost (Materials and Labor)^c</i>			<i>\$15,618.29</i>	<i>\$26,375.15</i>

GCPM = green-colored pavement marking. ^a The provided 2026 labor cost was adjusted to 2018 dollars. ^b Because Danville's labor unit cost was not available, the labor unit cost for the geographically nearest case study (VDOT Halifax Residency) was used to estimate total costs. Labor unit costs provided were 2026 dollars and were adjusted using 2025 National Highway Construction Cost Index values because 2026 values were not yet available. ^c All amounts refer to a 1-mile section of West Main Street.

Estimated Costs Over Time

Figure 18 depicts the real and estimated installation and maintenance costs—the latter being zero—for GCPMs in Danville from assumed installation in 2018 to 2026. Hypothetical 2026 replacement installation costs were calculated based on the material's typical expected service life and assuming an annual 5% increase in costs from 2025, but as of May 2026, researchers were not aware of plans to replace the markings.

Front Royal

The Town of Front Royal, with a population of 15,628, is in a rural area about 70 miles west of Washington, D.C. The case study site is a bicycle and pedestrian lane separated with flexposts on West Criser Road in a suburban to rural context.

Facility Overview

The separated bicycle and pedestrian lane on the south side of West Criser Road from Skyline Vista Drive to Luray Avenue is approximately 1,150 feet long (Figure 19). The lane is within a school zone for Skyline High School and has 56 removable orange flexposts mounted on recessed, plowable bases. West Criser Road is a two-lane major collector with a posted speed limit of 25 mph and ADT of 3,400 vehicles per day. The flexposts and separated lane were installed in 2024 as an interim improvement until a sidewalk with a curb and gutter can be installed as part of a \$3.1 million project anticipated to begin in the fall of 2027 (VDOT, 2026c). Community fundraising via an outside organization covered the cost of the delineators, and the town covered the installation cost. Generally, public feedback on the interim project has been positive. One resident involved in the fundraising process noted that although the project had increased perceived safety overall, the removable nature of the flexposts defeated their purpose to some degree, because they were not in place during the winter months, coinciding with much of the school year when students used the facility (Shotton, 2025).

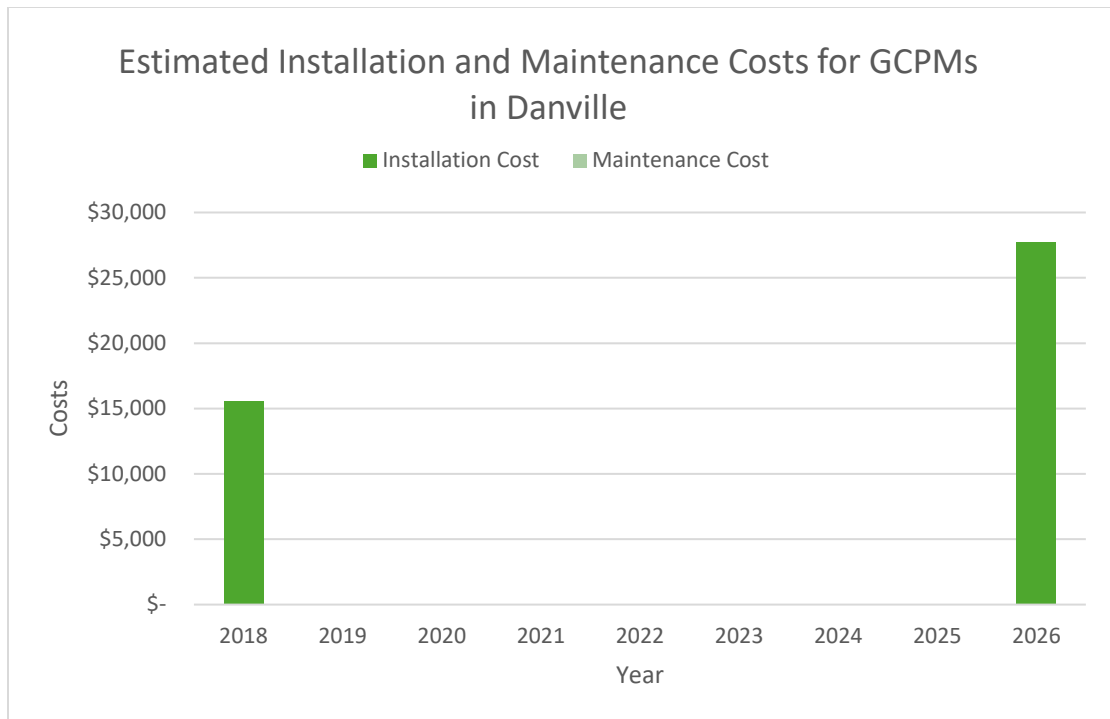


Figure 18. Estimated Installation and Maintenance Costs for GCPMs in Danville. GCPMs = green-colored pavement markings.



Figure 19. West Criser Road Bicycle and Pedestrian Lane Separated with Flexposts

Installation Information

The flexposts used for the West Criser Road bicycle and pedestrian lane are unique because of their recessed, plowable base. The base requires a divot to be ground into the asphalt so that a metal base can be epoxied into the pavement and sit flush with the surface. A plastic delineator base is attached to the recessed metal base via four lug bolts, and the delineator tube is attached to the plastic base via a locking pin. Specialized equipment is needed to install the metal bases, which may limit localities' ability to do so. Interviewees from Front Royal reported finding only one contractor in Virginia, Mullen's Markings, with the specialized equipment needed to install the bases.

The flexposts are installed within a buffer roughly 1 foot wide. Markings were installed prior to the flexposts project and are not included in the installation cost information in Table 4, which is based on the town staff's estimated labor cost for flexpost installation (\$178 to \$223) and a contractor's quote (Scheulen, 2025). That quote included 59 metal base installations, although the flexpost invoice included 56 flexposts, which matched field observations and information provided by the interviewee.

Table 4. Installation Costs for Flexpost-Separated Bicycle and Pedestrian Lane in Front Royal

Materials				
Item	Quantity	Unit Cost (2023/2024)	Total Cost (2023/2024)^a	Total Cost (2025)
Flexpost	56	\$45.38	\$2,541.28	\$2,579.33
Surface-Mount Base	56	\$11.33	\$634.48	\$643.77
Multi-Surface Anchor Kit	56	\$6.00	\$336.00	\$341.07
Recessed Base	56	\$30.00	\$1,680.00	\$1,665.26
Epoxy Kit	4	\$118.01	\$472.04	\$467.90
<i>Total Cost (Materials)</i>			<i>\$5,663.80</i>	<i>\$5,697.33</i>
Labor				
Item	Quantity	Unit Cost (2023/2024)	Total Cost (2023/2024)	Total Cost (2025)
Recessed Delineator Base Install (Contractor)	59	\$243.09	\$14,342.31	\$14,351.38
Flexpost Installation ^b			\$222.86	\$223.00
<i>Total Cost (Labor)</i>			<i>\$14,565.17</i>	<i>\$14,574.38</i>
<i>Total Cost (Materials and Labor)^c</i>			<i>\$20,228.97</i>	<i>\$20,271.71</i>

^a The quote for flexposts, surface-mount bases, and multi-surface anchor kits was dated November 20, 2023. The recessed base installation invoice was dated April 28, 2024. The quote for the recessed base and epoxy kit was dated February 8, 2024. Prices have not been adjusted because the National Highway Construction Cost Index (NHCCI) values are similar for these different dates. ^b Front Royal staff provided labor costs in 2025, which were assumed to be present rates at that time. NHCCI values were used to adjust the 2025 values accordingly, which was to dollars for the second quarter of 2024. ^c All amounts refer to a 1,150-foot section of West Criser Road.

Maintenance Information

Maintenance for West Criser Road included removal of flexposts in the fall or winter, reinstallation in the spring, replacement of missing or damaged flexposts, and semi-annual sweeping. For sweeping, the town switched from a walk-behind power brush to a skid-steer loader with a box broom and reported that it was much quicker. The town already owned the sweeping equipment prior to the installation of the separated bicycle and pedestrian lane.

Because the removal of the flexposts for the winter season allows the full width of the roadway to be plowed, no additional expense or labor was incurred for snow removal. As of November 2025, Front Royal reported that only one flexpost had needed replacement since the installation of the bicycle and pedestrian lane nearly 2 years earlier. Table 5 summarizes these maintenance costs. Overall, the estimated annual maintenance cost per mile for the flexpost-separated lane is approximately \$3,485 in 2025 dollars.

Table 5. Maintenance Costs for Flexpost-Separated Bicycle and Pedestrian Lane in Front Royal

Materials				
Item	Quantity	Unit Cost (2024)	Annual Cost (2024)	Total Cost (2025)
Flexpost	1	\$45.38	\$45.38	\$46.06
<i>Total Cost (Materials)</i>			\$45.38	\$46.06
Labor				
Item	Quantity	Unit Cost (2024)^a	Annual Cost (2024)^a	Total Cost (2025)
Sweeping	2x/year	\$169.90	\$339.79	\$340.00
Flexpost removal	1x/year	\$149.91	\$149.91	\$150.00
Flexpost reinstallation	1x/year	\$222.86	\$222.86	\$223.00
<i>Total Cost (Labor)</i>			\$712.56	\$713.00
<i>Total Annual Cost (Materials and Labor)^b</i>			\$757.94	\$759.06

^a Front Royal staff provided labor costs in 2025, which were assumed to be present rates at that time. The National Highway Construction Cost Index values were used to adjust the 2025 values to April 2024 dollars. ^b All amounts refer to a 1,150-foot section of West Criser Road.

Estimated Costs Over Time

Figure 20 depicts the real and estimated installation and maintenance costs for the West Criser Road bicycle and pedestrian lane from installation in 2024 to the project cost of maintenance in 2031. Future maintenance costs were calculated assuming an annual 5% increase starting in 2025.

Overall, annual maintenance costs were low (sweeping, flexpost replacement, and seasonal removal and reinstallation) compared with installation costs. In the first year, maintenance costs were approximately 3% of installation costs.

VDOT Halifax Residency

Halifax County is a primarily rural county on the North Carolina border, east of Danville, with a population of 33,368, including 7,795 in the Town of South Boston. The case study site is a separated pedestrian lane with flexposts on curb bases on Sinai Road adjacent to town limits. Properties on the side of the road adjacent to the pedestrian lane are in the town, but VDOT maintains Sinai Road via the Halifax Residency within the Lynchburg District. The context is rural transitioning to suburban.

Facility Overview

The 5-foot-wide, separated pedestrian lane along Sinai Road is approximately 2,300 feet long, from 75 feet east of Westside Drive to 275 feet west of River Road. Sinai Road is a two-

lane major collector with a posted speed limit of 35 mph and ADT of 6,300 vehicles per day. The separated lane consists of approximately 350 bases with flexposts that were initially installed in 2020 as a quick-build project via shoulder widening and roadway restriping. The intent was that Halifax County would apply for funding to construct a sidewalk. As of 2025, Sinai Road was in need of repaving, and the county’s funding application had not been approved, so VDOT reinstalled the bases and flexposts in January 2026 (Figure 21).



Figure 20. Estimated Installation and Maintenance Costs for Flexpost-Separated Lane in Front Royal



Figure 21. Sinai Road Pedestrian Lane in Halifax County: (left) August 2025; (right, courtesy of Roy Sage) January 2026

Installation Information

Local VDOT staff installed the flexpost-separated pedestrian lane in 2020. Since the lane installation, several flexposts have been removed because of sight-distance concerns from driveways on Sinai Road. The installation cost information in Table 6 does not include costs for pavement widening. In addition, the costs for the drill bits, dump truck, pickup truck, and labor are based on the costs for the January 2026 reinstallation of flexposts along the pedestrian lane (Craddock, 2025; Sage, 2026).

Table 6. Estimated Installation Costs for Flexpost-Separated Pedestrian Lane in Halifax County

Materials and Equipment				
Item	Quantity	Unit Cost (2020)	Total Cost (2020)^a	Total Cost (2025)
Shur-Curb Traffic Separator	350	\$71.16	\$24,906.00	\$42,376.37
Drill Bits			\$231.51 ^b	\$393.90
Dump Truck	4 days	\$41.23 ^b	\$164.92 ^b	\$280.60
Pickup Truck	4 days	\$13.72 ^b	\$54.89 ^b	\$93.40
<i>Total Cost (Materials and Equipment)</i>			<i>\$25,357.32</i>	<i>\$42,376.37</i>
Labor				
Item	Quantity	Unit Cost (2020)	Total Cost (2020)	Total Cost (2025)
Labor	192 hours	\$26.66	\$5,119.13 ^c	\$8,709.96
<i>Total Cost (Labor)</i>			<i>\$5,119.13</i>	<i>\$8,709.96</i>
<i>Total Cost (Materials and Labor)^d</i>			<i>\$30,476.45</i>	<i>\$51,086.33</i>

^a Costs for pavement widening are not included. ^b Drill bit, dump truck, pickup truck, and labor costs were provided in 2026 and were adjusted using 2025 National Highway Construction Cost Index values because 2026 values were not yet available. ^c The 2026 labor cost was adjusted to 2020 dollars. For example, the unit cost of labor in 2026 dollars was \$45.36 per hour, so with 192 hours, the total cost was $192 \times \$45.36 = \$8,709.12$, which was \$5,119.13 in 2020 dollars. ^d All amounts refer to a 2,300-foot section of Sinai Road.

Maintenance Information and Present Condition

VDOT has performed limited maintenance activities along the Sinai Road pedestrian lane since it was installed in 2020. The lane is not swept or snowplowed, and Halifax Residency staff advised that in typical snow events, snow would likely melt from the lane by the time the primary routes were cleared. During a site visit in August 2025, debris and vegetation were observed between the curb bases, and grass had encroached on the pedestrian lane along the shoulder of the roadway (Figure 22). In most places, the vegetation narrowed the usable width of the 5-foot-wide lane by at least 1 foot. In addition, many flexposts were damaged and discolored, and multiple curb bases were cracked, potentially a result of vehicles striking the flexposts.

Because of the intentional removal of flexposts for increased sight distance near driveways and the intentional installation of some bases without posts to avoid unnecessarily tightly spaced posts, the site visit could not determine the number of flexposts that had been previously installed but were missing. Halifax Residency staff advised that flexposts along the separated lane were replaced throughout the year, although it was uncommon. In such cases, often the curb base remained intact, and only the flexpost required replacement. Table 7 summarizes the estimated costs for lane maintenance and replacement, which was conducted in

January 2026 as part of repaving. Halifax Residency staff advised that 49 flexposts were replaced as part of that effort.



Figure 22. Sinai Road Pedestrian Lane in Halifax County: (left) vegetation overgrowth on shoulder in August 2025; (right, courtesy of Roy Sage) after repaving and reinstallation in January 2026

Table 7. Estimated Costs for Maintenance and Replacement of Flexpost-Separated Pedestrian Lane in Halifax County

Materials and Equipment				
Item	Quantity	Unit Cost (2020)	Total Cost (2020) ^{a, b}	Total Cost (2025)
Shur-Curb Traffic Separator	49	\$71.16	\$3,486.84	\$5,932.69
Drill Bits			\$231.51	\$393.90
Dump Truck	4 days	\$41.23	\$164.92	\$280.60
Pickup Truck	4 days	\$13.72	\$54.89	\$93.40
<i>Total Cost (Materials and Equipment)</i>			<i>\$3,938.16</i>	<i>\$6,700.59</i>
Labor				
Item	Quantity	Unit Cost (2020)	Total Cost (2020) ^{a, b}	Total Cost (2025)
Labor	192 hours	\$26.66	\$5,119.13	\$8,709.96
<i>Total Cost (Labor)</i>			<i>\$5,119.13</i>	<i>\$8,709.96</i>
<i>Total Cost (Materials and Labor)^c</i>			<i>\$9,057.29</i>	<i>\$15,410.55</i>

^a Drill bit, dump truck, pickup truck, and labor costs were provided in 2026 and were adjusted using 2025 National Highway Construction Cost Index values because 2026 values were not yet available. ^b The provided 2026 labor cost was adjusted to 2020 dollars. ^c All amounts refer to a 2,300-foot section of Sinai Road.

Table 8 summarizes the estimated maintenance cost for the annual replacement of flexposts. Halifax Residency staff estimated that flexpost replacement frequency was one flexpost per month. One hour of labor was assumed for monthly replacement activities. Overall, the estimated annual maintenance cost per mile for the flexpost-separated lane is approximately \$4,585 in 2025 dollars.

Table 8. Estimated Annual Maintenance Costs for Flexpost-Separated Pedestrian Lane in Halifax County

Materials and Equipment				
Item	Quantity	Unit Cost (2020)	Total Cost (2020)^{a, b}	Total Cost (2025)
Shur-Curb Traffic Separator	12	\$71.16	\$853.92	\$1,452.90
<i>Total Cost (Materials and Equipment)</i>			<i>\$853.92</i>	<i>\$1,452.90</i>
Labor				
Item	Quantity	Unit Cost (2020)	Total Cost (2020)^{a, b}	Total Cost (2025)
Labor	12 hours	\$26.66	\$319.91	\$544.32
<i>Total Cost (Labor)</i>			<i>\$319.91</i>	<i>\$544.32</i>
<i>Total Cost (Materials and Labor)^c</i>			<i>\$1,173.83</i>	<i>\$1,997.22</i>

^a Labor costs were provided in 2026 and were adjusted using 2025 National Highway Construction Cost Index values because 2026 values were not yet available. ^b The 2026 labor cost was adjusted to 2020 dollars. ^c All amounts refer to a 2,300-foot section of Sinai Road.

Estimated Costs Over Time

Figure 23 depicts the real and estimated installation and maintenance costs for the Sinai Road pedestrian lane from installation in 2020 to replacement in 2026. Costs from 2021 to 2025 were calculated using NHCCI values. The 2026 costs were calculated assuming an annual 5% increase in maintenance costs from 2025.

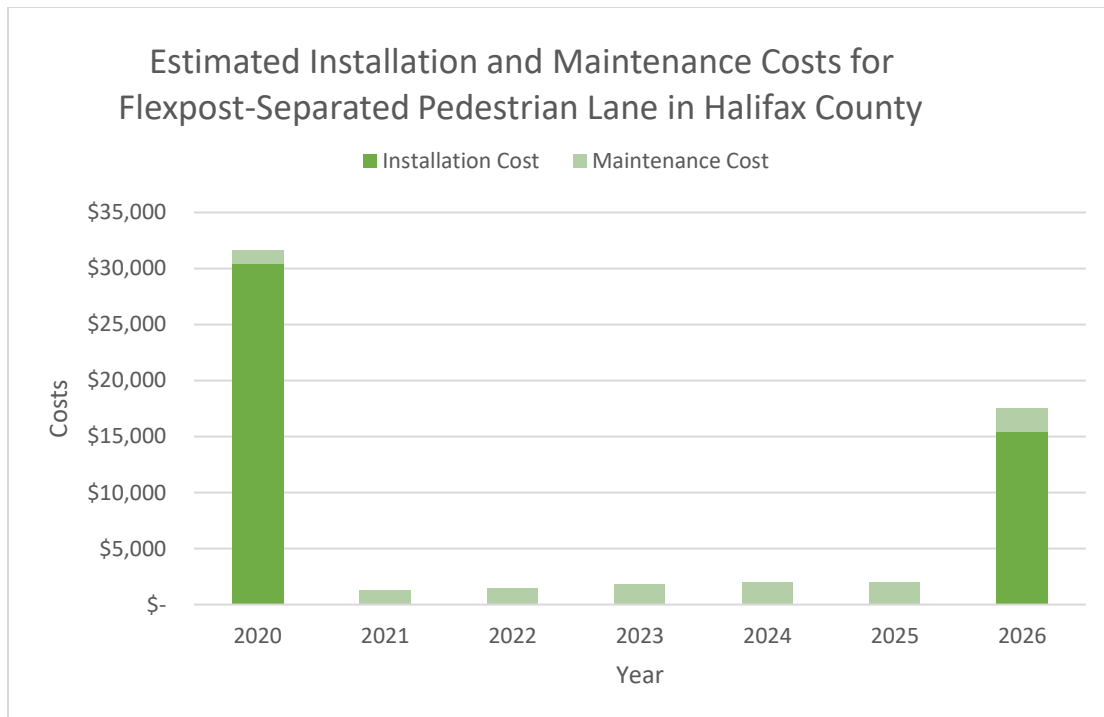


Figure 23. Estimated Installation and Maintenance Costs for Flexpost-Separated Pedestrian Lane in Halifax County

Overall, annual maintenance costs for flexpost replacement were low compared with installation costs. In the first year, maintenance costs were approximately 4% of installation costs. Annual maintenance cost increases are due to applying NHCCI values.

Arlington County

Directly across the Potomac River from Washington, D.C., Arlington County has a population of 247,056 and the highest population density of any county in Virginia. The case study site is Clarendon Boulevard from North Courthouse Road to North Oak Street, a one-way corridor in an urban and high-density suburban context. It had a standard bike lane through 2021 that was converted to a flexpost-separated bike lane, with portions hardened with concrete separators by 2025. The corridor also has GCPMs. The Materials Division did not collect green-colored or friction data for this site.

Facility Overview

The separated bicycle lane along Clarendon Boulevard is approximately 3,125 feet long. Clarendon Boulevard is a two-lane, one-way principal arterial with a posted speed limit of 25 mph and ADT of 6,400 vehicles per day. As adjacent properties were redeveloped, the Clarendon Boulevard bike lane evolved from a standard bike lane before 2012 to a flexpost-separated bike lane between November 2019 and July 2021. Most recently, the bike lane was upgraded with the installation of concrete separators in some areas between April 2023 and September 2024. In addition, GCPMs were added at conflict points, including major commercial driveways, bus boarding islands, and intersecting streets, between November 2019 and September 2021.

The roadway cross-section changes along the approximately 0.6-mile corridor. East of North Courthouse Road, the roadway includes (from left to right) two vehicle travel lanes, a parking lane, a buffer zone with flexposts, and a separated bicycle lane (Figure 24). At the time of the site visit, eight flexposts were installed along the bicycle lane from North Courthouse Road to the 1515 Clarendon Boulevard parking garage entrance and six GCPM skips at that entrance.



Figure 24. Clarendon Boulevard Flexpost-Separated Bike Lane: (left) from North Courthouse Road to 1515 Clarendon Boulevard parking garage; (right) thermoplastic green-colored pavement marking skips at 1515 Clarendon Boulevard

From 1515 Clarendon Boulevard to the nearby bus boarding island, the bicycle lane is curb-separated and has MMA GCPMs on ramps adjacent to a raised crosswalk (Figure 25).



Figure 25. Clarendon Boulevard Bike Lane: (left) curb-separated lane; (right) methyl methacrylate green-colored pavement markings at bus boarding island

From the bus boarding island to the parking garage entrance slightly west of the North Troy Street intersection, the bicycle lane is separated by flexposts and adjacent to a buffer zone and street parking. Fourteen flexposts were present along this portion of the bicycle lane, with six thermoplastic GCPM skips at the parking garage entrance.

At the intersection of Clarendon Boulevard and North Troy Street, the Clarendon Boulevard bicycle lane is a curb-separated lane, which continues to North Scott Street. Six thermoplastic GCPM skips were present at the Retail Parking entrance, and 13 thermoplastic GCPM skips were present at the North Scott Street intersection (Figure 26).



Figure 26. Clarendon Boulevard Unprotected Bicycle Lane: (left) thermoplastic skips at Clarendon Boulevard and North Scott Street; (right) standard bicycle lane from North Scott Street to North Rhodes Street

From North Scott Street to North Rhodes Street, the facility is a standard bicycle lane, without separators or buffers, between general-purpose lanes and curbside street parking (Figure 25). Eleven thermoplastic GCPM skips and one two-stage turn box were present in the North Rhodes Street intersection (Figure 27).



Figure 27. Clarendon Boulevard and North Rhodes Street: (left) thermoplastic skips; (right) two-stage turn box

From North Rhodes Street to North Quinn Street, the facility is a separated bicycle lane to the right of on-street parking, with a buffer zone and flexposts. Seven flexposts were present in this section, and five flexposts appeared to be missing. Ten thermoplastic GCPM skips were observed at the North Quinn Street intersection, one of which appeared to have been partially removed by pavement patching (Figure 28).



Figure 28. Clarendon Boulevard Bicycle Lane: (left) flexpost-separated bike lane from North Rhodes Street to North Quinn Street with missing flexposts; (right) thermoplastic skips at Clarendon Boulevard and North Quinn Street intersection

The parking-separated bicycle lane continues from North Quinn Street to North Queen Street. Eight flexposts were present in this section, and one or two flexposts appeared to be missing. Eleven thermoplastic GCPM skips were present at the North Queen Street intersection, which appeared to have been replaced recently following repaving (Figure 29).



Figure 29. Clarendon Boulevard Bicycle Lane: (left) flexpost-separated bike lane from North Quinn Street to North Queen Street; (right) thermoplastic skips at Clarendon Boulevard and North Queen Street intersection

From North Queen Street to the bus boarding island slightly west of North Pierce Street, the parking-separated bicycle lane had four flexposts present and two or three missing. At the bus boarding island, the bicycle lane is separated by a curb. MMA GCPMs were adjacent to the intersection crosswalk at the end of the bus platform. A second crosswalk in the center of the bus platform had no GCPMs (Figure 30).



Figure 30. Clarendon Boulevard Bicycle Lane: (left) flexpost-separated bike lane from North Queen Street to North Pierce Street with missing flexposts; (right) crosswalk to bus boarding island slightly west of North Pierce Street intersection

At the Clarendon Boulevard and North Pierce Street intersection, eleven thermoplastic GCPM skips and a two-stage turn box were present (Figure 31).

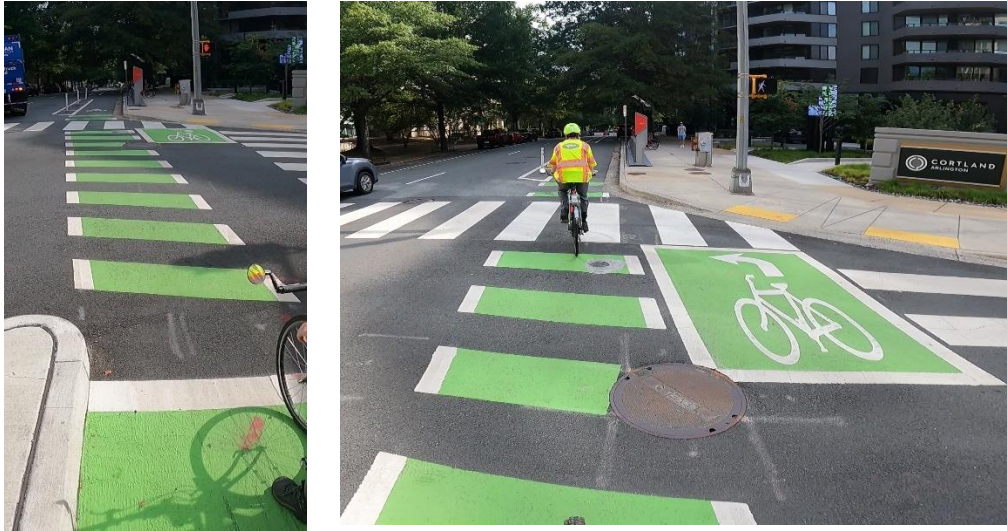


Figure 31. Clarendon Boulevard and North Pierce Street Intersection Green-Colored Pavement Markings: (left) thermoplastic skips; (right) two-stage turn box

From North Pierce Street to North Ode Street, the bicycle lane is separated by flexposts, with a buffer zone, and has three flexposts at the beginning of the block. It then becomes a buffered bike lane, without flexposts between general-purpose lanes and curbside parking. Seventeen thermoplastic GCPM skips were present at the Clarendon Boulevard and North Ode Street intersection (Figure 32).

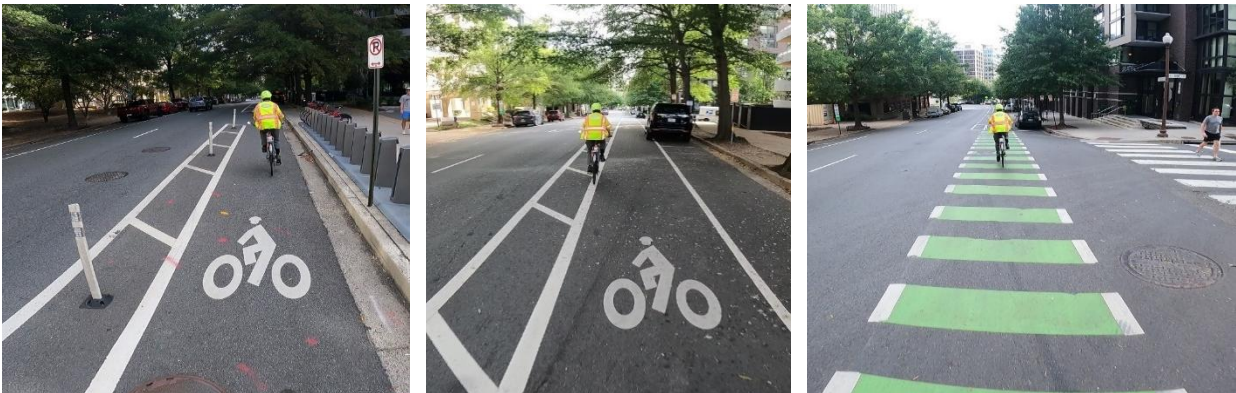


Figure 32. Clarendon Boulevard Bicycle Lane from North Pierce Street to North Ode Street: (left) flexpost-separated bicycle lane; (center) buffered bicycle lane adjacent to curbside parking; (right) thermoplastic green-colored pavement marking skips at the Clarendon Boulevard and North Ode Street intersection

The buffered bike lane adjacent to curbside parking continues briefly after the North Ode Street intersection, becomes a shared lane through a bus stop, and then returns to a buffered bike lane (Figure 33).

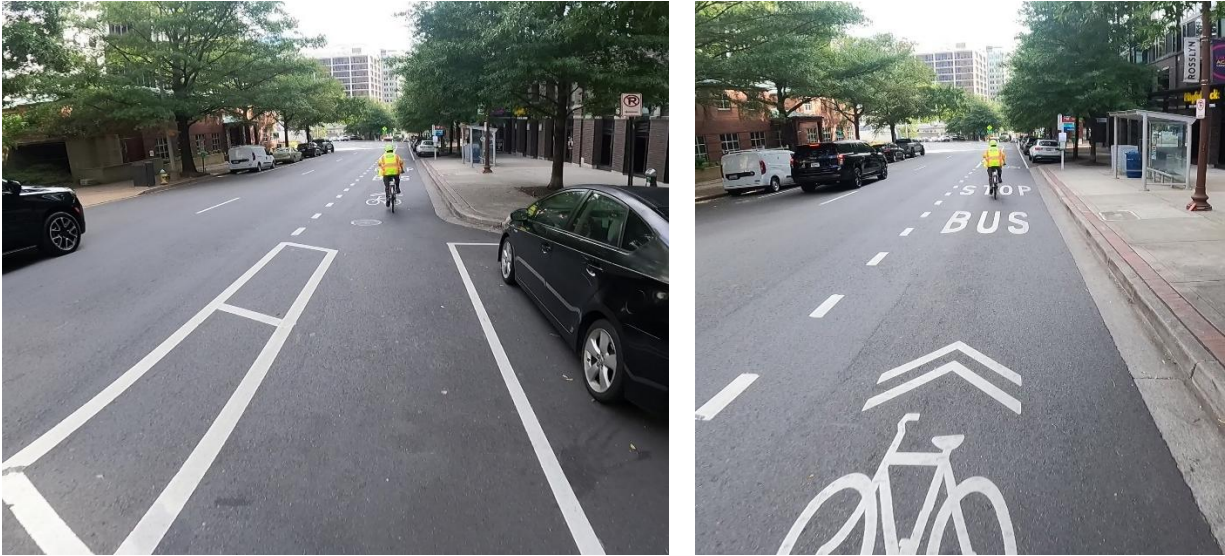


Figure 33. Clarendon Boulevard Bicycle Lane: (left) buffered bicycle lane; (right) shared lane at bus stop

Leading up to and through the skewed Clarendon Boulevard and 17th Street North intersection, two flexposts, a mountable delineator, and seven thermoplastic GCPM skips were present. On the east side of the intersection, one flexpost was down, and curb-stop separators were damaged (Figure 34).



Figure 34. Clarendon Boulevard and 17th Street North Intersection: (left) flexposts and thermoplastic green-colored pavement marking skips; (right) downed flexpost

From the 17th Street North intersection to the North Oak Street intersection, the facility is a standard bicycle lane, without separators or buffers, between general-purpose lanes and curbside street parking (Figure 35). Nine thermoplastic GCPM skips and one two-stage turn box were observed at the Clarendon Boulevard and North Oak Street intersection (Figure 35).



Figure 35. Clarendon Boulevard Bicycle Lane: (left) standard bicycle lane from 17th Street North to the North Oak Street intersection; (right) thermoplastic green-colored pavement marking skips and a two-stage turn box at the Clarendon Boulevard and North Oak Street intersection

Installation Information

As adjacent properties were redeveloped, the Clarendon Boulevard bike lane evolved from a standard bike lane prior to 2012 to a flexpost-separated bike lane between November 2019 and July 2021. Portions were upgraded with the installation of concrete separators in some areas between April 2023 and September 2024. In addition, GCPMs were added to conflict points, including major commercial driveways, bus boarding islands, and intersecting streets, between November 2019 and September 2021. Some of the GCPMs and flexposts were installed as part of development improvements, and Arlington County and its contractors installed some. The installation cost information in Table 9 does not include costs for the concrete separators or restriping. Arlington County provided the unit costs for GCPMs, including materials and labor. Arlington County also provided the unit cost for its on-call contractor to furnish and install flexposts (\$44 each) at the time of conversion to a flexpost-separated bike lane but noted that county crews installed the flexposts along Clarendon Boulevard, so the actual cost would have been less.

There are 107 preformed thermoplastic skips along the Clarendon Boulevard bike lane. Skips were estimated to be 2 feet long and 5 feet wide (10 square feet per skip), resulting in a total estimated area of 1,070 square feet of preformed thermoplastic skips. Four MMA areas are adjacent to crosswalks near bus platforms, each estimated to be 6 feet long and 5 feet wide (30 square feet per raised approach), with a total MMA area of 120 square feet. Three two-stage turn boxes are present, each estimated to be 9 feet long and 5 feet wide (45 square feet per box), resulting in a total estimated area of 135 square feet for preformed thermoplastic two-stage turn boxes.

Table 9. Estimated Installation Costs for Flexpost-Separated Bike Lane in Arlington County

Materials and Labor				
Item	Quantity	Unit Cost (2020)	Total Cost (2020)^a	Total Cost (2025)^b
Flexposts	57 posts	\$44.00 EA	\$2,508.00	\$4,151.13
Preformed thermoplastic skips	1,070 SF	\$12.47/SF	\$13,342.90	\$22,084.56
Preformed thermoplastic turn boxes	135 SF	\$12.47/SF	\$1,683.45	\$2,786.37
MMA at certain crosswalks	120 SF	\$10.47/SF	\$1,256.40	\$2,079.54
Total Estimated Cost^c			\$18,790.75	\$31,101.59

EA = each; MMA = methyl methacrylate; SF = square feet. ^a Costs for concrete separators and restriping are not included. ^b The flexpost, preformed thermoplastic, and MMA unit costs were provided for 2020 and have been adjusted using 2025 National Highway Construction Cost Index values. ^c All amounts refer to a 3,125-foot section of Clarendon Boulevard.

Because of the evolution of the Clarendon Boulevard bike lane, the number of flexposts along it has changed during the years. The 57 flexposts used in the installation cost calculation represent the number of flexposts that were, or were meant to be, present at the time of the site visit in September 2025. That is, it includes flexposts that appeared to be missing but not flexposts that had been replaced by concrete separators.

Maintenance Information and Present Condition

Arlington has not replaced any GCPMs (preformed thermoplastic or MMA) on this section of Clarendon Boulevard because of wear. Some sections of GCPM may have been replaced because of utility work or in conjunction with projects that required repaving, such as the Clarendon Boulevard and North Pierce Bus Boarding Island project. These improvements were not included in the maintenance cost calculation.

At the time of the site visit, all three preformed thermoplastic two-stage turn boxes and all four MMA raised crosswalk approaches were observed to be in excellent condition. Only one of the 11 locations with thermoplastic GCPMs along the corridor showed significant wear (Clarendon Boulevard and North Rhodes Street; Figure 36). The GCPM skips at Clarendon Boulevard and North Rhodes were installed between April 2018 and September 2021. Eleven GCPM thermoplastic skips are through the intersection; five were in good condition, four were in fair condition, and two were in poor condition. The skips exhibited signs of wear in the earliest available Google StreetView imagery (July 2021), suggesting a potential installation issue.

Of the estimated 57 flexposts along the bike lane, 10 were missing at the time of the site visit. Because Arlington County indicated that flexposts are monitored annually, this number has been assumed to represent the annual number of flexposts requiring replacement.

Per the county website, street sweeping is conducted on Clarendon Boulevard four times a year (Arlington Virginia, 2026), using a Duvelo 850 Ride-On Street Sweeper, which the county can also use to sweep other separated bike lanes. County staff estimated a labor requirement of 45 minutes to 1 hour per mile to sweep separated bike lanes during the summer or early fall, and 1 hour to 1.5 hours per mile to sweep separated bike lanes during the winter or spring. Although this section of the Clarendon Boulevard bike lane is only approximately 3,125 feet long, the 1-

mile labor estimate was used in the calculations to account for the mobilization of a sweeping crew, resulting in 5 hours of labor annually to sweep the lane. The county provided the hourly labor rate for the separated bike lanes. Although Arlington County indicated that the bike lane is snowplowed, no information was provided regarding the labor amount or rate for plowing. The labor amount and rate calculated for sweeping the separated bike lane were assumed for snowplowing the lane. Overall, the estimated annual maintenance cost per mile for the flexpost-separated lane is \$1,910 in 2025 dollars (Table 10).



Figure 36. Thermoplastic Green-Colored Pavement Marking Skips at the Clarendon Boulevard and North Rhodes Street Intersection: (left) visible wear in the earliest available Google Maps imaging after installation (image capture: July 2021 © 2026 Google); (right) visible wear to the same skips from a site visit conducted in September 2025

Table 10. Estimated Annual Maintenance Costs for Flexpost-Separated Bike Lane in Arlington County

Materials				
Item	Quantity	Unit Cost (2020)	Total Cost (2020)	Total Cost (2025)
Flexpost	10	\$44.00 EA	\$440.00	\$728.27
<i>Total Cost (Materials)</i>			<i>\$440.00</i>	<i>\$728.27</i>
Labor				
Item	Quantity	Unit Cost (2020)	Total Cost (2020) ^{a, b}	Total Cost (2025)
Sweeping	5 hours	\$24.29	\$121.44	\$201.00
Snowplowing	5 hours	\$24.29	\$121.44	\$201.00
<i>Total Cost (Labor)</i>			<i>\$242.88</i>	<i>\$402.00</i>
<i>Total Annual Cost (Materials and Labor)^c</i>			<i>\$682.88</i>	<i>\$1,130.27</i>

EA = each. ^a Labor costs were provided in 2026 and were adjusted using 2025 National Highway Construction Cost Index values because 2026 values were not yet available. ^b The provided 2026 labor costs were adjusted to 2020 dollars. ^c All amounts refer to a 3,125-foot section of Clarendon Boulevard.

Estimated Costs Over Time

Figure 37 depicts the real and estimated installation and maintenance costs related to GCPMs and flexposts on the Clarendon Boulevard separated bicycle lane from the estimated installation cost in 2020 to 2026. Costs from 2021 to 2025 were calculated using NHCCI values.

The 2026 costs were calculated assuming an annual 5% increase in maintenance costs from 2025.

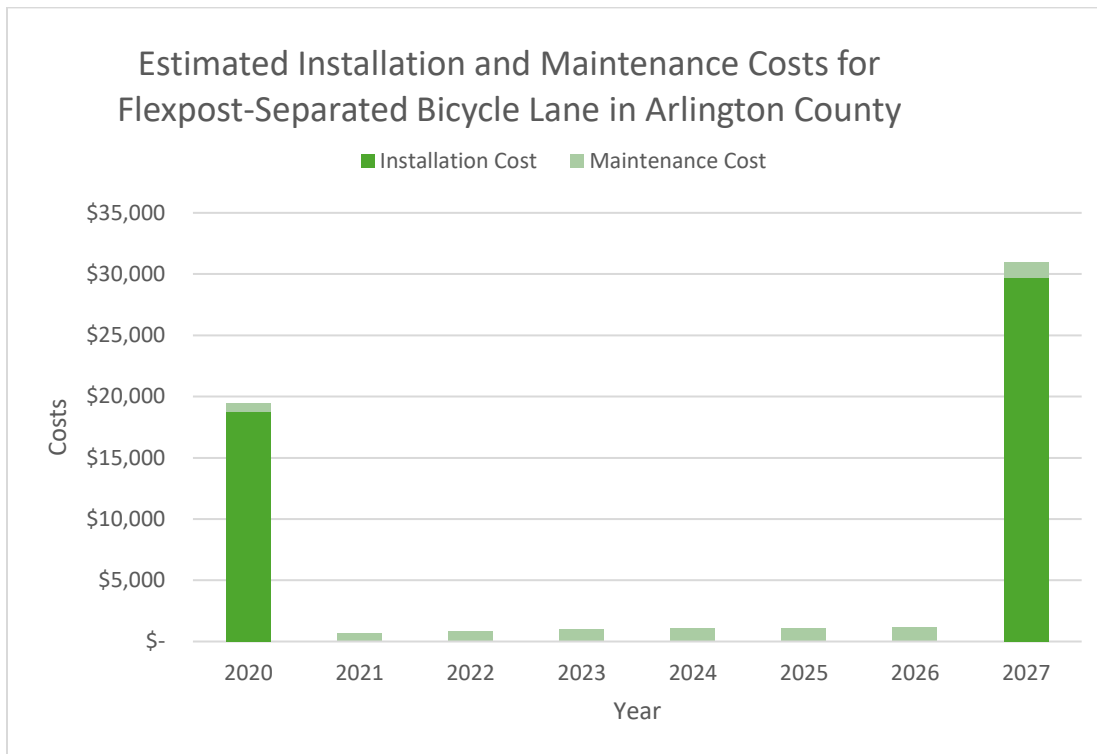


Figure 37. Estimated Installation and Maintenance Costs for Flexpost-Separated Bicycle Lane in Arlington County

Overall, annual maintenance costs were relatively low, including sweeping, snow plowing, and flexpost replacement, compared with installation costs. Annual maintenance cost increases are due to the application of NHCCI factors. In the first year, maintenance costs specific to flexpost separation were estimated to be approximately 27% of the installation costs for only the flexposts. That is, the maintenance cost in 2020 was estimated at \$682.88, which is 27% of the installation costs for only the flexposts (\$2,508.00). The presence of GCPMs along the lane did not contribute to the annual maintenance costs, and their installation costs were not included in this calculation.

Summary of Findings

Regarding GCPMs:

- *The condition of the existing pavement prior to GCPM installation may play a substantial role in the durability of markings, specifically with thermoplastic markings.*
- *Surface preparation prior to GCPM installation is an important step and may affect the long-term durability of markings, specifically markings installed on older pavement. One agency also had an example of GCPMs with durability issues that were installed on new pavement but could not pinpoint the cause.*

- *Overall, monitoring of GCPMs was not reported to be labor intensive and was included under the umbrella of jurisdictions' existing monitoring of other pavement markings. This task was typically performed through staff observations as they passed through the areas or via a public reporting system.*
- *No effects on sweeping or snowplowing operations were reported due to the presence of GCPMs, but snowplowing might degrade GCPMs.*
- *Eradication of existing MMA or traffic paint GCPMs prior to replacement is not needed; thermoplastic markings typically require eradication before replacement. One agency had examples of thermoplastic markings that were touched up without eradication but advised that it would do so no more than once per location. Another agency that replaced thermoplastic markings without eradicating existing ones also indicated a more frequent replacement timeline for thermoplastic markings than other agencies.*
- *The cost, labor, and equipment needed to replace GCPMs are approximately the same as those for their original installation, after accounting for changes in construction costs. Higher labor costs for eradication and contractor mobilization costs could cause spot work to have a higher unit cost than larger jobs.*
- *Actual or anticipated replacement timelines were typically every 7 years for thermoplastic, every 5 to 7 years for MMA, and every 2 years for traffic paint GCPMs, consistent with replacement timelines for other colors using the same marking material.*
- *Overall, more frequent replacement was required for GCPMs in areas with high vehicular traffic volumes, within the wheel path for turning vehicle movements, exposed to higher rates of heavy vehicles, and extended through intersections. These types of locations also tend to be where GCPMs can provide enhanced conspicuity because of "conflicting, weaving, or crossing movements" between bicyclists and other traffic (FHWA, 2023a).*

Regarding flexposts used for bicycle and pedestrian applications:

- *The longevity of individual flexposts bolted into the pavement may be negatively affected by using two bolts instead of four to fasten flexposts to the pavement.*
- *Flexposts with a recessed, plowable base allow for flexposts to be removed for the winter season to enable typical snowplowing operations but require additional installation costs, equipment, and labor. These devices were also not on VDOT's approved list for use in the roadway.*
- *Many agencies used a public reporting system as a means for monitoring flexposts.*
- *Other than replacing downed flexposts, no clear consensus emerged regarding how agencies determined if damaged flexposts needed replacement or repair.*

- *Pedestrian and bicycle lanes with flexposts can often be swept and plowed with small equipment that agencies already own.* A leaf blower or walk-behind broom can clear debris, and a snowblower on a small skid-steer loader, a small truck, or an ATV can clear snow. Because of this uncomplicated effort and the relative infrequency of snowfall in Virginia, snow removal was not reported to be a major cost or labor problem.
- *Generally, flexposts need replacement less than twice per year but could need more frequent replacement shortly after a new traffic pattern is created, when placed in higher-traffic areas, including intersections, and when placed in areas along roadways with frequent access points.* Substantial risk of damage to flexposts appears to be posed by snowplowing the adjacent roadway, more so if flexposts are secured to the roadway with epoxy rather than bolted.

Regarding Future Research Opportunities

Several topics not covered in this study could be explored in the future. Comprehensive guidance on materials selection, installation, and maintenance would couple manufacturer recommendations with field evaluations that address visibility, color, durability, and safety. As one example, GCPM color consistency over time (resistance to fading) could be of interest. The MUTCD requires the green hue to remain within certain chromaticity values. Although the Materials Division recorded chromaticity values with a colorimeter at several of this study's case study sites, those measurements captured only a single moment in time, and comparable values from the original installation date were unavailable. That is, it was not possible to know whether older GCPMs had faded but simply their condition as of the date of the site visit. As a second example, skid resistance is a key consideration regarding GCPM safety and should be evaluated against manufacturer recommendations and field experience, both when the markings are new and over time. As with GCPM color, the Materials Division collected skid resistance readings at several of this study's case study sites but only at a point in time.

For bolt-mounted flexposts, the question of when to use four bolts versus two could be of interest. In general, using four bolts should increase a flexpost's longevity. However, when a downed post must be re-bolted into the surface, a two-bolt post can be mounted in the same place (using two new holes), whereas a four-bolt post might have to be moved (using four new holes). The additional holes could result in increased pavement damage and possible deterioration. A similar question could be when to use curb-mounted post units versus individual posts.

The cost information in this study is applicable to the Commonwealth of Virginia and may not be transferable to facilities in other states with different considerations, such as climate, labor costs, and maintenance policies.

CONCLUSIONS

- *GCPMs incurred no predictable annual maintenance costs other than periodic replacement, as the following notes, whereas the cost of maintenance for flexposts during the first year is*

3% to 27% of the installation costs. Flexpost maintenance costs varied as a function of facility length, pavement condition, and number of flexposts needing replacement, such that the three case studies showed annual per-mile costs of \$1,910, \$3,485, and \$4,585 in 2025 dollars.

- *The frequency of GCPM maintenance varies by material—7 years for thermoplastic, 5 to 7 years for MMA, and 2 years for traffic paint, and flexpost replacement frequency also varies but is less than twice per year.* Using the Danville case study as an example and the hypothetical 2026 replacement installation costs from Figure 18, the annualized maintenance cost would be about \$4,000 for a 1-mile-long street with 24 GCPMs in standard bike lanes.
- *Maintaining GCPMs and flexposts did not typically require increased staffing or major equipment purchases.* GCPMs did not affect sweeping or snowplowing operations. For flexposts, sweeping and snow removal were often feasible with existing equipment and personnel, but some localities with extensive networks of flexpost-separated bike lanes purchased specialized sweeping equipment. Monitoring GCPMs was generally part of monitoring existing conditions. For monitoring flexposts, public reporting systems augmented staff monitoring.
- *Labor requirements vary by agency.* For GCPMs, replacement could typically be performed with four people or fewer. For flexposts, most agencies studied (seven) required two people for replacement, although two agencies required four people.

RECOMMENDATIONS

1. *VDOT should include attributes indicating the presence of flexposts and GCPMs in the Bicycle Facilities feature layer in the Statewide Active Transportation Map Hub.* An accurate facility inventory, including both VDOT-maintained and locally maintained facilities, can support planning, operations, and maintenance initiatives.
2. *VDOT should consider maintenance implications when incorporating GCPMs and flexposts into agency procedures and guidance materials.* Elements of this recommendation would likely encompass the following considerations:
 - a. *Suitability.* For GCPMs, suitability would include types of locations where the markings are recommended, discouraged, and prohibited to balance effectiveness and maintainability. For flexposts, guidance could indicate conditions where they are a viable option for separating users, given expected maintenance needs.
 - b. *Material/product selection.* Most agencies with GCPMs selected either MMA or thermoplastic, which have a longer expected service life than traffic paint, based on experience with those materials. A variety of flexposts were used.
 - c. *Installation.* For example, one element to include in GCPM installation guidance is the importance of pavement quality and surface preparation.

3. *VDOT should explore local partnerships for routine maintenance of separated bicycle lanes and pedestrian facilities with flexposts on VDOT roads.* For example, county or town staff could remove debris or snow from flexpost-separated areas and report damaged flexposts to VDOT.

IMPLEMENTATION AND BENEFITS

The researchers and the technical review panel (listed in the Acknowledgments) for the project collaborate to craft a plan to implement the study recommendations and determine the benefits of doing so. This process is to ensure that the implementation plan is developed and approved with the participation and support of those involved with VDOT operations. The implementation plan and the accompanying benefits are provided here.

Implementation

Regarding Recommendation 1, within 6 months of this report's publication, the Statewide Bicycle and Pedestrian Planner will determine whether GCPMs and flexposts can be incorporated as attributes within the Bicycle Facilities feature layer in the Statewide Active Transportation Map Hub and, if so, how. The results of this study's screening survey can help populate GCPM and flexpost attributes for existing facilities. The Transportation and Mobility Planning Division's (TMPD) existing annual process for reporting new bicycle and pedestrian facilities, along with its Statewide Bicycle Facility Inventory Guide, could be updated to note those that include GCPMs and flexposts. Because bike lanes are digitized at the segment level and GCPMs typically appear only along a portion of a bike lane segment, a comment field could note the presence of GCPMs. As VDOT continues to update the statewide sidewalk inventory, opportunities may arise to indicate the presence of flexposts used for pedestrians.

As part of that effort, TMPD will evaluate adding one or more new attributes in the Bicycle Facilities layer to indicate the presence and type of separation for flexpost-separated bicycle lanes. Making this update would mirror a newly established specification aiming to standardize bicycle and pedestrian infrastructure data. In early 2026, a national collaboration originally convened by the U.S. Department of Transportation's Bureau of Transportation Statistics adopted version 1.0 of the General Active Transportation Infrastructure Specification (GATIS; National Collaboration on Bicycle, Pedestrian, and Accessibility Infrastructure Data, n.d.). In GATIS, bikeways have a required attribute, "separation_elements," via which the presence of flexposts or other barrier types can be recorded. Another attribute, "separation_permeable_car," allows flexposts to be denoted as a type of "soft separator" that is easily bypassed by motor vehicles. However, GATIS version 1.0 does not explicitly address GCPMs. In TMPD's inventory, the facility type might be "separated bike lane," with a new attribute indicating the means of separation.

Regarding Recommendation 2, within 12 months of this report's publication, the Statewide Bicycle and Pedestrian Planner will coordinate with the Central Office's TOD, Materials Division, Maintenance Division, and other divisions as needed to initiate productive revisions to guidance documents related to GCPMs and flexposts.

The right column of Table 11 identifies potential revisions that might be productive. The two left columns list, for each potential revision, the guidance document and the VDOT division with authority over that document. Table 11 is not an exhaustive list.

Table 11. Procedures and Guidance Documents Related to GCPMs and Flexposts

Document; Responsible Division	Relevant Treatments	Potential Revisions
Policy for siting GCPMs (in development); TOD's Traffic Control Devices Section	GCPMs	TOD could incorporate findings from this report. GCPMs through intersections and in areas with high vehicular turning volumes may incur relatively higher maintenance costs, such conflict areas where increased conspicuity can be most beneficial, much like pedestrian crosswalks.
Potential new policies; TOD's Traffic Control Devices Section	Flexposts	TOD could use the information within this report to evaluate if flexposts are well suited to use in pilot programs and as interim solutions. Future guidance should address roadway context criteria for transitioning from interim flexpost installations to permanent treatments. For example, on lower-speed roadways, flexposts may be a viable longer-term option for separating users, although areas near intersections and with frequent delivery parking might require different permanent treatments to minimize maintenance costs. Curb-mounted flexposts would also fall under the purview of the Traffic Control Devices Section. Such guidance should consider compatibility with resurfacing and maintenance operations.
Materials Approved Lists; Materials Division	GCPMs	The Materials Division could evaluate whether GCPMs should be added to its approved lists, which already include several models of individual flexposts but not curb-mounted flexposts (VDOT, 2026d). TOD is already coordinating with the Materials Division to select materials (Cottrell, 2026).
Potential new guidance; Maintenance Division	GCPMs and flexposts	The Maintenance Division updates a pavement condition map annually for VDOT-maintained roads (VDOT, 2025). The Maintenance Division could evaluate whether guidance should discourage installing methyl methacrylate and thermoplastic GCPMs on pavement rated Very Poor in the most recent condition assessment. If GCPMs are needed for such facilities where repaving is likely within a year or two, the shorter lifecycle of paint might suffice. Guidance might recommend deferring flexpost installation on these roadways until after repaving.
Potential new guidance; Transportation and Mobility Planning Division	GCPMs and flexposts	To assist planners from VDOT and localities who may not be familiar with the multiple resources from different divisions of VDOT (e.g., the <i>Road Design Manual</i> , approved product lists, TOD policies, and the pavement condition map), the Transportation and Mobility Planning Division could develop simplified guidance that references and unifies the various procedures, guidance documents, and lists as they relate to GCPMs, flexposts, and potentially other elements of active transportation infrastructure. Such guidance could also suggest that VDOT districts or localities consider their previous experience with a particular marking material when choosing a GCPM material type. For flexposts, it could reinforce requirements, such as those in the <i>Manual on Uniform Traffic Control Devices</i> , regarding post colors (FHWA, 2023a). To support context-driven local maintenance decisions regarding flexpost-separated facilities, VDOT could share the cost data from this study with localities.

GCPMs = green-colored pavement markers; TOD = Traffic Operations Division.

Regarding Recommendation 3, within 2 years of this report's publication, the Statewide Bicycle and Pedestrian Planner will coordinate with at least one VDOT residency to arrange a meeting with the locality to discuss establishing a pilot agreement for routine maintenance on a bicycle or pedestrian facility with flexposts.

Implementing this recommendation would be highly context specific. For a facility in a smaller town with VDOT-maintained roads (or on a VDOT road adjacent to a town, such as the Sinai Road pedestrian lane), the town might desire more frequent debris removal than VDOT would perform, given budget limitations. The town might already have or be willing to acquire small equipment for sweeping and snow removal that it uses to clear nearby town-owned sidewalks or park facilities. If that equipment is housed closer to the site than the nearest VDOT facility, it could be more efficient for the town to conduct routine maintenance than for VDOT to do so. In a larger county with VDOT-maintained roads, facilities might exist where VDOT conducts routine maintenance, others where the county clears debris, and possibly some facilities where entities such as business improvement districts perform maintenance.

VDOT would likely retain responsibility for repairing potholes and replacing damaged flexposts as needed, but local partners could report these issues to VDOT.

Benefits

The primary benefit of the three recommendations is to provide better information for decision-making, where localities and VDOT have a more complete understanding of total costs (installation and maintenance) for GCPMs and flexposts. Because providing this information incurs labor costs, it is reasonable to ask what value this information provides. Any such valuation will be dependent on assumptions, but an order-of-magnitude estimate is feasible.

From the perspective of a locality, a question might arise as to whether the maintenance costs associated with GCPMs or flexposts are worth it, regardless of construction costs. At least two different scenarios are possible under which this information could be used:

1. A locality chooses to install and maintain GCPMs or flexposts.
2. A locality chooses not to install and maintain GCPMs or flexposts.

Scenario 1. Choosing to Maintain GCPMs or Flexposts

The benefit in this case is that a locality is otherwise willing to have flexposts but is hesitant to use them because the maintenance costs are unknown. For streets with a history of bicycle crashes where flexposts can convert a standard bicycle lane into a separated one, the value of this benefit can be estimated by assuming a reduction in crash costs. For streets without a history of bicycle crashes, assuming a mode shift that reduces vehicular travel can allow for an estimation of benefits.

Either way, assume a locality has a 3-mile-long street with standard bicycle lanes that can be converted to separated bicycle lanes with flexposts. Table 10 suggests an annual maintenance cost of \$1,130 for a 3,125-foot section of separated bike lane, which translates to a maintenance

cost of \$5,728 for this 3-mile section if it had a single separated bike lane or a bidirectional one—either way uses a single line of flexposts on one side of the street. Assuming the configuration has two directional separated bike lanes, the annual maintenance cost would be about \$11,455.

Crash Cost Reduction

If the street has a history of bicycle crashes, reducing crashes is the goal, and the maintenance costs of flexpost-separated bike lanes are acceptable to the locality, then what is the value of having information on those maintenance costs for the locality’s goal?

In 2024, 25 bicycle fatality crashes and 623 injury crashes (138 of which were serious injuries) were documented in Virginia (Virginia Highway Safety Office, n.d.). The following calculation assumes that during the past 5 years, the corridor had two bicyclist crashes resulting in evident injury and two resulting in possible injury. This assumed number of crashes appears reasonable compared with a 0.6-mile corridor under study in Charlottesville that had three bike crashes during 8 years (Connect Charlottesville, 2026), a crash rate equivalent to nine bike crashes for a 3-mile corridor during a 5-year period. For the hypothetical corridor, converting bicycle lanes to separated bicycle lanes could halve the number of crashes (FHWA, 2023b). Crash costs from VDOT for 2025 were used to estimate monetary benefits from crash reductions during a 5-year period, as Table 12 shows (Read, 2025). Crashes with only property damage were not included. Assuming two directional separated bike lanes and ignoring inflation in maintenance costs, the 5-year maintenance cost would be about \$57,277, leading to the benefit-cost ratios shown in Table 12. A ratio greater than 1.0 is desirable, showing that the benefits exceed the cost. For this hypothetical corridor, the 5-year crash-reduction benefits of maintaining the flexpost-separated bike lanes would exceed the maintenance costs by more than nine times.

Table 12. Benefits of Maintaining Flexpost-Separated Bicycle Lanes Converted from Standard Bicycle Lanes on a Hypothetical Street with a History of Bicycle Crashes During a 5-Year Period

Crash Type	Assumed Corridor Crash Reduction	Cost (\$) per Crash Avoided (Benefit)	Monetary (\$) Crash Reduction Benefits	Benefit-Cost Ratio ^a
Evident Injury	1	325,011	325,011	5.7:1
Possible Injury	1	188,599	188,599	3.3:1
Total			513,610	9:1

^a Based on a 5-year maintenance cost of \$57,277.

For this hypothetical corridor, subtracting the 5-year maintenance cost from the total benefit in Table 12 yields a 5-year benefit of \$91,266 per year, which is the value used in the summary of quantitative benefits here. If the corridor had only a single “possible injury” crash eliminated during a 5-year period, the benefit (\$188,599) minus the maintenance cost during the same period (\$57,277) yields a 5-year benefit of roughly \$131,322 or \$26,264 per year.

Mode Shift

For example, suppose a locality wants to increase the use of nonmotorized modes and reduce vehicle miles traveled (VMTs) by providing higher-comfort facilities for nonmotorized travel. The locality may be interested in using flexposts on a 35-mph roadway because they are a less expensive option for separating bicyclists from vehicular traffic than constructing an off-

road shared-use path. If the maintenance costs are acceptable to the locality, then what is the value of this information for this particular locality's goal?

One way to tabulate this value is to consider the effect flexposts have on mode split. Tao et al. (2026) suggested that a one-unit reduction in the level of traffic stress on a four-point scale (i.e., 4 being very stressful and 1 being minimally stressful) increases the mode split for biking and walking by 0.3% and 4.5%, respectively. The Montgomery County Planning Department (2017) suggested that adding flexposts can reduce traffic stress by 0.5 or 1 point (on a scale from 1 to 5), depending on factors such as speed limit and number of lanes.

Given a two-lane road with a two-way left turn lane that is 3 miles long with a 35-mph speed limit and ADT of 10,000, the addition of flexposts could increase mode share for biking and walking by $0.3\% \times 10,000 + 4.5\% \times 10,000 = 30 + 450 = 480$ daily nonmotorized trips. If each of these trips represents a switch from a solo driving trip, then it entails a reduction of $3 \text{ miles} \times 480 \text{ vehicles} = 1,440 \text{ VMTs}$. Butner and Davis Noll (2020) suggested that a gallon of fuel yields \$2.00 in externalities for congestion and traffic crashes. The authors also report additional externalities for local pollution and greenhouse gas emissions, but they are not used herein. For a vehicle that gets 20 miles per gallon, this calculation suggests that each VMT generates 10 cents in congestion and crash costs, such that the 1,440 VMT reduction amount is \$144 in crash and congestion costs each day. If these reductions are only realized for two-thirds of the year, assuming the other one-third is unseasonably hot or cold, then one would expect annual reductions in congestion and crash costs of $\$144 \times 243 \text{ days} = \$34,992$ per year. However, from the locality's perspective, the locality must absorb the maintenance costs. Assuming the configuration has two directional separated bike lanes, the net benefit would be $\$34,992 - \$11,455 = \$23,537$.

These amounts could increase or decrease depending on the specific local context. For a locality with the same goal of reducing VMTs, if many potential bicycle trips were observed between two points, 3 miles apart, where most of the route was a shared-use path with a small gap consisting of a nonseparated bike lane, the benefit of the flexposts could be quite high relative to the cost of installation. By contrast, installation would be less beneficial in terms of mode split if no vehicle trips could simply be diverted to a nonmotorized mode. Localities might also have a different goal than mode split. The separation provided by flexposts clearly increases comfort for nonmotorized users (Montgomery County Planning Department, 2017), and thus the value of this increase in comfort could be a sufficient goal for some localities.

Scenario 2. Choosing Not to Install and Maintain GCPMs or Flexposts

A locality might, on reviewing the information in this study and considering the maintenance and replacement costs, decide not to install GCPMs or flexposts. An example could be a locality that was willing to seek grant funding for a project to install a separated bicycle lane with GCPMs and flexposts. On realizing that it would not be able to cover maintenance costs of up to \$4,585 per mile, the locality could decide not to pursue the project. In such a situation, the chief benefit of this maintenance cost information is the avoided construction expenditures for a transportation improvement that would not be maintained. Debris in the facility could pose a

hazard to users, as FHWA (2024a) noted. The benefit of avoiding such a condition is not quantified here.

Tables 3, 4, and 6 presented case studies of single installations in relatively small localities with installation costs converted to 2025 dollars of \$26,375 in Danville, \$20,272 in Front Royal, and \$51,086 in Halifax. These costs could conceivably be appropriate for a hypothetical scenario in which a locality has not fully considered its capacity to maintain GCPMs and flexposts. In this case, the average avoided installation cost would be \$32,576.

Summary of Quantitative Benefits for Both Scenarios During a 5-Year Period

For many of Virginia's 133 cities and counties, it may be the case that additional information resulting from recommendations 1, 2, and 3 has no effect under the two scenarios described here. Some localities, such as Arlington, are already making investments and accepting the maintenance costs, and other localities may never consider making these investments. In both cases, the monetary benefits described here would not be realized. However, given that one motivation for this work was local interest in these maintenance costs, one would expect some localities, especially those with interest but limited experience with these treatments, to find this information beneficial. If three of Virginia's 133 localities found this information beneficial—one for scenario 1 (crash reduction), another for scenario 1 (mode shift), and one for scenario 2—then in a single year, one would expect the value of this information, using the assumptions provided here, to be $\$91,266 + \$23,537 + \$32,576 = \$147,379$. During 5 years, the crash-reduction and mode-shift benefits plus the one-time scenario 2 benefit would total more than \$600,000.

The quantitative benefits do not include the potential results of recommendations 2 and 3—greater efficiency of maintenance practices. One example is the guidance helping a locality avoid installing thermoplastic GCPMs on pavement that is rated Very Poor; another example is a locality entering into an agreement with VDOT, in which each party undertakes the activities it can do more efficiently. However, it is not possible to quantify these benefits without additional local context information, such as the results of the pilot noted in recommendation 3, and thus those benefits are not included here. Similarly, the benefits to transportation system users are not included. In addition, maintenance costs are only one factor in determining whether to use GCPMs or flexposts. Other context-specific considerations include operational impacts, maintenance capabilities, facility lifecycle costs, and more.

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APPENDIX

Screening Survey to Identify Localities and VDOT Districts with Green-Colored Pavement Markings or Flexposts

The following text and images were presented to survey respondents as an overview. Questions and branching logic are displayed in the flow diagram following the overview.

Survey Overview

The Virginia Transportation Research Council (VTRC) is performing a study on the long-term maintenance costs and needs of green-colored pavement markings (GCPMs) and flexible post delineators (flexposts) used for bicycle and pedestrian infrastructure within Virginia. This study will assess the use of GCPMs and flexposts in Virginia to help localities and VDOT make informed decisions concerning which types of treatments they can reasonably maintain and to inform their maintenance budgets.

Green-Colored Pavement Markings

GCPMs are often used to denote the roadway space where bicyclists operate. GCPMs may deter drivers from parking in bike lanes and help decrease obstructions in bicycle facilities. A wide variety of marking types using green-colored materials have been used to designate bicycle facilities. Some examples of GCPM use are shown below.





Flexposts

Flexposts are used in several different roadway applications to delineate lanes and channelize traffic. This study will examine flexposts in the context of separated bicycle lanes (primarily) and pedestrian facilities.

Flexposts for Bicycle Applications

Also known as cycle tracks or protected bike lanes, separated bicycle lanes have some form of vertical physical separation from motor-vehicle traffic, in contrast to standard or buffered bike lanes that utilize striping alone to separate the bicycle lane from the general-purpose lane. An example of flexposts used in a bicycle application is shown below.



Flexposts for Pedestrian Applications

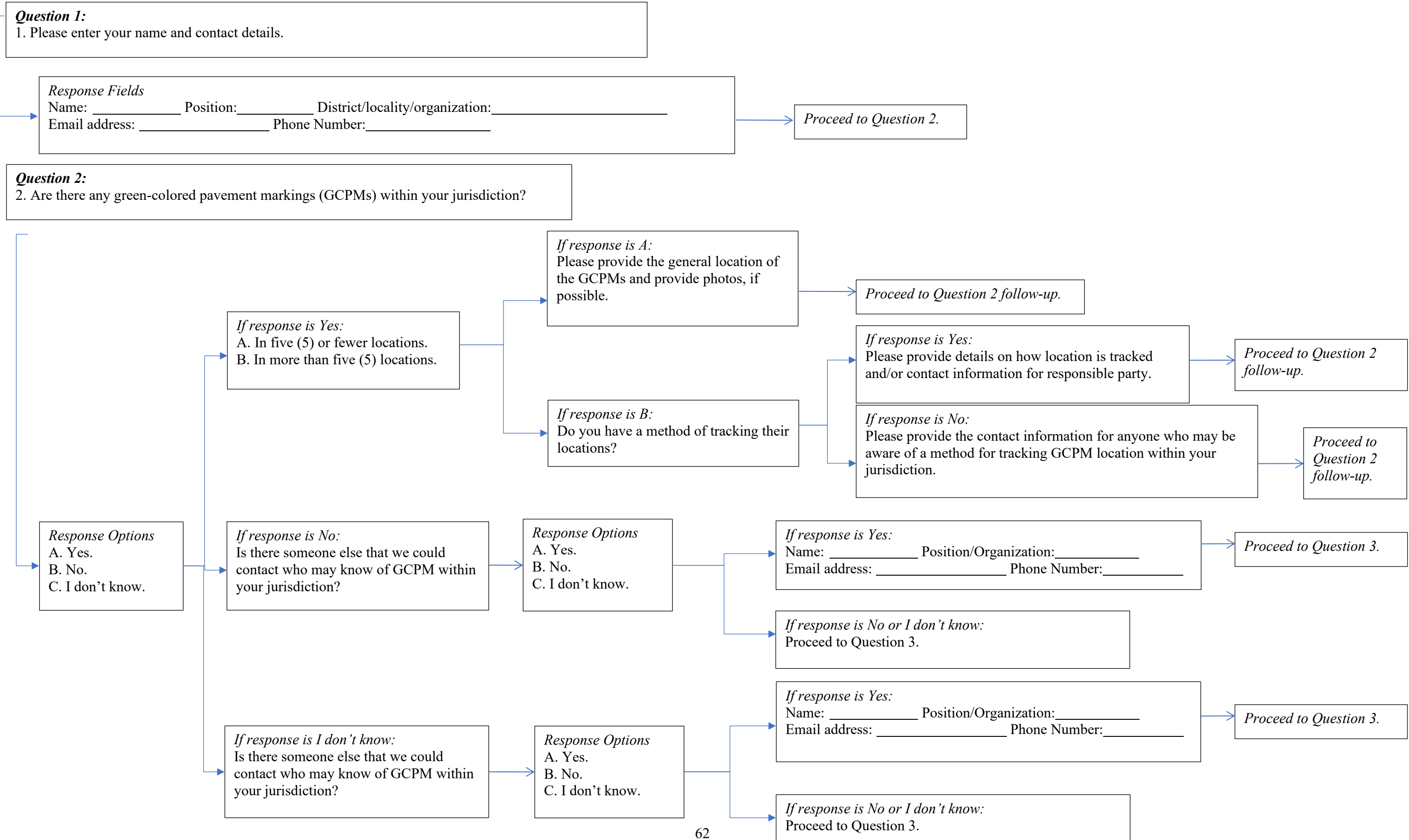
Flexposts have been employed in pedestrian facility applications such as curb extensions and interim pedestrian lane facilities, where they offer a flexible, low-cost solution for enhancing pedestrian visibility and safety in temporary or constrained environments. Examples of flexposts used in pedestrian applications are shown below.



Two surveys will be conducted as part of this project:

1. A screening survey (this survey) to collect information on which localities and districts within Virginia deploy these infrastructure elements and to collect contact information for maintenance personnel.
2. An in-depth survey of maintenance personnel from localities and/or districts with these infrastructure elements to gather information on materials used and their applications, along with maintenance costs, frequency, labor required, and equipment. The in-depth survey is anticipated to be sent out in early May 2025.

A brief description of the project can be found here: <https://vtrc.virginia.gov/projects/all-projects/126298/>.



Question 2 Follow-Up:

This study will include a few case study locations, looking in-depth at installation and maintenance costs and requirements for green-colored pavement markings. Are there any locations within your jurisdiction that you believe would be good candidate locations?

Response Fields

Location: _____ Infrastructure (GCPM, flexposts, both): _____
Installation year: _____

Proceed to Question 3.

Question 3:

3. Are there flexible post delineators (flexposts, tubular markers, etc.) used for **bicycle infrastructure** within your jurisdiction?

If response is Yes:

- A. In five (5) or fewer locations.
- B. In more than five (5) locations.

If response is A:

Please provide the general location of the flexposts and provide photos, if possible.

Proceed to Question 3 follow-up.

If response is B:

Do you have a method of tracking their location?

If response is Yes:

Please provide details on how location is tracked and/or contact information for responsible party.

Proceed to Question 3 follow-up.

If response is No:

Please provide the contact information for anyone who may be aware of a method for tracking flexpost location within your jurisdiction.

Proceed to Question 3 follow-up.

Response Options

- A. Yes.
- B. No.
- C. I don't know.

If response is No:

Is there someone else that we could contact who may know of flexposts used for bicycle infrastructure within your jurisdiction?

Response Options

- A. Yes.
- B. No.
- C. I don't know.

If response is Yes:

Name: _____ Position/Organization: _____
Email address: _____ Phone Number: _____

Proceed to Question 4.

If response is No or I don't know:

Proceed to Question 4.

If response is Yes:

Name: _____ Position/Organization: _____
Email address: _____ Phone Number: _____

Proceed to Question 4.

If response is No or I don't know:

Proceed to Question 4.

Question 3 Follow-Up:

This study will include a few case study locations, looking in-depth at installation and maintenance costs and requirements for flexposts used for **bicycle infrastructure**. Are there any locations within your jurisdiction that you believe would be good candidate locations?

Response Fields

Location: _____ Infrastructure (GCPM, flexposts, both): _____
Installation year: _____

Proceed to Question 4.

Question 4:

4. Are there flexible post delineators (flexposts, tubular markers, etc.) used for **pedestrian infrastructure** within your jurisdiction?

If response is Yes:

- A. In five (5) or fewer locations.
B. In more than five (5) locations.

If response is A:

Please provide the general location of the flexposts and provide photos, if possible.

Proceed to Question 4 follow-up.

If response is B:

Do you have a method of tracking their location?

If response is Yes:

Please provide details on how location is tracked and/or contact information for responsible party.

Proceed to Question 4 follow-up.

If response is No:

Please provide the contact information for anyone who may be aware of a method for tracking flexpost location within your jurisdiction.

Proceed to Question 4 follow-up.

Response Options

- A. Yes.
B. No.
C. I don't know.

If response is No:

Is there someone else that we could contact who may know of flexposts used for **pedestrian** infrastructure within your jurisdiction?

Response Options

- A. Yes.
B. No.
C. I don't know.

If response is Yes:

Name: _____ Position/Organization: _____
Email address: _____ Phone Number: _____

Proceed to Question 5.

If response is No or I don't know:

Proceed to Question 5.

If response is Yes:

Name: _____ Position/Organization: _____
Email address: _____ Phone Number: _____

Proceed to Question 5.

If response is No or I don't know:

Proceed to Question 5.

Question 4 Follow-Up:
This study will include a few case study locations, looking in-depth at installation and maintenance costs and requirements for flexposts used for **pedestrian infrastructure**. Are there any locations within your jurisdiction that you believe would be good candidate locations?

Response Fields

Location: _____ Infrastructure (GCPM, flexposts, both): _____
Installation year: _____

Proceed to Question 5.

Question 5:
5. Whom should we contact regarding detailed maintenance information for GCPMs and/or flexposts?

Response Options

- A. Me.
- B. Someone else.
- C. I don't know.

If response is Me:
Proceed to Question 6.

If response is Someone else:
Name: _____ Position/Organization: _____
Email address: _____ Phone Number: _____

Proceed to Question 6.

If response is I don't know:
Is there someone else that we could contact who may be able to put us in touch with maintenance personnel?

Response Options
A. Yes.
B. No.
C. I don't know.

If response is Yes:
Name: _____ Position/Organization: _____
Email address: _____ Phone Number: _____

Proceed to Question 6.

If response is No or I don't know:
Proceed to Question 6.

Question 6:
6. Please provide any additional information, photographs, or contacts that you think would be useful for our study. Thank you!

End Survey.