TECHNICAL REPORT STANDARD PAGE

1. Title and Subtitle
Best Practices for Maintenance of Control-of-Access Fencing

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5. Report No.
FHWA/LA.25/706

6. Report Date
March 2025

7. Performing Organization Code
LTRC Project Number: 23-8SS
SIO Number: DOTLT1000378

8. Type of Report and Period Covered
Final Report
1/2023–12/2024

9. No. of Pages
106

10. Supplementary Notes
Conducted in Cooperation with the U.S. Department of Transportation, Federal Highway Administration.

11. Distribution Statement
Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161.

12. Key Words
C-of-A fencing; right-of-way fencing; fencing maintenance; pedestrian and animal crashes

13. Abstract
This report examines the current practices and challenges associated with the maintenance of control-of-access (C-of-A) fencing along highways, with a particular focus on the Louisiana Department of Transportation and Development (DOTD). C-of-A fencing is an essential infrastructure component, designed to enhance the safety, security, and operational efficiency of highways by preventing unauthorized access and reducing wildlife and pedestrian incidents. Despite its critical role, the maintenance of C-of-A fencing faces significant challenges, especially in regions such as Louisiana, where environmental conditions, high traffic volumes, and budget constraints complicate maintenance efforts.

The primary purpose of C-of-A fencing is to safeguard the perimeters of highways from intrusion by people, animals, and vehicles, thereby ensuring the unimpeded flow of traffic and enhancing roadway safety. The American Association of State Highway and Transportation Officials (AASHTO) recommends that both fully and partially managed facilities consider the establishment of C-of-A fencing as part of comprehensive access control management. In Louisiana, maintenance challenges are exacerbated by frequent damage from run-off-road crashes, particularly in urban areas with high average annual daily traffic (AADT), and the degradation caused by overgrown vegetation due to irregular maintenance schedules.

This report reveals that Louisiana DOTD, like many other state DOTs, currently employs a reactionary maintenance strategy. This approach involves addressing fencing issues as they arise, often in response to specific requests from local governments and stakeholders. Such a strategy, while common, leads to delayed responses and potentially higher long-term maintenance costs due to the accumulation of unaddressed minor damage that could escalate into major repairs.

Through a comprehensive review and a survey conducted across all 50 U.S. states, this report identifies best practices and common challenges in the maintenance of C-of-A fencing. The materials most commonly used for these fences include galvanized steel, chain link, and woven wire, which are chosen for their durability and effectiveness. However, even these robust materials are vulnerable to damage from environmental factors, vehicular impacts, and vandalism.

The findings from the survey underscore the varied approaches adopted by different states regarding the installation and maintenance of C-of-A fencing. While some states have stringent regulations requiring fencing along all highway rights-of-way, others assess the need on a case-by-case basis, particularly for interstate highways. This variability reflects diverse statutory and regulatory environments across the states. Moreover, maintenance responsibilities are primarily managed by state DOTs, with occasional collaboration with other entities, highlighting a predominant state role in fencing maintenance.

This report advocates for a shift toward preventive maintenance strategies. These strategies involve regular inspections and the early detection of potential issues, which could significantly reduce repair costs and extend the lifespan of the fencing. Additionally, exploring alternative materials and standardizing installation and maintenance practices could further enhance the durability and cost-effectiveness of C-of-A fencing.

In conclusion, improving the maintenance of C-of-A fencing is imperative for ensuring the safety and efficiency of highway infrastructure. This report recommends that Louisiana DOTD, along with other state DOTs, consider revising their fencing policies to incorporate preventive maintenance measures and explore the use of alternative materials. By adopting a more proactive maintenance approach and updating policies to clarify ownership and responsibilities, states can ensure that C-of-A fencing remains a reliable and economically viable component of highway safety and management. This strategic shift not only promises to mitigate current maintenance challenges but also streamline operations and potentially reduce overall costs associated with fencing repairs and replacements.

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Best Practices for Maintenance of Control-of-Access Fencing

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LTRC Project No. 23-8SS
SIO No. DOTDLT1000472

conducted for
Louisiana Department of Transportation and Development
Louisiana Transportation Research Center

March 2025

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Through a comprehensive review and a survey conducted across all 50 U.S. states, this report identifies best practices and common challenges in the maintenance of C-of-A fencing. The materials most commonly used for these fences include galvanized steel, chain link, and woven wire, which are chosen for their durability and effectiveness. However, even these robust materials are vulnerable to damage from environmental factors, vehicular impacts, and vandalism.

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regulations requiring fencing along all highway rights-of-way, others assess the need on a case-by-case basis, particularly for interstate highways. This variability reflects diverse statutory and regulatory environments across the states. Moreover, maintenance responsibilities are primarily managed by state DOTs, with occasional collaboration with other entities, highlighting a predominant state role in fencing maintenance.

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In conclusion, improving the maintenance of C-of-A fencing is imperative for ensuring the safety and efficiency of highway infrastructure. This report recommends that Louisiana DOTD, along with other state DOTs, consider revising their fencing policies to incorporate preventive maintenance measures and explore the use of alternative materials. By adopting a more proactive maintenance approach and updating policies to clarify ownership and responsibilities, states can ensure that C-of-A fencing remains a reliable and economically viable component of highway safety and management. This strategic shift not only promises to mitigate current maintenance challenges but also streamline operations and potentially reduce overall costs associated with fencing repairs and replacements.

Acknowledgments

The research team acknowledges the assistance provided by the maintenance division of the Louisiana Department of Transportation and Development (DOTD) in supporting this study. The team also expresses gratitude to the employees of various state DOTs across the U.S. who participated in the survey.

Implementation Statement

This report, along with the accompanying informational guide, should assist in the adoption of comprehensive maintenance guides based on manufacturer recommendations. Aligning these with existing resources and budget allocations can significantly enhance the effectiveness of fencing management.

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Introduction

Control-of-access (C-of-A) fencing around a highway is a barrier to keep people, animals, machinery, and other objects from trespassing into the vicinity of moving traffic or operating right-of-way (ROW). According to the American Association of State Highway and Transportation Officials (AASHTO), both fully and partially managed facilities should be considered for establishing C-of-A fencing as part of access control management [1] [2]. C-of-A fencing can be an integral part of the overall highway infrastructure and is built wherever the safety of highway operations necessitates it [1].

C-of-A fencing has been identified as a maintenance issue for Louisiana DOTD. Inadequate maintenance could compromise safety and mobility on high-volume roadways by allowing access to vulnerable road users such as pedestrians, cyclists, and animals and by enabling illegal vehicle entry from frontage and side roads. Maintaining these fences can be particularly challenging due to damage from run-off-road crashes, especially in high-volume urban areas where such crashes are more frequent. Additionally, budgetary constraints further complicate the repair and replacement of aging or damaged fences. Due to limited funding, local governments sometimes request that DOTD remove or replace current fencing for maintenance purposes or aesthetic reasons. To address these maintenance challenges, it is important for Louisiana to evaluate the best practices of other state DOTs and jurisdictions for maintaining C-of-A fencing.

Maintenance management costs require knowledge of current design standards. Louisiana's current design standard typically allows fences to be constructed at 5 feet tall and often allows for an additional 1 foot of barbed wire if needed [3]. In terms of the materials used, current standards permit the use of aluminum alloy, galvanized ductile steel, aluminum-coated ductile steel wire, and Polyvinyl Chloride (PVC)-coated steel, which are designated as Type I, II, III, and IV fencing respectively.

To minimize fencing maintenance costs while ensuring mobility on controlled-access highways, an improved understanding of the factors contributing to fencing damage should be beneficial. Reviewing available national practices and alternative guidance resources, including but not limited to synthesis reports, can be advantageous. Additionally, assessing current statewide fence management strategies, encompassing any available fence maintenance policies and practices, can be useful. Design standards and alternative fencing options, along with how they vary by state based on the fence's purpose, are explored in this report.

Literature Review

The following section lays the foundation for this report by discussing key topics such as highway functional class, access control, and criteria for the implementation of C-of-A fencing. It provides the necessary context and background to frame the subsequent Discussion of Practices section, which explores specific design and maintenance practices from various states, with a particular emphasis on Louisiana.

Highway Functional Class and Accessibility

Functional classification categorizes highways, roads, and streets by the service they provide, based on the balance between mobility and access. This process guides transportation planners to efficiently channel travel through an interconnected road network [4]. Effective access management necessitates that a road be planned, developed, and maintained to offer the balance of accessibility and mobility required for its functional classification. In Figure 1, the relationship between mobility and accessibility is illustrated; this is illustrated in greater detail with specific highway classes in Figure 2 [5].

Figure 1. Roadway functional class and accessibility mobility [6]

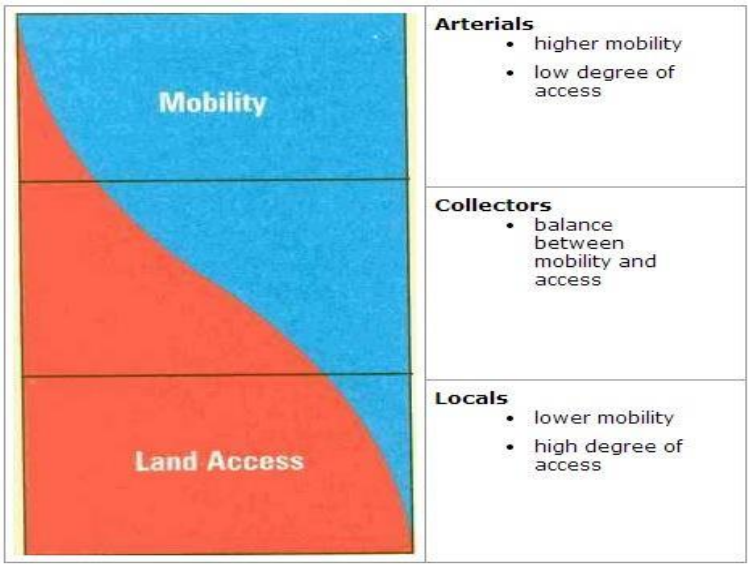
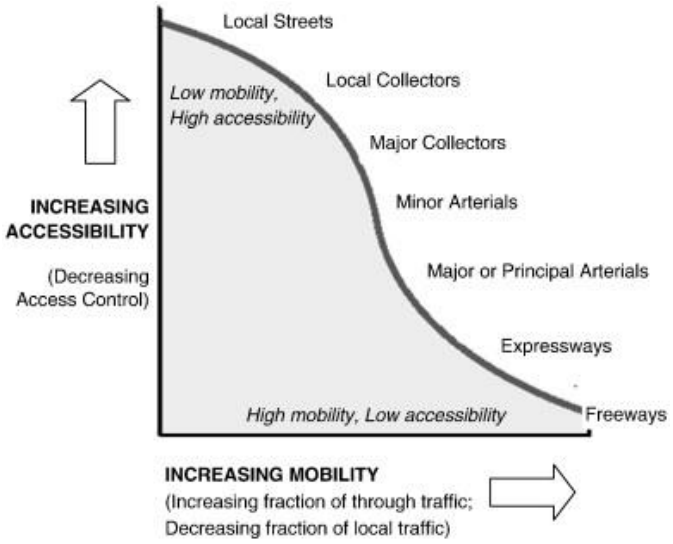


Figure 2. Relationship of balance between accessibility and mobility by highway class [5]



Highway functional classification divides roads into urban and rural areas based on the mobility and access provided within the road network. While local roads are used for shorter trips, arterials are employed for longer trips because of their high mobility but limited access to the property. Collectors provide the link between arterials and minor roads. The classification of roadways is crucial for road upgrades to be conducted properly and to prevent failures [6].

Depending on the functional class and accessibility level of a given roadway, various levels of access control can be employed by state DOTs. To increase safety and manage traffic flow, DOTs have guidelines and regulations for C-of-A fencing, which rely on the functional classifications or level of accessibility of the highway. AASHTO categorizes the functional class into numerous categories, from local roads to major highways. This classification is primarily determined by the type of traffic the roadway serves [7]. Access control and management are typically required on interstates and principal arterials.

Access Control

Access control is a technique for making a highway user's environment safe while protecting the investment in a highway design's physical and capacity components [8]. Access control focuses on ensuring mobility, enhancing safety for highway users, and protecting the investment in a highway's physical and capacity components. A roadway agency responsible for access management enforces these measures through regulations and physical infrastructure [9]. By restricting the number of entry points and controlling the types of

vehicles and pedestrians allowed, access control is crucial for reducing the possibility of crashes caused by unlawful or unsafe entry to the road. These methods also improve traffic flow, reduce congestion, and enhance overall safety by limiting potential conflict points. Furthermore, the strategic management of entry points contributes significantly to highway safety and operational efficiency.

There are three levels of access control, which differ based on accessibility and mobility needs. The following are descriptions of the three fundamental categories of access control:

- **Type 1—Full Control (Freeway):** This type of access is only permitted at interchanges with specific public routes, allowing for complete access control. There may not be any at-grade crossings or connections to private driveways [9]. The terms used to identify this type of access control can differ by jurisdiction; for example, the California Department of Transportation (CALTRANS) and Virginia DOT describe this type of access as limited access [10] [11], while Indiana DOT defines it as full limited access [12]. Complete access control offers priority to through traffic by creating access connections with specific public roadways via interchanges [13].
- **Type 2—Partial Control:** Partially controlled access falls between total control and regulatory limitation. Through traffic is given preference; however, at-grade crossings and private driveway connections are permitted in certain places [9].
- **Type 3—Control by Regulation (Conventional Roadway):** This type warrants some access restrictions on all roads. The adverse effects on traffic capacity and safety can be mitigated by strategically designing and placing access points [9]. Direct vehicular access from neighboring properties to and from the through traffic lanes is allowed on typical roads, although access management guidelines should limit direct access.

Access Control Examples

Typical examples of implementing access control include the use of physical obstacles, signage, and traffic signals. For instance, on-ramps and off-ramps may be equipped with traffic signals or barriers to control the flow of traffic onto and off of the highway. Median barriers can prevent vehicles from encroaching into opposite lanes, reducing the risk of crossover collisions. In some cases, fences or walls may be constructed to keep people off the highway or to protect nearby homes from noise and pollution generated by the highway, though this is atypical. It is important to understand the levels of access control, as these measures are often implemented based on the specific level of access required.

Public roadways can only be connected via interchanges when access is fully controlled. Connections to specific public roads and specific drives are made possible by partial control of access to service the neighboring homes. For instance, CALTRANS and Wisconsin DOT emphasize access management's significance in preserving the efficiency and safety of state highways [14]. CALTRANS manages access along routes and reduces conflicts between traffic and local traffic using a variety of measures, including frontage roads, service roads, and interchanges [10] [15]. In much the same way, Texas Department of Transportation (TxDOT) employs access management techniques to enhance traffic flow and safety along state roadways. TxDOT regulates highway access and reduces the adverse effects of development on traffic operations by using various methods, such as driveway design, signalization, and right-of-way purchases [16] [17]. Other states using access management techniques in their transportation planning and innovation are the Florida Department of Transportation (FDOT) [18] and the North Carolina Department of Transportation (NCDOT) [19] [20]. FDOT uses frontage roads, overpasses, and turn lanes, while NCDOT employs spacing regulations, median crossovers, and traffic signal spacing to control access and improve road safety.

Louisiana DOTD makes efforts to inform the public of how access management strategies improve road safety and efficiency by controlling the location and design of driveways, intersections, and traffic signals [21]. The emphasis is on reducing conflict points—locations where vehicle paths intersect or diverge, increasing the risk of accidents. The document highlights several effective practices: 1) ensuring the adequate spacing of commercial driveways to prevent traffic issues; 2) installing exclusive lanes for turning to improve traffic flow and reduce obstructions; 3) using raised medians to safely manage turning options; and 4) building roads parallel to main highways to handle local traffic and alleviate main road congestion. These methods collectively enhance roadway capacity, minimize delays, and promote economic development by ensuring the smoother movement of goods and services.

Relationship between Access Control and Control-of-Access Fencing

Depending on the functional class of the roadway and the needed level of accessibility, several access control mechanisms, such as C-of-A fencing, may be used. For instance, arterial roads designed for high-speed, high-volume traffic may require more restrictive access control measures, such as C-of-A fencing and limited access points, to ensure safe and efficient traffic flow [9]. On the other hand, collector and local roads, which are intended for slower-moving and lower-volume traffic, require less stringent measures, such as median barriers or traffic signals. These roads often feature intersections and designated pedestrian facilities and typically do not require C-of-A fencing.

The functional class of the roadway can heavily influence the level of C-of-A fencing required. For example, New York DOT [13] determines its rules for C-of-A fencing based on the functional class and amount of access to a roadway. A high-traffic, high-speed arterial road generally needs more rigorous controls to regulate access and deter illegal entry. Louisiana has C-of-A fencing installed on both fully controlled and partially access controlled highways. Figures 3 and 4 display C-of-A fences segregating frontage roads from I-10 in St. Tammany Parish and the US 90 freeway between I-12 and LA 22, respectively.

Figure 3. C-of-A fencing on I-10, a fully-controlled highway

Figure 4. C-of-A fencing on US 90, a partially-controlled highway

Warrants for C-of-A Fencing

Warrants for C-of-A fencing outline the conditions justifying the installation of fencing for security, safety, privacy, or property protection purposes in a specific area. The warrants include:

- Locations with reported pedestrian or animal crashes
- Urban roadways with high-speed traffic

All of the listed locations have a high potential for conflict between roadway users, and the installation of fencing is justified as a measure to manage accessibility and prevent conflicts. This includes specific urban areas where mobility is prioritized and where limiting access is necessary to reduce the potential for safety or security issues. The warrants collectively focus on mitigating risks in environments with heightened interaction between different road users.

AASHTO considers traffic flow safety as the primary justification for highway fencing, targeting roadway hazards that need to be prevented in high-speed, high-AADT traffic [1]. According to AASHTO, fencing is warranted for at least one of the following purposes [1]:

- To keep wildlife off of the road
- To prevent children, pedestrians, and bicycles from using the road
- To prevent objects from being thrown onto the road from an overcrossing structure

Additionally, the unauthorized movement of vehicles from frontage or auxiliary roads, as well as vehicles that are restricted on fully or partially access-controlled roads (e.g., all-terrain vehicles), can be prevented using C-of-A fencing.

Major access control measures, such as raised medians and reduced crossing U-turns, can limit or manage vehicle movement; however, C-of-A fencing is particularly justified when it is necessary to restrict road access and prevent unlawful or dangerous entry from outside the roadway. In contrast, while roadside barriers are designed to prevent vehicles from unintentionally leaving the road and entering dangerous areas, thus ensuring the safety of drivers and passengers [22] [23], C-of-A fencing aims to protect roadway users from unexpected and unauthorized entry by vehicles, pedestrians, and animals, all of which can pose serious hazards.

Locations with Reported Pedestrian or Animal Crashes

The need for C-of-A fencing addresses two major access control functions on partially or fully controlled high-speed roadways where mobility is prioritized: preventing unauthorized pedestrian crossings and restricting animal movements. The presence of pedestrians without designated access points or intersections can be particularly dangerous. Identifying areas where frequent pedestrian or animal crashes have been reported is crucial to implement effective safety measures such as C-of-A fencing. These locations often indicate potential hazards or deficiencies in existing infrastructure that need to be addressed. By analyzing the data on these crashes, state DOTs can pinpoint specific areas where it is necessary to enhance safety and prevent future crashes. Implementing targeted interventions based on crash reports can significantly reduce the risk of injuries and fatalities in these areas, making streets safer for motorists.

Interstate highways incorporate exit and entry ramps to facilitate uninterrupted vehicle flow, eliminating the need for intersection controls. Some U.S. highways also provide such facilities to a lesser extent, maintaining partial access control. Aligned with optimizing safe and efficient transport, emergency response agencies aim to ensure safety and quickly restore operational status post-crash on these access-controlled highways [24] [25]. This approach discourages the presence of vulnerable road users, particularly pedestrians, whose access to interstates is restricted by state laws to prevent crashes [26] [27] [28]. The National Highway Traffic Safety Administration (NHTSA) prioritizes pedestrian safety primarily in urban areas, excluding interstates where pedestrian access might be intentionally prevented [29]. Figure 5, derived from Stamatiadis et al. (2018) [29], illustrates the varying levels of pedestrian facilities needed, highlighting the general exclusion of interstates and principal arterial highways from these considerations, especially in rural areas where pedestrian traffic is lower.

Figure 5. Pedestrian priorities in functional classification system and area type

	Rural	Rural Town	Suburban	Urban	Urban Core
Interstate	 Prohibited	 Prohibited	 Prohibited	 Prohibited	 Prohibited
Principal Arterial	 Low	 Medium	 Low	 Medium	 High
Minor Arterial	 Low	 High	 Medium	 High	 High
Collector	 Low	 High	 Medium	 High	 High
Local	 Low	 High	 Medium	 High	 High

Another important function of C-of-A fencing is restricting known animal movement on high-speed, high AADT roadways. Additionally, alternative animal movement facilities and warning signs for oversized animals are commonly used [30], especially in states like Ohio, Wyoming, and Montana where animal activities near access-controlled highways are prevalent and require wildlife deterrents with C-of-A fencing [31]. However, Louisiana is a moderate-risk state for animal vehicle crashes [32]. A study in Louisiana indicates that while the majority of animal-related crashes result in only property damage, examples in which human injuries occur can be identified, particularly in open country locations on interstate highways with speed limits of 60 mph or higher [33] [34].

Roadways in Urban Areas with High Speeds or Traffic Volumes

C-of-A fencing is usually warranted when it is necessary to restrict access to the roadway and increase safety. The choice to erect C-of-A fencing is often based on an evaluation of individual site circumstances, potential threats to road users, and nearby land usage, without considering functional classification. High-traffic urban areas are critical for congestion, crashes, and safety hazards. Understanding traffic flow dynamics and pedestrian movement may be crucial

for developing effective strategies, such as C-of-A fencing, to mitigate risks and improve safety. C-of-A fencing may be needed on highways with significant traffic or speeds to restrict unauthorized access and increase safety, as recommended by Washington State DOT (WSDOT) [22]. The fence assists in regulating traffic flow and lowering the danger of crashes on these routes, which often have few entry points.

According to WSDOT, the protection of nearby land uses such as residential areas, pedestrian facilities, or roadway bicycle facilities may necessitate the installation of a fence to enhance the quality of life for those who live nearby [22]. CALTRANS notes that in exceptional circumstances where a lower fence would be in keeping with neighboring land, a Type CL-4 fence (i.e., chain link fence) may be used instead of a Type CL-6 fence (i.e., median fencing) [10]. Additionally, according to Alabama DOT (ALDOT), the average speed on the road directly corresponds to how the route is supposed to perform. Compared with lower-speed roads that allow access to nearby roadside development, higher-speed highways enable travel between various places, such as cities, regions, and other geographic locations (e.g., businesses, residences, schools, etc.) [35].

For instance, a high-traffic, high-speed arterial road will generally need more rigorous controls to regulate access and deter illegal entry. Managing traffic and ensuring safety in densely populated urban areas presents distinct challenges. Increased pedestrian activity and jaywalking raise the likelihood of crashes. Implementing C-of-A fencing can significantly improve safety, helping to create more livable and sustainable environments for city dwellers.

Objective

The objectives of this project were to:

- Determine the best maintenance practices for control-of-access (C-of-A) fencing.
- Develop an informational guide for control-of-access (C-of-A) fencing maintenance which may aid in updating the existing fencing policy.
- Determine alternative fencing options and other practices to lower maintenance costs.

Scope

This project involved reviewing design and maintenance practices in Louisiana and other U.S. states through the analysis of reports, manuals, and guidelines. Researchers conducted a survey across all 50 states to assess access fencing practices, focusing on fully and partially controlled areas. They collaborated with state DOTs to gather information on varying practices and guidelines. Their aim was to provide a comprehensive understanding of C-of-A fencing practices, inform policy and maintenance strategies, and deliver a report outlining notable findings and recommendations.

Methodology

This study reviewed available national and state-level documents to gather information regarding C-of-A fencing installation and maintenance practices, including state guidelines, policies, recommendations, and state-of-the-art strategic maintenance practices. Additional sources such as scientific journals, conference proceedings, and presentations were also reviewed.

To supplement the available information, researchers sought to comprehensively evaluate C-of-A fencing practices across various states. The survey instrument, a structured questionnaire, was designed to gather insights into fencing design, fencing maintenance practices and procedures, fencing policy and procedural documents, and alternative fencing options. The survey comprised four main sections.

The first section of the survey sought information about the construction and maintenance practices for C-of-A fencing in other jurisdictions. It asked about the level of requirement for the installation of C-of-A fencing, the organization's approach to determining whether to install fencing, who is responsible for maintenance, the frequency of inspections, priority criteria for maintenance, and the most essential maintenance activities for ensuring the longevity and functionality of C-of-A fencing.

The second section of the survey sought information on alternative fencing practices and strategies to lower maintenance costs related to C-of-A fencing, including which options have been considered and which are most effective.

The third section of the survey sought information on informational guides and policies used in other states for C-of-A fencing. It asked about the process for weighting control in maintenance budgets, use of guides, plans to develop guides, and preferred guides.

The fourth section of the survey sought information about the design of C-of-A fencing in other jurisdictions, including the material type, height, post type, designated post spacing, and if other types of fencing are used.

The survey was conducted from September 2023 to June 2024. Contact information, including phone numbers and email addresses for various state DOTs, was collected using Google. Several calls were made to verify the accuracy of the collected contact details. Emails were sent to individuals who agreed to participate in the survey. The survey achieved a response rate of 42 out of 50 states, or 84%. The list of states that responded is provided in Appendix A.

The survey methodology entailed constructing a survey using Qualtrics [24], which was distributed to relevant state departments or experts responsible for C-of-A fencing across all 50 states. A comprehensive review of state policies and guidelines from all 50 states was conducted to answer the survey questions. Responses were systematically analyzed, with qualitative data undergoing thematic analysis. A comparative analysis was conducted to contrast different states, with a particular emphasis on Louisiana as a benchmark. Ethical considerations included maintaining respondent confidentiality, voluntary participation, and obtaining informed consent from all participants.

This methodology for survey data collection and analysis aimed to provide important insights into the variations and commonalities in C-of-A fencing practices, thereby contributing to a better understanding of the diverse approaches adopted by different states.

Discussion of Practices

Overview of C-of-A Guidelines

Federal Fencing Guidelines

Federal laws and regulations requiring fences were not found after a preliminary literature search. For its fencing regulations, the FHWA adopted standard 23 CFR 625 (AASHTO A Policy on Design Standards—Interstate System). One of the few national sources on the subject is a guide for C-of-A fencing that AASHTO released in 1990 [1]. This informational resource briefly discusses general best practices for fence ownership, type, and location. While offering general advice on C-of-A fencing, FHWA defers to state policies regarding the management of interstate access. As a result, several state DOTs have included C-of-A fencing requirements depending on their fencing purposes in their highway policy documents.

State Fencing Policies: Examples from Other States

State DOTs may revise their fencing policies for various reasons; these decisions are often driven by specific challenges and needs within each state. These revisions presumably aim to enhance safety, address environmental issues, adapt to shifting land use patterns, integrate technological advances, and comply with legal and regulatory requirements. Such modifications ensure that fencing policies effectively provide safety and security, while also responding to the evolving demands of the communities they serve.

Given the recent updates in several states, it is evident that periodic reviews and modifications of fencing policies are taking place, likely aiming to keep said policies current and effective in minimizing risks and enhancing safety for all road users. Examples of recent state updates include:

- California Department of Transportation (CALTRANS)—July 1, 2020 [10]
- Kentucky Transportation Cabinet—November 8, 2017 [25]
- Texas DOT—April 29, 2021 [36]
- Idaho DOT—January 9, 2014 [26]
- North Carolina DOT—August 30, 2019 [27]

State DOTs have updated their fencing policies for various reasons, reflecting changes in safety requirements, environmental considerations, land use, technology, and legal obligations. The policies focus on effectively enhancing safety and security while addressing the dynamic needs of communities. Below are insights into each state's approach to fencing, emphasizing the specific aspects and updates. Relevant details of these new policies are discussed in the following sections, which provide insights into each state's approach to the purpose and function of fences, ownership responsibilities, types of fences, and exceptions to standard fence types.

CALTRANS (California Department of Transportation) [10]

- **Access Control:** Fences are intended to signal limited access rather than act as complete physical barriers.
- **Ownership and Responsibility:** CALTRANS owns and maintains fences within its rights-of-way. Fences outside the rights-of-way are considered private and are the responsibility of the property owner.
- **Types of Fences:** CALTRANS constructs three types of fences for freeway and expressway access control: departmental, median, and privacy fences. Standard freeway fencing includes chain link (Type CL-6), barbed wire (Type BW), wire mesh (Type WM), and median fencing (Type CL-4). Exceptions are permitted if alternative designs meet or exceed the standards of durability, maintenance, and dimensions.
- **Special Design Fences:** Distinctive designs are used for wildlife control or where aesthetics is a concern, allowing for lower fences that blend with surrounding properties.
- **Gate Controls:** In cases where access control requires more than physical barriers alone, CALTRANS may install locked gates as part of the fencing structure. These gates are used to control entry to restricted areas, ensuring that only authorized personnel have access. Proposals for locked gates must address a defined necessity, particularly on routes where controlled access is crucial. This addition helps maintain operational integrity and security along the highways.

KYTC (Kentucky Transportation Cabinet) [25]

- **Fencing Policy Update 2017:** Responding to damage, vegetation overgrowth, and aesthetic requests, KYTC recommended replacing existing fences with more decorative options, such as vinyl or wood.

- **Right-of-Way and C-of-A Fences:** These fences serve as a quick method to assess encroachments. While typically required to stay in place to prevent unauthorized encroachments, removal may be permitted on certain roadways with proper agreements.
- **Fencing Requirements:** New fences must be at least 48 inches tall, built with durable materials, and positioned 1 to 2 feet outside the right-of-way line. Maintenance responsibilities fall to the permittee, with potential for separate maintenance agreements.

TxDOT (Texas Department of Transportation) [36]

- **C-of-A Fencing:** TxDOT underscores the need for fencing along rights-of-way to prevent unauthorized access to roadways and ensure traffic safety. The agency is responsible for construction and maintenance, ensuring uniformity and compliance with safety standards.
- **Engineering Determination:** An engineering review is necessary to determine the need for fencing during right-of-way acquisitions, ensuring FHWA compliance and enhanced safety.
- **Land Acquisition:** When C-of-A fencing is required for a highway facility, TxDOT is responsible for constructing and maintaining the fence as part of the land acquisition process. This ensures proper installation and maintenance, enhancing safety along rights-of-way. Responsibility for maintaining the fences rests with TxDOT, not the landowner.
- **Installation:** TxDOT must adhere to specific procedures when installing C-of-A fencing. Purchase agreements for extra right-of-way include detailed clauses outlining TxDOT's responsibilities for fence installation and maintenance, including gates or cattle guards where necessary.

Louisiana Fencing Guidelines from Engineering Directives and Standards Manual

Louisiana DOTD provides guidelines for constructing, replacing, and maintaining fences on highway rights-of-way, as detailed in the Engineering Directives and Standards Manual (EDSM), Volume II, Chapter 2, Section 1, Directive 3 (EDSM No: II.2.1.3), issued on May 10, 2017 [3]. This concise document outlines responsibilities for fence construction and removal, compensation for affected property owners, and the installation of C-of-A fencing. The issues associated with the report are outlined below:

- **Uniform guidance for constructing and replacing fences on highway rights-of-way:** These guidelines provide a standardized method for installing and removing fences to ensure they meet specified standards and are properly maintained. All fences built to control access must be maintained by DOTD. Only other fences with an approved project

permit can only be placed on the highway rights-of-way. Improperly located fences must be corrected before DOTD will accept them.

- **Rebuilding, reconstruction, replacement, or compensation for fencing:** The guidelines specify procedures for replacing, rebuilding, or compensating for fencing that encloses residual property when a roadway is constructed or rebuilt. DOTD is responsible for rebuilding, reconstructing, replacing, or providing compensation for existing fencing under these circumstances. The permittee is tasked with replacing any permitted fence on the highway right-of-way.
- **Ownership and payment for fencing:** The guidelines specify that negotiations for the purchase of rights-of-way should include the cost for the property owner to replace any existing fencing. When a right-of-way acquisition entails the destruction of a livestock fence enclosure, the rebuilt or new fence will be included in the contract for construction on the owner's property to restore the enclosure. Compensation will only be provided for the portion of cross fencing that is removed and not replaced due to the reduction in size of the remaining property.
- **Removal of existing fences and placement of new fences:** The guidelines state that the contractor hired by DOTD during construction will remove any existing fences, and no payment will be made for any fences installed by permit. Fences placed on the highway right-of-way without a permit will be deemed an encroachment and must be removed according to DOTD guidelines.
- **Guidelines for C-of-A fencing:** In addition to addressing ownership and maintenance issues, the directive stipulates that erecting C-of-A fencing on highway rights-of-way requires a properly executed and issued project permit by DOTD guidelines. DOTD is responsible for constructing and maintaining these fences. Fences that are inappropriately positioned must be corrected before DOTD will accept the work.

Common C-of-A Fencing Types and Design Issues

This section discusses design-related practices in other states, including common fencing types, their characteristics, fencing gates, and more. Highways and other transportation infrastructure are protected by various fencing types and designs used by state DOTs [9] [28]. The following types of fences typically apply, either singularly or in combination, based on the purpose in view. Various fencing options are available depending on each type's durability, appearance, and maintenance. According to the transportation departments of New York, North Carolina, and Mississippi, the two most prevalent types of fences encountered on

American freeways are the woven wire fence and the chain link fence [9] [19] [23]. Additionally, New York DOT has reintroduced the mandate for local districts' involvement in determining the distinct features of the fence, such as the post type and the height of the chain link fence. States with high animal populations, such as Ohio, Montana, and Wyoming, often implement specific fencing designs tailored to animal sizes and seasonal movement patterns to mitigate vehicle collisions on access-controlled highways [31]. These designs aim to maintain mobility while preventing severe incidents involving large animals. Extremely tall fences (i.e., 7 to 10 feet high) may be used in areas with large concentrations of deer or elk [22]. The following subsections cover general fencing height, material, and design requirements for various fencing types .

Design issues may impact the effectiveness of C-of-A fencing as a deterrent. C-of-A fencing can help prevent access, but it may not be sufficient to stop determined people or vehicles from attempting to breach or bypass the fence. An example of Washington State DOT using 10 foot 4 inch fence can be found at several interstate entry points of I-5 [37].

Woven Wire Fence

According to AASHTO, woven wire fencing is used for controlling livestock, small animals, and children (see Figure 6), and according to West Virginia DOT, the fence is made of 3 feet 11 inch tall galvanized woven wire [1] [38]. Michigan DOT describes it as the most common type of fence found in rural regions. It is often approximately 4 feet high, made of steel posts and utilizing wooden posts if built on soggy ground. Steel posts typically cost less than wood, causing contractors to prefer steel to wood whenever possible [28]. According to Mississippi DOT requirements, timber poles must be used in rural areas, while concrete posts must be used inside interchange borders [9]. Additionally, according to Alaska DOT, the woven wire fabric must conform to AASHTO M 279 standards, specifically Design Number 726-6-12 ½, Grade 60, with Coating Type Z and Coating Class 3 [39]. In the specification, Coating Type Z typically refers to zinc coating, while the coating class specifies the thickness or weight of the zinc coating. Zinc coating is often used to protect steel and iron materials from corrosion. The higher the class number, the thicker the zinc coating. In this case, Coating Class 3 suggests a specific thickness or weight of the zinc coating.

In Georgia, the fabric for woven wire fences must meet the American Society for Testing and Materials (ASTM) standard A 116, Design Number 1047-6-11, with a Class 3 coating, ensuring uniform galvanizing and less than 5% deficient zinc joints per ASTM A 239. Aluminum-coated steel fabric that meets ASTM A 584, Design Number 1047-6-11, is also acceptable. Posts should be steel or wood of specified sizes, with wood posts meeting

Subsection 862.2.01 requirements and steel posts and bracing conforming to ASTM A 702, hot-dip galvanized per ASTM A 123/A 123M [40]. It is essential to ensure that fencing does not straddle or obstruct surveying monuments [22].

Figure 6. Woven wire fence on I-75 in Georgia [41]

Chain Link Fence

In Texas, chain link fences are typically 4 feet high, increasing to 6 feet where needed for pedestrian control on urban and suburban freeways [42]. If frontage roads exist alongside urban and suburban freeways, C-of-A fences should be positioned approximately midway between the mainlines and frontage roads, at least 30 feet from the mainline pavement, and can double as right-of-way fences when aligned with the right-of-way line.

Mississippi DOT and Connecticut DOT advise that chain link fences should be constructed 5 feet high in urban or developed areas; areas with significant pedestrian activity should have fences 6 feet high [9] [43]. In Georgia, chain link fences must use zinc or aluminum-coated steel fabrics, fittings, accessories, and posts. The fence fabric should be 2 inch square mesh, with zinc-coated fabric conforming to AASHTO M 181, Type I, Class C, and aluminum-coated fabric to AASHTO M 181, Type II [40]. West Virginia DOT employs a 2 inch mesh, 5 foot high chain link fence with an aluminum or zinc coating [38]. Arizona, by contrast, only allows one type of material (either zinc-coated galvanized steel or aluminum-coated steel) for each

project [44]. In urban areas in Michigan, chain link fences are most common, and in some cases, both woven wire and chain link fencing are implemented if the nearby development has both rural and urban characteristics [28]. The height of chain link fences can be modified to suit the need. For example, Florida DOT recently constructed a 10 foot high fence topped with barbed wire to prevent panthers from crossing Interstate 75 [45], as shown in Figure 7.

Figure 7. Chain link fence at 10 feet high on I-75 in Naples, Florida [45]

High Tensile Eight-Wire

Some DOTs, such as Michigan DOT, use a high-tensile eight-wire fence as an alternative to the woven wire fence for right-of-way fencing. This fence type is more cost-effective due to its wire strand construction and lack of vertical tie wires (see Figure 8). It is also thought to be more cost-effective to maintain than a woven wire fence that has been damaged or cut [28].

Figure 8. High tensile eight wire fence [46]

Gates

According to CALTRANS, gates may be provided in C-of-A fencing solely for highway maintenance personnel access [10]. In Kansas, the gates serve the additional purpose of securing the closure of cattle guards at farm crossings [47]. In Washington, gates are essential to fencing systems, allowing controlled access to fenced areas while maintaining security [22]. Gates are recommended for:

- Limited access highways to provide access for highway maintenance personnel and equipment without using the highway or freeway main line
- Providing access to utility supports, manholes, and other infrastructure within rights-of-way
- Highly developed and landscaped areas where maintenance equipment is parked outside the fence and where double gates are recommended

The integrity and security of access must always be ensured. Maintenance personnel must keep gates locked and secured when they are not in use to prevent unauthorized access. To achieve this, various gate types have been designed and implemented, including basic swing gates, swing gates with locks, and electrified gates. Simple swing gates may be suitable for low-traffic areas, whereas swing gates with locks and electrified gates may be more suitable for locations that require a higher level of protection. Typically, gates should be the same height as the fence [15] [43] [48]. In Wyoming, one-way fence gates are used to allow moose, elk, deer, and other animals to escape highway rights-of-way. In Alabama and Connecticut, all

gates must be delivered fully outfitted with certified tamper-proof hinges, latches, auxiliary braces, and all other essential fittings, as well as a large padlock with two keys and one master key for each gate [43] [49]. WSDOT recommends using gates of the same type as the adjoining fence to maintain uniformity and security. Continuous fencing is not provided on limited access highways; approaches are normally gated and locked, with a short section of fence on both sides of the gate [22].

Current Louisiana Design and Construction Details

Placement of C-of-A Fencing

Prior to discussing maintenance, it is important to discuss fencing design. In terms of the placement of C-of-A fencing, the current Louisiana DOTD policy can be divided into three categories:

- C-of-A for ramp/frontage road interchanges
- C-of-A for X-pattern interchanges with frontage roads
- C-of-A for other interchanges

The C-of-A design details for these three interchange types are presented in Appendix B; they are taken from the design documents publicly available on the DOTD website [50]. All three design cases specifically state that all C-of-A and/or ROW lines shall have fences. The fencing between access-controlled highways and frontage roads prevents illegal entry of vehicles onto the access-controlled highway. However, the C-of-A fencing outside the frontage road can also mark the ROW line and serve a dual function as a right-of-way fence.

- **C-of-A for ramp/frontage road interchanges:** C-of-A for ramp/frontage road interchange design details the placement and length of the fencing needed to prevent the encroachment of vehicles from the frontage road, as seen in Figure B1.
  - — Downstream of the interchange cross road, mainline C-of-A fencing is provided both before and after the entry ramp, separating the auxiliary or frontage road from the access-controlled road.
  - — Downstream of the interchange, outside the entry ramp on the outside of the frontage road, a minimum of 200 feet of C-of-A fencing and a minimum of 100 feet of overlap before or after the physical gore should be provided.

— Upstream of the interchange cross road, mainline C-of-A fencing is provided only before the exit ramp, separating the auxiliary or frontage road from the access-controlled road.

— Downstream of the exit ramp, outside the frontage road, a minimum of 1100 or 1320 feet of C-of-A fencing is provided from the interchange cross road, extending at least an additional 100 feet beyond the ramp. The 1100 or 1320 feet is based on a 60 or 70 mph speed limit of the main access-controlled road. This ensures that the right-in-right-out with frontage road upstream of the exit ramp cannot directly access the access-controlled main highway.

— Upstream of the frontage road, on the outside of the frontage road, at least 350 feet of C-of-A fencing is usually provided, overlapping the fencing between the frontage road and the access-controlled road. This ensures that the right-in-right-out with the frontage road downstream of the interchange cannot directly access the access-controlled main highway.

— Some overlap occurs with the fencing between the frontage road and the access-controlled road just downstream of the interchange. On the outside of the frontage road, 350 feet of C-of-A fencing is provided, beginning at the turnout radii. Additionally, C-of-A fencing is installed outside of the interchange cross roads.

Although the fencing separating the access-controlled road and the frontage road is designed to prevent encroachment from the frontage road to the access-controlled roadway, the fencing present outside the frontage road and the interchange cross road also serves as a ROW marker.

- **C-of-A for X-pattern interchanges with frontage roads:** The design case of an X-Pattern interchange with a frontage road, presented in Figure B2, shows a somewhat different placement for C-of-A fencing. In this case, the design illustrates the placement of additional fencing between controlled access roads and the frontage roads upstream of the interchange, after the exit ramp.
- **C-of-A for other interchanges:** The third design case highlights that a minimum of 1000 feet of C-of-A fencing starts at the turnout radii, downstream of the interchange cross road, as presented in Figure B3. This is complemented by a 1320 feet raised median control of access, with mandatory fencing along all control-of-access and right-of-way lines to secure and regulate roadway access.

Additionally, C-of-A fencing has been used in Louisiana to segregate railway lines from main access-controlled roadways.

Design and Materials of Fencing

The height of chain link fencing can be customized to suit specific needs, ranging from 4 to 6 feet, with an additional 1 foot of barbed wire (i.e., 3 wire strands). Posts are typically spaced 6 to 8 feet apart, and the fence uses 9 gauge, 2 inch diamond mesh fabric tied at 24 inch intervals, with truss rods and turnbuckles to maintain tension. Pressed steel caps per ASTM F626 are used on top of the posts. The fence's design includes stretcher bars (3/16 inch x 3/4 inch flat) at each corner or pull post, with additional stretcher bar bands. Figure 9 shows a chain link fence in Louisiana.

Chain link fabric, posts, rails, ties, bands, bars, rods and other fittings and hardware covered by specification shall be composed of the following types of material: Type I—Zinc-coated steel; Type II—Aluminum-coated steel; Type III—Aluminum alloy; Type IV—Polyvinyl Chloride (PVC)-coated steel. Zinc-5 Percent Aluminum-Misch-metal alloy metal that meets the requirements of ASTM B 750 may be substituted for zinc coating (hot-dipped) at the application rate specified herein for hot-dip zinc coating. Figure 10 shows a picture of a gate with chain link fence. Three types of gates are used for chain link fence: Single-Swinging Walkgate; Single-Swinging Driveway Gate; and Double-Swinging Driveway Gate.

Figure 9. Chain link fence in Louisiana

Field and line type fences are also used in Louisiana, especially on rural interstate highways. Wooden gates are typically used for this kind of fence. Details of the fence design can be found in Louisiana DOTD's design manual [51].

Figure 10. Chain link fence gate in Louisiana

Maintenance Practices

Based on the literature review, state DOTs and other organizations managing and maintaining roadways are generally responsible for fencing along highways and other transportation infrastructure. To protect the security and safety of the roadways, it is the responsibility of the DOT and/or organizations managing and maintaining highways to keep the fencing in good condition and make any required repairs as soon as necessary. Regardless of who oversees the fencing maintenance, it is crucial that the fencing is maintained properly and that any repairs are completed promptly to ensure the safety and security of the roadways. For instance, Idaho DOT specifically mentions that they are responsible to conduct the requisite repairs and pursue remedies in cases where C-of-A fences sustain damage due to highway usage [26]. DOTs may have more specific protocols in place to monitor the condition of the fencing and react immediately to any problems that may arise.

State-Specific Practices and Policies Associated with C-of-A Fencing Maintenance

State DOTs may have specific practices and policies about C-of-A fencing maintenance that can impact maintenance practices and requirements. These may include maintenance responsibilities, inspection prerequisites, design specification criteria, funding sources, and environmental factors.

- **Maintenance responsibilities:** It is common for states to hold responsibility for the maintenance of C-of-A fencing. States may have specific guidelines for fencing. For

example, West Virginia DOT has scheduled fence maintenance for every season as part of their roadside maintenance [52]. In Connecticut, the adjoining proprietor and the Commissioner of Transportation share responsibility for fencing between agricultural properties and state highways, with the commissioner reimbursing the proprietor for half of the cost after construction or replacement [53].

- **Inspection criteria:** Specific inspection criteria for C-of-A fencing may exist in some states, which can impact maintenance procedures. For instance, C-of-A fencing in Florida and West Virginia are subjected to recurrent inspections by their respective DOTs to guarantee compliance with state regulations [38].

- **Design standards:** Some states have specific design requirements for access fencing, which may impact maintenance needs and procedures. For instance, specific design regulations for C-of-A fences, such as minimum heights and clear zones, are required in Ohio. TxDOT and New York DOT have established guidelines for the design and installation of C-of-A fencing, but they do not seem to have a formal maintenance program for fencing [17] [23].

- **Funding sources:** The funding sources also vary for C-of-A fencing maintenance between states. Some states may rely on local property owners or other sources [10] [16] [18], while others may have specialized financing sources, such as state or federal highway funds designated explicitly for funding maintenance initiatives [23] [54].

- **Environmental considerations:** Special environmental restrictions or considerations in some areas may impact C-of-A fencing maintenance procedures. For instance, C-of-A fencing must be built and maintained in California with the least possible adverse effects on wildlife habitats and migration routes [10]. Additionally, Arizona, Alabama, and Alaska have specified that C-of-A fencing must be built to endure extreme weather, such as heavy snowfall and intense winds. This may entail using robust materials and corrosion resistance and ensuring the fence is securely fastened to the ground [55].

Warrants for Scheduled Repair and Replacement of Fences

Depending on the state and its prevailing conditions, several elements, such as safety, functionality, and regulatory compliance, may impact the regular repair and replacement of C-of-A fencing. Factors that may warrant the scheduled repair or replacement of C-of-A fencing include [56] [57]:

- **New construction:** New construction projects requiring alterations to the right-of-way often require adjustments to fencing infrastructure as well. Expansion projects or acquisitions of new lands may require fence repair or replacement. Proper placement ensures safety measures and regulatory compliance, and if existing fencing no longer meets safety standards, repair and replacement are necessary. Aging fences may suffer from corrosion, structural degradation, or environmental damage, necessitating proactive measures.
- **Age and deterioration:** Due to weather exposure, other environmental conditions, wear and tear from vehicular crashes, and other impacts, C-of-A fencing may deteriorate over time [58]. The lifespan of fencing can be estimated based on several variables, including age, condition, and the type of material used in construction. Furthermore, the anticipated lifespan of fencing materials may vary based on the material used. The guidelines for fence repair or replacement according to Indiana DOT, for example, are as follows [8]:
  - In a partial 3R project (resurfacing, restoration, and rehabilitation), the fence is designed to last for approximately 10 years, and provisions for fence patching should be made to ensure its longevity.
  - In a crack and seat project, the fence design life extends to approximately 15 years, necessitating the determination of a suitable quantity of fence patching to maintain its condition.
  - For a pavement rubblization and replacement project, the fence design life is notably longer, spanning approximately 25 to 30 years, reflecting the need for a more durable and long-lasting fencing solution.
- **Maintenance costs:** In the case of budgetary constraints, if the cost of repairing the fencing is greater than the cost of replacing it, it may be more cost-effective to replace it. Similarly, replacement may be a more viable option if the cost of maintaining the fencing is becoming too high.
- **Damage and vandalism:** Vandalism and harm are frequent causes of damage to C-of-A fencing. Accidental damage can occur from crashes or natural events like powerful windstorms, while deliberate vandalism, such as cutting or ripping the fence or removing its posts, can inflict severe damage on the structure [58] [59]. Additionally, harsh weather conditions pose a threat, as prolonged exposure to heavy rain, snow, ice, or extreme temperatures can degrade fencing materials, leading to rust, corrosion, or structural weakening. Moreover, vehicle collisions, especially on highways, can cause significant damage to C-of-A fencing, resulting in bent or broken posts, torn fencing material, or

complete structural failure, thereby posing potential hazards for both drivers and pedestrians.

- **Maintenance inspections:** Maintenance checks are essential for finding fencing issues that necessitate immediate repair or replacement. During routine maintenance checks, personnel can examine the fencing for signs of damage or deterioration, such as cracks, corrosion, or loose sections [58] [59]. For instance, Indiana DOT's requirements to repair or replace fencing are discussed during field checks [8]. If any damage or deterioration is found, the maintenance team can move immediately to repair or replace the fencing to re-establish access control and maintain public safety.
- **Changes in land use:** Depending on changes in land use or nearby facilities, C-of-A fencing may need to be changed or rebuilt [10]. Both CALTRANS and TxDOT have found that if a new construction or development project necessitates changes to the fencing to maintain access control, such as the addition or removal of gates or the alteration of the fence's height or placement, the fencing may need to be repaired or replaced [10] [36].
- **Compliance with regulations:** For access control and safety purposes, state and federal rules may require the maintenance or replacement of C-of-A fencing. For instance, the FHWA mandates that C-of-A fencing be installed and maintained by specific standards, including minimum heights and clear zones; as a result, states need to plan repairs or replacements to bring fencing in line with these rules [60].

Scenarios that Trigger Unscheduled Repair or Replacement

Unexpected circumstances that weaken access control or pose a safety concern frequently prompt the unscheduled repair or replacement of C-of-A fencing. Unplanned repairs or replacements may occur for various reasons, depending on the status and situation. The fundamental objective is always to make sure the fence is functioning correctly and protecting the safety of drivers and pedestrians. Examples of scenarios that could result in unexpected C-of-A fencing repair or replacement include:

- **Emergency situations:** Emergency situations requiring unscheduled repairs or replacements of C-of-A fencing are particularly critical at interstate or dangerous intersections due to heightened security risks and safety priorities. Situations such as natural disasters or vandalism urgently demand immediate action to restore fencing integrity, prevent unauthorized access, and ensure compliance with safety regulations. This is especially vital in high-risk areas along interstate junctions or intersections prone

to crashes, where robust security measures are essential to safeguard public safety and maintain operational continuity.

Strategies to Optimize Maintenance Cost

C-of-A fencing requires regular maintenance to remain cost-effective over time. State DOTs across the U.S. are continually exploring strategies to optimize the maintenance costs of C-of-A fencing while upholding safety standards and minimizing the financial burden. In this context, several key strategies have emerged that aim to strike a balance between effective maintenance and cost savings, with each state tailoring its approach to its unique needs and circumstances. These strategies include:

- **Not placing a fence:** In some instances, abstaining from providing fencing altogether serves as a cost-saving strategy. By assessing locations where natural barriers such as heavily wooded forests, gullies, bodies of water, or difficult terrain naturally prevent access, fencing may be deemed unnecessary. This approach not only minimizes initial installation expenses but also eliminates ongoing maintenance costs in such areas, contributing to overall maintenance cost optimization.
- **Implementing preventive maintenance:** Preventive maintenance strategies for access fencing are crucial for maintaining transportation infrastructure integrity. Regular inspections, timely repairs, and quality materials mitigate potential risks. Regular assessments help identify issues before they escalate, thereby reducing costs. Integrating predictive technologies and data analysis optimizes asset performance. Investing in preventive maintenance extends fencing lifespans, saving time, money, and resources.
- **Maintenance strategy:** TxDOT also stresses the importance of keeping roadside accessories in good condition to guarantee the proper operation of routes and improve safety. TxDOT has a thorough strategy to manage access fencing and maintain roadside auxiliary equipment. TxDOT regularly inspects C-of-A fencing as part of its strategy, which is a standard practice among state DOTs [58]. These regular inspections have the dual functions of quickly identifying and addressing maintenance requirements. These activities include fixing broken parts, tightening loose fasteners, and attending to general wear and tear. TxDOT effectively protects nearby communities from the disruptions caused by the highway system by maintaining visual barriers.
- **Additions to fencing:** When there are budgetary constraints involved, maintenance expenses become extremely important in managing fences. It is vital to investigate affordable options in such circumstances. To optimize maintenance costs, incorporating PVC pipes alongside the right-of-way has proven to be an affordable and effective solution.

As demonstrated by the Wyoming DOT in Figures 11 and 12, the PVC prevents animals from getting stuck in the fence, damaging the fence and hurting the animals.

Figure 11. PVC pipe threaded over bunched fence wires [30]

Figure 12. Similar installation of PVC pipe threaded over bunched fence wires [30]

- **Defining work limit:** The practice of defining work limits optimizes costs by ensuring clarity during the installation of right-of-way fences and other maintenance activities as deployed by the Alabama DOT [59]. This standardized procedure not only streamlines operations but also reduces the risk of misunderstandings or disputes with property owners. By securing written permission before entering the property and notifying owners in cases of permanent easements, the department fosters positive relationships and minimizes potential legal complications. This approach promotes the efficient use of resources by avoiding unnecessary delays or legal expenses, ultimately contributing to cost optimization in maintenance operations.
- **Prioritizing high-quality materials:** Investing in high-quality materials for C-of-A fencing installation or replacement is recommended due to their durability, reduced repair needs, and long-term cost savings. In regions such as Kentucky and Connecticut, vinyl is a popular choice known for its durability, while common materials like zinc or aluminum coating can enhance the longevity of the fence [25] [43] [61]. Additionally, the importance of utilizing quality materials in road infrastructure projects is emphasized by the Indiana maintenance plan. Indiana DOT ensures that durable materials are incorporated into each project type by delineating the expected design life of fences in different road projects. For example, in resurfacing, restoration, and rehabilitation projects, where the expected design life is 10 years, the emphasis may be on materials capable of withstanding frequent wear and tear. Similarly, materials resilient to environmental factors may be prioritized in crack and seat projects with a 15 year design life. For pavement rubblization and replacement projects, in which the design life ranges from 25 to 30 years, materials known for their longevity and structural integrity are likely to be selected [8]. This proactive approach not only minimizes the need for frequent repairs or replacements but also optimizes the lifespan of the infrastructure, ultimately enhancing safety and reducing long-term maintenance costs.
- **Using local materials:** Wood fencing has intrinsic resilience, particularly when properly treated and maintained, prolonging the lifespan of the fencing and reducing the need for frequent, expensive replacements. For example, Connecticut DOT has realized the value of emphasizing high-quality local materials, with a focus on the plentiful local resource of wood [43] [62]. This strategic choice not only aligns with the state's economic and environmental goals but also underscores the practicality of utilizing readily available materials. Connecticut DOT makes use of the region's natural abundance by selecting wood as the primary fencing material, which lowers transportation expenses related to importing materials from distant sources [2]. This demonstrates Connecticut DOT's dedication to sustaining a strong transportation infrastructure while maximizing spending

in the administration of C-of-A fencing, exemplifying a cost-effective and sustainable approach.

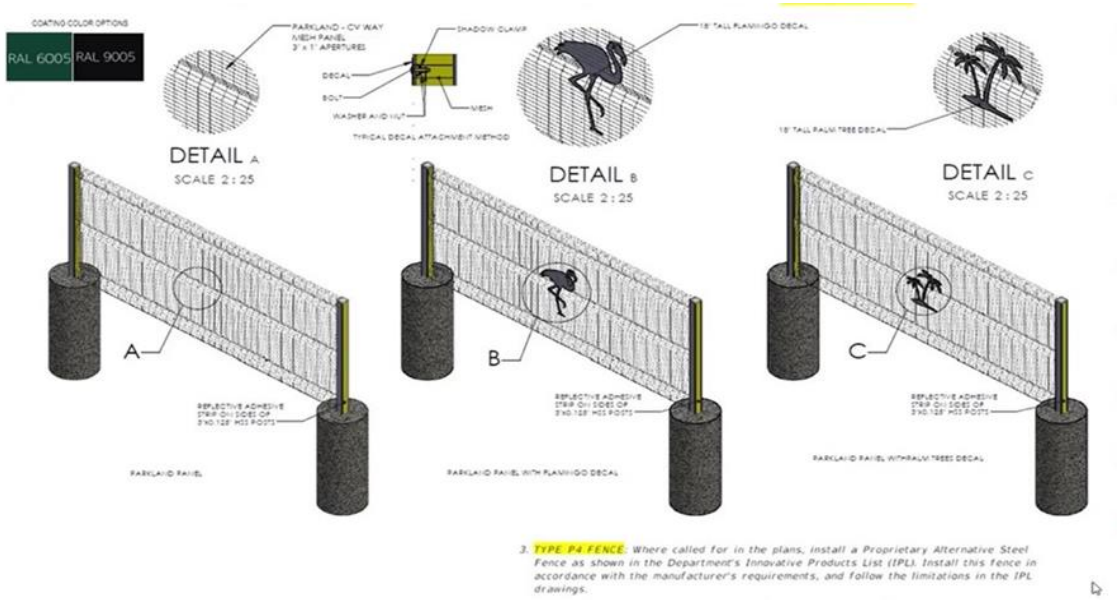
- **Retaining an existing better substitute:** Optimizing costs in infrastructure projects, such as freeway ramp terminals in California, involves considering alternatives to standard fencing when appropriate. In cases where standard fencing may not be aesthetically suitable due to adjacent property development, CALTRANS allows for the use of non-standard options like the California non-standard wall. CALTRANS ensures both aesthetic appeal and functionality by accommodating property owners' concerns and proposing more compatible alternatives such as walls, ornamental iron fences, or chain link fences. This approach not only minimizes potential objections and disputes but also avoids costly revisions or replacements of standard fencing, ultimately optimizing project costs while meeting aesthetic and functional requirements [10].
- **Developing a maintenance schedule:** Developing a maintenance schedule involves establishing a structured plan that outlines routine tasks such as inspections, cleaning, lubrication, and minor repairs. This structured approach not only helps in staying organized but also ensures that maintenance activities are carried out regularly and efficiently. Moreover, regular monitoring is required to detect maintenance needs before they escalate. Assigning responsibility for maintenance may be determined during the planning phase, since maintenance needs can vary based on the site and the season of the year [63].
- **Training personnel:** In cases where a team is tasked with maintaining the fencing, it is advisable to offer appropriate training on fencing maintenance techniques, safety protocols, and identifying potential issues. Well-trained personnel can handle routine maintenance tasks effectively and may be able to address minor fencing repairs in-house, reducing the need for outsourcing and its associated costs [59].
- **Ensuring proper installation:** It is imperative to ensure that fencing is installed correctly, either by adhering to the manufacturer's instructions or by employing professionals experienced in such installations and well-versed in the state DOT’s maintenance manuals [59]. This meticulous approach not only guarantees the fencing's structural integrity but also plays a vital role in controlling access effectively. A practical installation can avoid premature wear and damage to the fencing, which lowers maintenance guidelines, such as new constructions being outside the clear zone [64].
- **Using alternative fencing types:** Alternative fencing reduces maintenance costs compared to traditional wood and chain link fencing, which require frequent repairs. Modern options such as composite, vinyl, and recycled materials are durable, low-maintenance, and

visually appealing. The following section explores these fencing types and their benefits and challenges.

— **Rope fence:** The Type P3 Rope Fence is a cost-effective and flexible solution for pedestrian channelization, utilizing polypropylene rope threaded through wooden posts for easy installation and adjustment, as used by Florida DOT [65]. Its simplicity and affordability make it ideal for temporary or permanent setups, and retroreflective sheeting on end posts enhances visibility and safety. However, due to its material durability, it may require more frequent maintenance, and its utilitarian design might not suit areas needing a more polished look. Despite these limitations, it remains a practical choice for creating pedestrian barriers.

— **Proprietary alternative steel fence:** According to Florida DOT, a Proprietary Alternative Steel Fence (Type P4 Fence) is an innovative and cost-effective fencing option listed on the Department's Innovative Products List (IPL) per Dev-550 specifications, as shown in Figure 13 [65]. Designed to balance functionality and aesthetic appeal, it features a clear mesh design that enhances visibility and blends unobtrusively into various environments. It is available in black or hunter green. Its unique design eliminates horizontal members, significantly increasing climbing resistance and enhancing security. Standing 4 to 6 feet tall, it meets various pedestrian channelization needs, with reflective adhesive strips at posts for improved visibility in low-light conditions. Constructed from Parkland CW mesh panels with 1 by 3 inch apertures, the fence can be decorated with decals for added visual appeal. Complying with Dev-550 specifications and IPL standards, the Type P4 Fence is a reliable and attractive choice for modern fencing requirements.

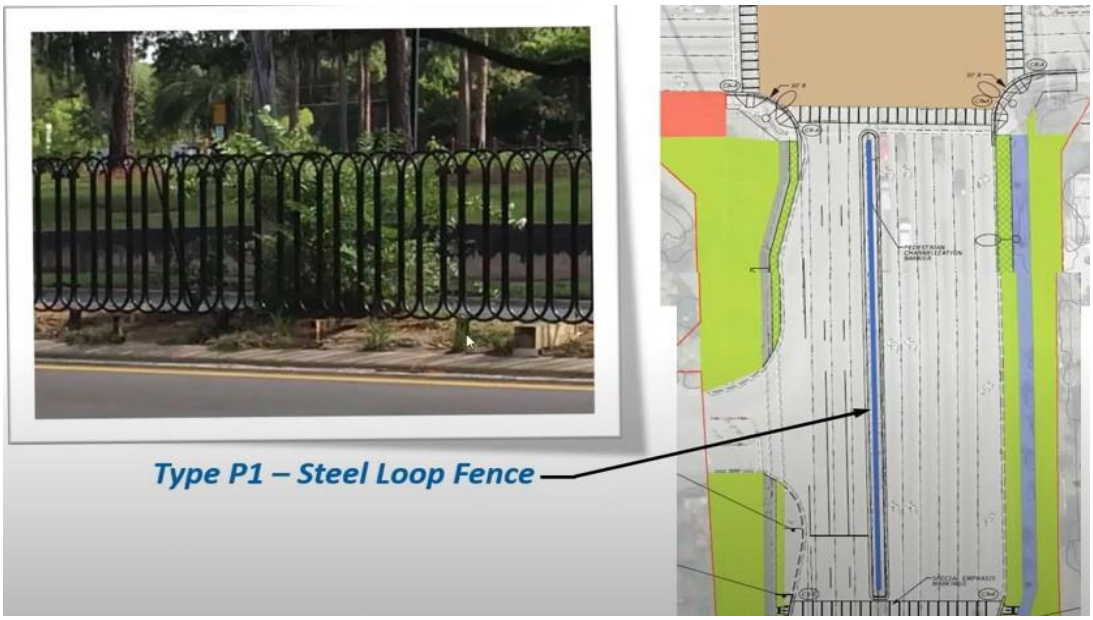
Figure 13. Florida DOT Proprietary Alternative Steel Fence (Type P4 Fence) [65]



— **Steel loop fence:** The pedestrian channelization fence, specifically the steel loop fence, is designed to provide aesthetic appeal and functional security, as shown in Figure 14. It is used when critical safety needs are identified, guiding pedestrians to safe crossing points and improving the overall visibility and predictability of pedestrian movements for drivers. The robust and climb-resistant design ensures long-lasting effectiveness in controlling pedestrian traffic [65]. The primary purpose of pedestrian channelization fencing is to guide pedestrians to marked crosswalk locations, making crossings more visible and predictable for drivers. This enhances safety by ensuring that pedestrians cross at designated spots, reducing the likelihood of crashes. Key features of pedestrian channelization fencing include:

- Heavy Design: The robust construction of the steel loop fence contributes to its high cost.
- Premium Aesthetic: The design and materials give it a high-end look, suitable for areas where visual appeal is essential.
- No Horizontal Members: This feature enhances climbing resistance, making the fence more secure.
- Climbing Resistance: The lack of horizontal elements prevents easy scaling, providing an additional layer of security.

Figure 14. Florida DOT steel loop fence (Type P1 Fence) [65]



Current Louisiana Maintenance Issues

A lack of maintenance of C-of-A fencing appears to be common in Louisiana. Based on observations and discussions with maintenance personnel, the research team has identified several maintenance issues that can be addressed.

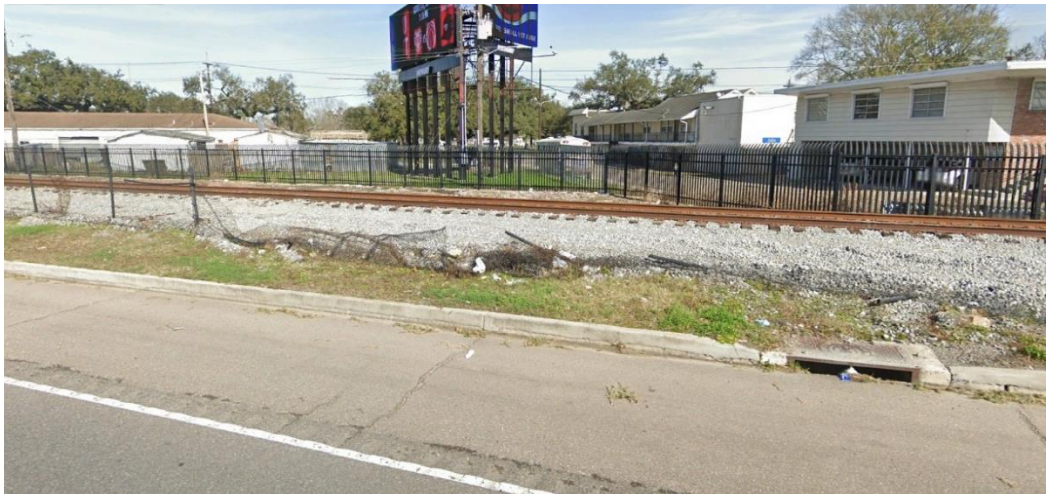
- **Damage from roadway departure crashes:** Although the functionality of C-of-A fencing extends to deterring illegal vehicle entry from outside, these fences are still vulnerable to damage from impacts on the mainline roadways due to run-off-road incidents. Damages caused by vehicles running off the road are reported to be more frequent near urban areas. Figure 15a-c shows pictures of damaged fencing; however, it cannot be confirmed that the damages are from run-off-road vehicles. Additional pictures of damage can be found in Figure D1.
- **Damage from growing vegetation:** Growing vegetation can be found on rural interstate highway C-of-A fences near interchanges, including both C-of-A fences segregating the main highway from the frontage road (Figure 15d) and those serving as both C-of-A and ROW fences (Figure 15e). Louisiana DOTD has a specific policy document for roadside vegetation management approaches [66]. “Bare Ground,” or Complete Vegetation Control, involves using soil-active herbicides to maintain vegetation-free areas, especially where plant growth poses a safety risk or decreases maintenance efficiency, but requires careful management to avoid harming desirable vegetation. “Selective Weeding” targets specific

undesirable species using herbicides that do not permanently damage the surrounding desired plants; herbicides may be applied either before or after the plants emerge. "Chemical Mowing" uses herbicides to control unwanted vegetation close to valuable plants and is suitable for maintaining areas under fences. It appears from Figure 15d-e that some fencing areas require "Bare Ground" vegetation control, which could be followed subsequently by "Selective Weeding" or "Chemical Mowing."

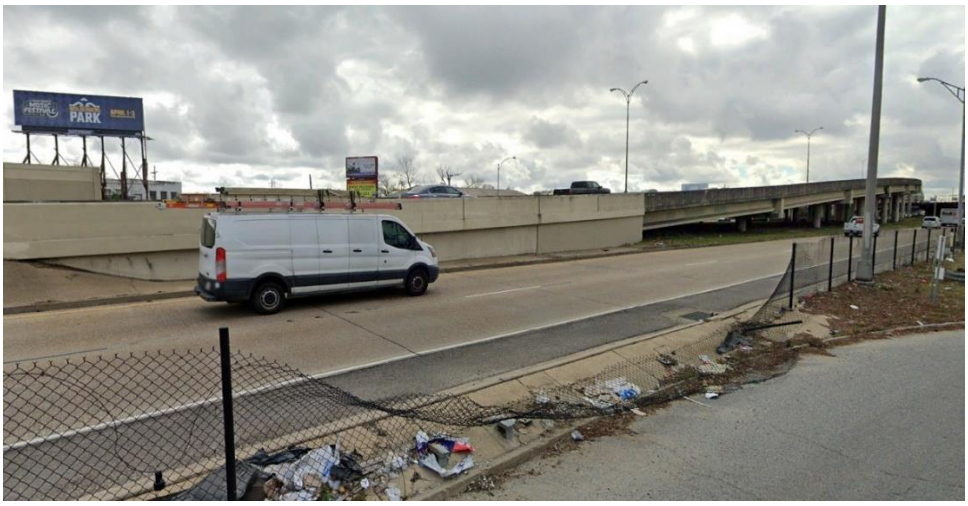
- **Budgetary constraints and less prioritized maintenance in rural areas:** Fences are often maintained through requests from local agencies and feedback from road users. Maintenance of fencing remains a supplementary item to other major construction projects. Due to budgetary constraints for exclusive maintenance of fencing, reactive maintenance occurs in urban areas to prioritize damage fixing in urban areas with less frequent maintenance in rural areas. Additionally, damages due to large animals such as deer are not well-studied in Louisiana, which could be attributed to the fact that the majority of animal-vehicle crashes result in property damage only.
- **Insufficient documentation of current fence inventory:** C-of-A fencing is also a supplementary item of construction, although Louisiana DOTD states that all the C-of-A and/or ROW lines should have fences. It appears that exclusive documentation of the existing fencing locations by the DOTD is not readily available.
- **Other issues:** It is common to have local governments request to replace the typical "ugly" fencing with ornamental fencing, or to remove it totally. One example of such a request is on the US 190 freeway section between I-12 and LA 22 in Mandeville.

Figure 15. Damage to C-of-A fencing (a), (b), and (c), Growing Vegetation (d) and (e)

(a)



(b)



(c)

(d)

(e)

Survey

Survey Questionnaire

One of the primary tasks of this study was to conduct a survey aimed at gaining knowledge about fencing design and maintenance practices across all 50 U.S. states. This survey was expected to provide insights into fencing practices that could be applicable in Louisiana. Additionally, the survey questionnaire was intended to complement the knowledge gained from the literature review. The survey was structured around four major issues: Construction and Maintenance Practices; Alternative Fencing and Practices; Informational Guide and Policy; and Design. The survey contents are outlined below. Details of the questionnaire can be found in Appendix A.

Background Information

At the outset of the survey, participants received a consent and information form outlining a study commissioned by DOTD to evaluate and improve control-of-access fencing maintenance practices. This document detailed the study's objectives, including gathering data on fencing policy, maintenance practices, and cost-reduction strategies across transportation jurisdictions in the U.S. Additionally, it explained participation requirements and data usage, as well as providing contact information for inquiries. The form also requested basic background information from participants to better understand their responses.

Construction and Maintenance Practices

The initial set of questions, titled "Construction and Maintenance Practices," explored the installation requirements, maintenance responsibilities, inspection frequencies, and criteria for prioritizing repairs and regular maintenance. This section also examined maintenance activities that impact the longevity and functionality of C-of-A fencing, along with other factors influencing its maintenance and effectiveness. The goal was to gather information to identify common practices, pinpoint challenges, and highlight potential areas for improvement in managing C-of-A fencing across various regions.

Alternative Fencing and Practices

The three questions in the "Alternative Fencing and Practices" section were designed to ascertain whether alternative fencing options had been considered or implemented to reduce

maintenance costs, and to identify which alternatives or practices are most effective in lowering overall maintenance expenses. This inquiry aimed to gather insights into cost-saving measures associated with C-of-A fencing.

Informational Guide and Policy

The "Informational Guide and Policy" section explored the incorporation of C-of-A fencing into maintenance budgeting, examining formal and informal processes. Participants were asked about their use of informational guides or procedural documents for fencing maintenance, including details on any resources utilized and the potential for adopting new guides. The survey also gathered feedback on the most beneficial existing guides, aiming to enhance and streamline fencing maintenance practices through improved documentation and policies.

Design

The “Design” section of the survey explored the materials and design elements employed in C-of-A fencing across various jurisdictions. It collected information on fencing types, materials, heights, post types, and spacing to better understand the decision-making processes behind fencing design. This data will aid in evaluating the cost-effectiveness of different design strategies and materials, shedding light on their implications for both initial installation and ongoing maintenance expenses.

Survey Results

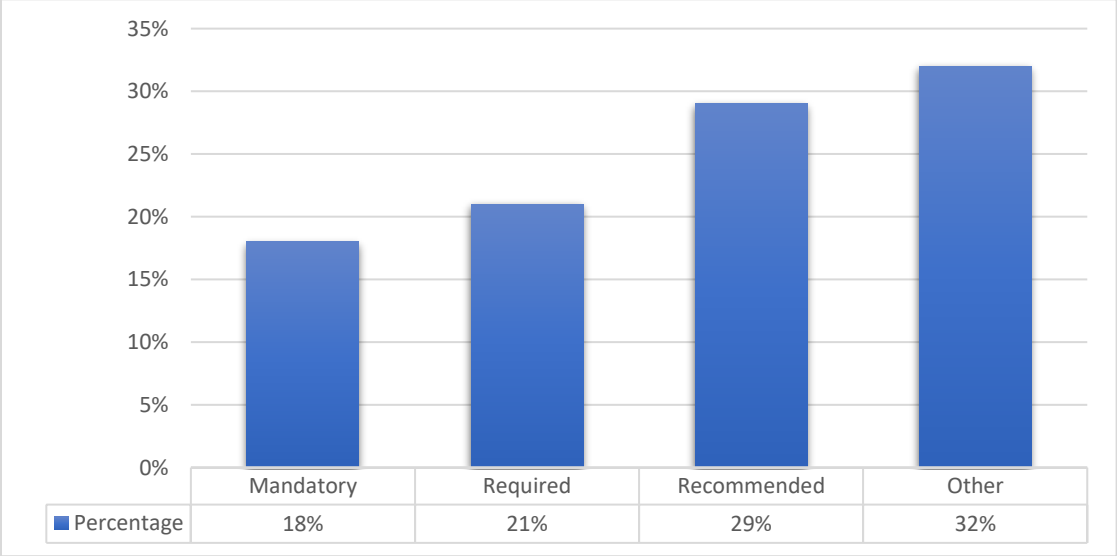
The following section presents the outcomes of the C-of-A fencing survey, which sought to identify best maintenance practices. Designed using Qualtrics [24] and distributed to state DOTs and other experts responsible for C-of-A fencing in all 50 U.S. states, the survey achieved an 84% response rate. The compiled information is presented in graphs, charts, and tables, providing an overview of how state policies and guidelines are associated with the cost-effectiveness and operational efficiency of C-of-A fencing in various jurisdictions. The states that participated in the survey are listed in Table A1. Additional tables can be found in Appendix C.

Results on Construction and Maintenance Practices

Q: What is the level of requirement for the installation of control-of-access fencing in your jurisdiction?

In terms of installation practice requirements, the survey data revealed diverse levels of obligation for installing C-of-A fencing. As illustrated in Figure 16, the presence of "recommended" installations in 29% of responses indicates that the guidance is robust but not mandatory. Also, 21% of the responses were classified as "required" installations, which denote specific circumstances under which fencing must be installed. The installation of C-of-A fencing is strictly regulated in jurisdictions, as evidenced by the fact that "mandatory" installations were least common, at 18%. The most prevalent response, at 32%, was "other," which denotes that the requirements are unique or situational and cannot be rigorously classified as mandatory, recommended, or required.

Figure 16. Requirement for installation of C-of-A fencing



Q: If the installation of fencing is required or mandatory, please provide the specific state/local statute, provision or law.

Various mandates have been specified across different states necessitating the installation of C-of-A fencing (50% of total), as indicated by the specific state/local statutes, provisions, or laws. Table C1 lists specific state/local statutes, provisions, or laws if fencing installation is required or mandatory.

- Montana and South Dakota comply with FHWA regulations, which is equivalent to Mississippi's mandate for protection on all interstate routes.
- Vermont adheres to Title 19, Utah specifies its requirements in Utah Administration Rule 930-6 and Utah Code 72-1-202, and Idaho also referenced their administrative policy.
- Four states identified their roadway design or access control policies: Washington, Connecticut, New Mexico, and Georgia.

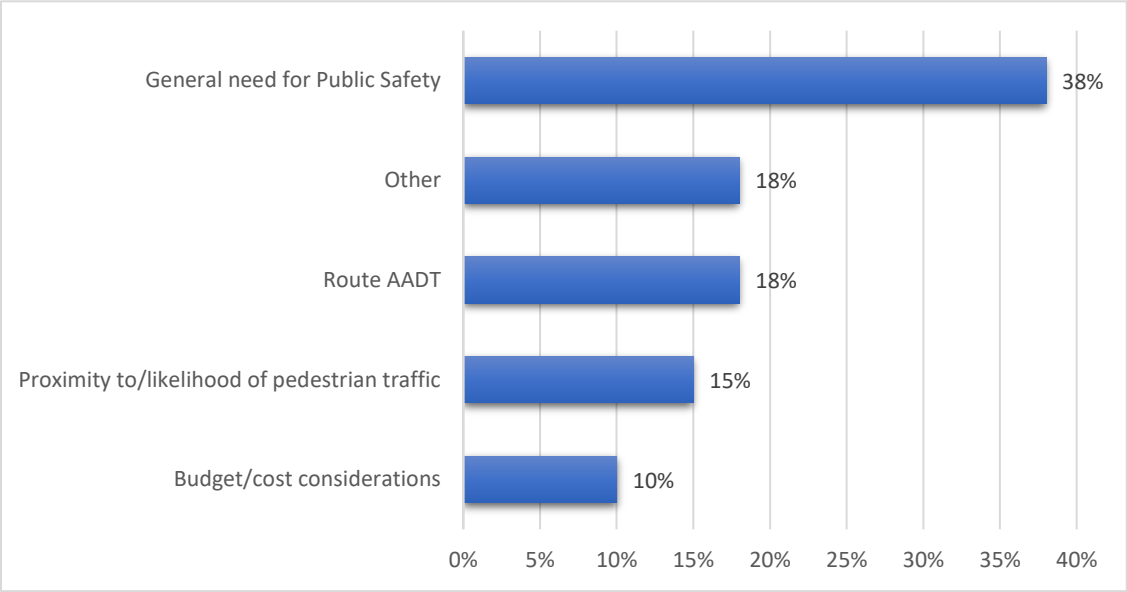
With regard to other issues related to installation requirements, some states require fencing along all highway rights-of-way, while others decide on a case-by-case basis, as presented in Table C2. Conversely, fencing is mandatory on interstates in certain states. 32% of responding states could not specify the requirements. Other reasons mentioned included the following:

- Two respondents (5% of total) noted that installation requirements were dependent on right-of-way.
- Two respondents (5%) mentioned that their DOT or specific department therein was responsible to make a judgment for installation.
- Two respondents (5%) mentioned that installation requirements could vary case-by-case.
- Two respondents (5%) specified the installation requirements for interstates or limited access highways only.
- Two respondents (5%) specified conditions for installation requirements, such as the presence of livestock or driveways.
- One respondent (2%) specifically mentioned FHWA-driven installation, while another (2%) identified the requirement as "unknown."

Q: If the installation of fencing is required or recommended, please describe your organization's approach to determine whether to install fencing. What criteria or considerations contribute to your determination?

Various approaches among state DOTs are indicated in Figure 17, which outlines criteria or considerations for fencing installation. The general need for public safety is the most significant criterion, cited by 38% of respondents, and 10% of decisions are influenced by budget or cost considerations.

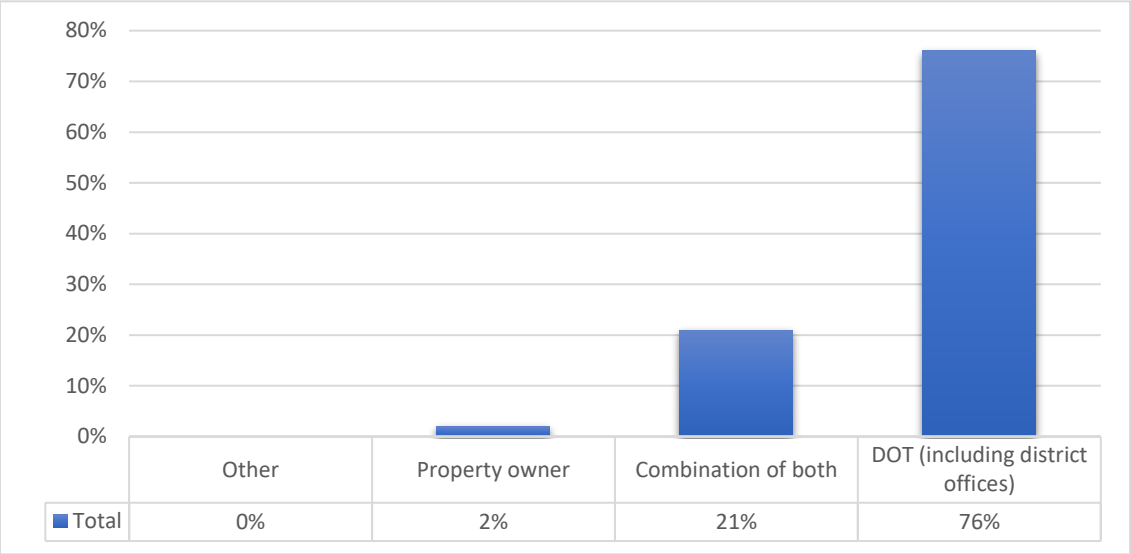
Figure 17. State DOT criteria and considerations in determining fencing installation



Q: Who is responsible for the maintenance of the control-of-access fencing in your jurisdiction?

Figure 18 shows that 76% of jurisdictions assign the responsibility for maintaining C-of-A fencing to the DOT, which includes district offices. In another 21% of cases, there is shared responsibility between the DOT and other entities. The property proprietor was cited as the responsible party by only 2% of respondents. This distribution emphasizes that state DOTs are primarily responsible for the maintenance of C-of-A fencing, with some instances of shared responsibility or alternative arrangements.

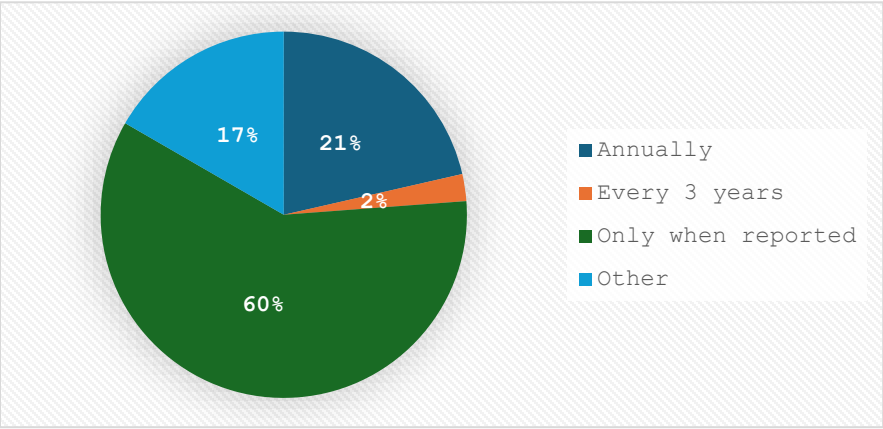
Figure 18. Maintenance responsibility for C-of-A fencing



Q: How often is control-of-access fencing inspected and maintained for damage or necessary repairs?

The survey data on the frequency of C-of-A fencing inspection and maintenance reveals that 60% of states inspect and maintain fencing only in response to damage complaints, as shown in Figure 19. This indicates a reactive approach. By contrast, only 2% of respondents conduct inspections every three years, while 17% of respondents maintain annual inspections.

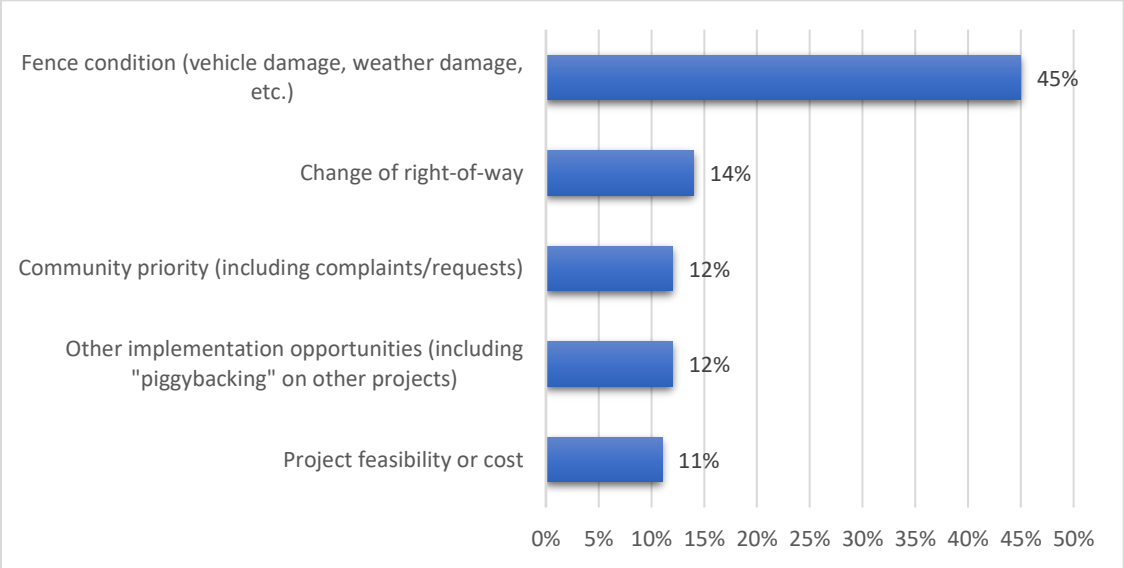
Figure 19. Inspection criteria of C-of-A fencing



Q: What are the criteria used to prioritize maintenance of control-of-access facilities on existing roads?

Figure 20 shows the distribution of the criteria for prioritizing maintenance of C-of-A fencing facilities, highlighting several critical factors. The condition of the fence, including damage from vehicles or weather, is the most prevalent criterion, cited by 45% of respondents. Financial considerations also play a role, with 11% of decisions influenced by project feasibility or cost.

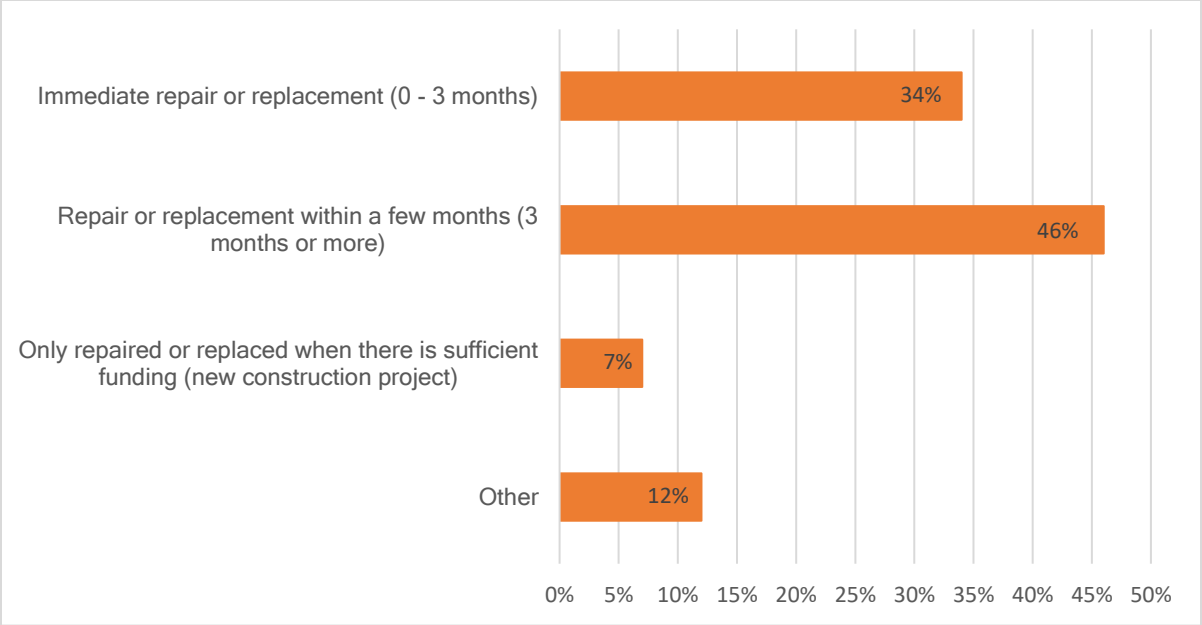
Figure 20. Criteria used to prioritize maintenance of C-of-A fencing



Q: How is damage to the control-of-access fencing typically addressed?

Figure 21 shows how jurisdictions handle C-of-A fencing damage. 34% of respondents complete repairs immediately, within 0-3 months; 46% of respondents complete repairs or replacements beyond 3 months; 7% of respondents only repair or replace fencing when there is sufficient funding or as part of a new construction project; and 12% of respondents responded “other.”

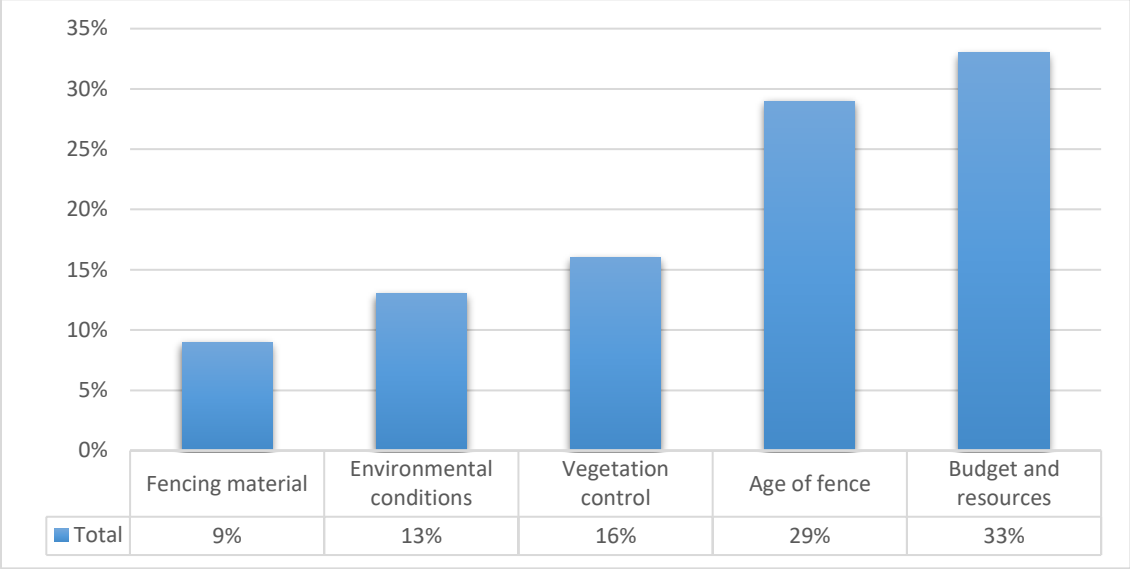
Figure 21. How damage to C-of-A fencing is addressed



Q: Which of these factors are most critical when determining maintenance frequency?

Financial considerations are not the sole factor determining the frequency of maintenance; rather, the physical condition and surroundings of the fencing also play a significant role. Figure 22 shows various key parameters affecting C-of-A fencing maintenance frequency. Budget and resources are most important to 33% of respondents, demonstrating that financial availability affects maintenance schedules. Older fences may need more maintenance; therefore, 29% of respondents indicated fencing age, while another 9% considered fencing material, which influences longevity and maintenance.

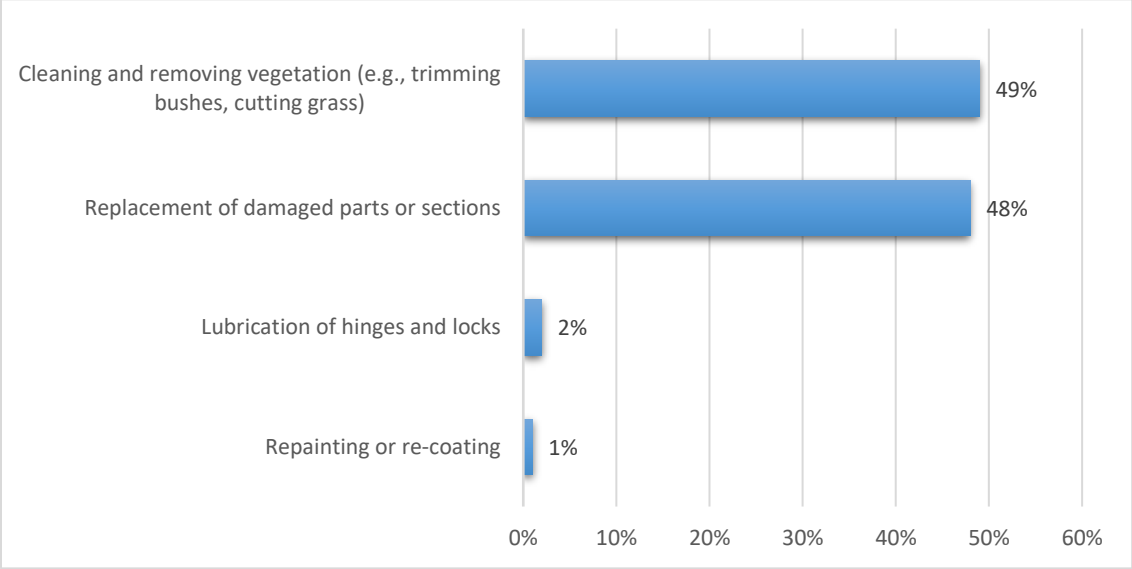
Figure 22. Criteria when determining maintenance frequency of C-of-A fencing



Q: Which of the following maintenance activities do you consider most essential for ensuring the longevity and functionality of control-of-access fencing?

The primary activities that ensure the effectiveness and durability of C-of-A fencing are regular vegetation control and prompt restorations. The survey data in Figure 23 suggests that 49% of respondents deemed it essential to clean and remove vegetation, including trimming bushes and cutting lawns, while 48% of respondents emphasized the replacement of damaged portions or sections. Lubrication of hinges and locks and repainting or recoating were cited by only 2% and 1% of respondents, respectively.

Figure 23. Maintenance activities essential for longevity of C-of-A fencing



Q: Are there any other factors that impact the longevity and functionality of control-of-access fencing?

Several additional factors affecting the longevity and functionality of C-of-A fencing were identified by various state DOTs. 68% of respondents reported no additional factors, while 32% acknowledged a variety of factors that affect longevity and functionality, as illustrated in Table C3. The responses indicated the following:

- Crashes and traffic-related damage were reported by Utah, Indiana, and Connecticut as key factors impacting the longevity of C-of-A fencing.
- Adjacent property and land use activities were cited by Arkansas and Connecticut as factors affecting the condition of C-of-A fencing.
- Idaho identified animal-related damage, specifically from livestock, as a significant issue for maintaining C-of-A fencing.
- Environmental and weather-related factors were mentioned by New Mexico, South Carolina, North Dakota, Minnesota, and Colorado, with issues ranging from snow depth and wind to debris and falling trees.
- Budget constraints were reported by South Carolina as a challenge, with funds often diverted to other priorities.

Results on Informational Guide and Policy

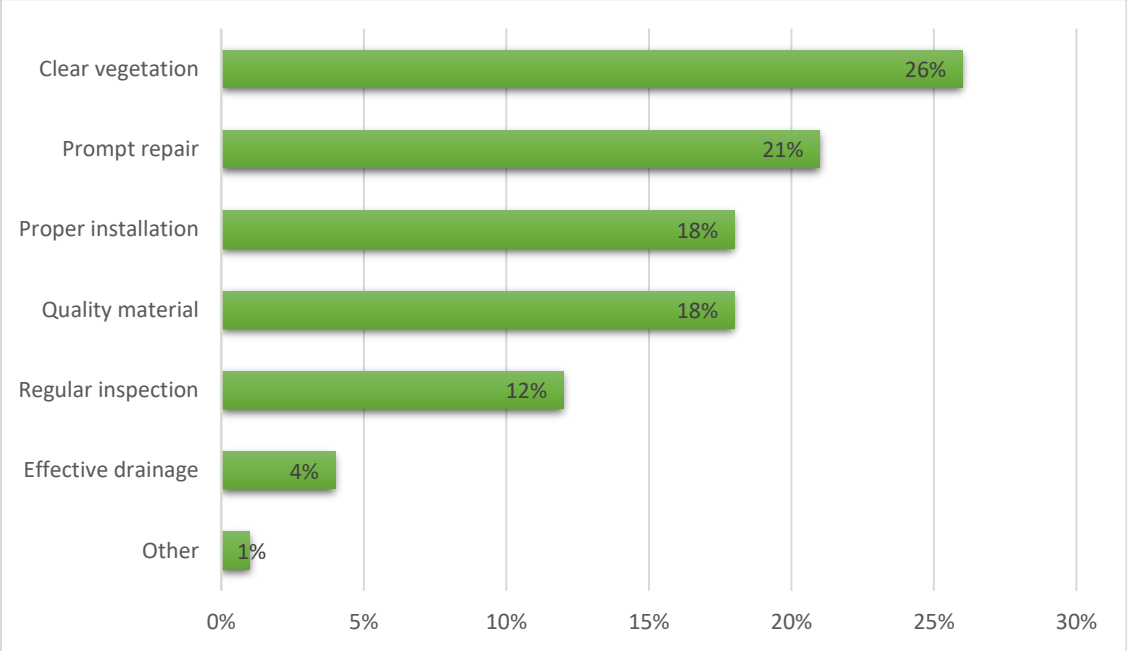
Q: Which alternative fencing options have been considered or used to lower maintenance costs?

A few jurisdictions are exploring the use of natural barriers and composite materials to enhance the durability of C-of-A fencing and reduce maintenance costs. 12% of respondents have investigated or implemented alternative fencing options to achieve these cost savings.

Q: What other strategies or practices have you found to be most effective in reducing overall maintenance costs related to control-of-access fencing?

As shown in Figure 24, several major strategies and practices help reduce C-of-A fencing maintenance costs. The most popular technique is clear vegetation maintenance, with 26% of respondents indicating its effectiveness. Additionally, 21% of respondents highlighted that the rapid repair of issues prevents further deterioration. Other effective methods include proper installation, the use of quality materials, regular inspections, and ensuring effective drainage.

Figure 24. Other strategies found to be most effective in reducing maintenance costs



The complete list of other strategies is found in Table C4. Several responses regarding other strategies are highlighted below:

- Louisiana uses composite fencing, which is a combination of wood and metal, as well as wooden fencing, as alternative options.
- North Dakota employs natural barriers such as trees and hedges, along with concrete posts and a single large chain, as alternative fencing solutions.
- Connecticut utilizes natural barriers such as trees and hedges, in addition to sound barriers, for fencing purposes.
- Kansas has implemented a single cable fence mounted on guardrail posts as an alternative fencing option.
- South Dakota uses smooth wire woven wire as a fencing alternative.

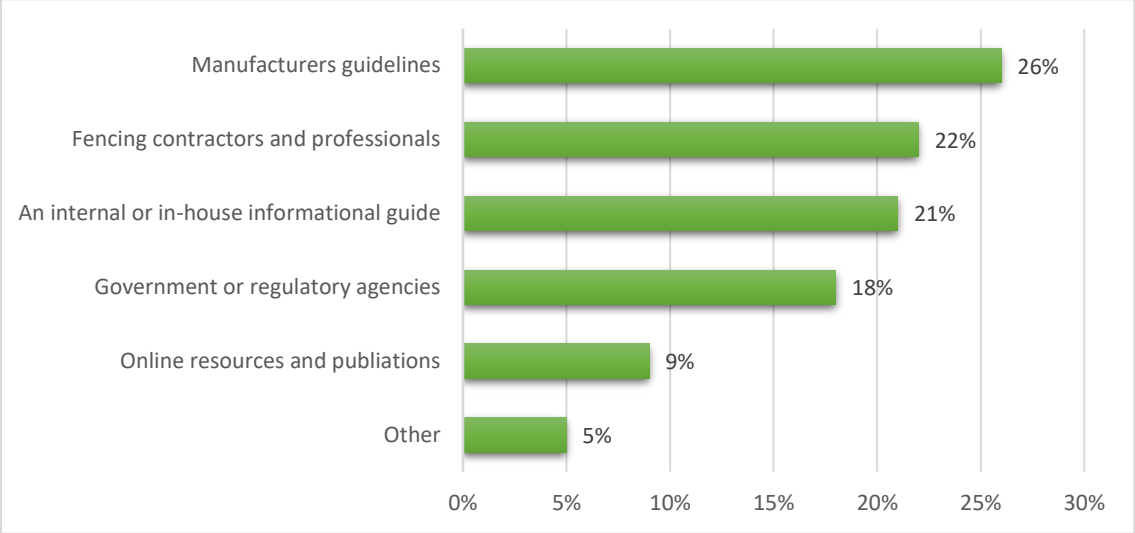
Q: Which of the following best describes the process for evaluating and including control-of-access fencing in the maintenance budget?

The process for evaluating or including C-of-A fencing in the maintenance budget is diverse across jurisdictions. Formal and informal methods are equally employed, with 34% of respondents reporting that they employ a combination of formal (i.e., comprehensive plans) and informal (i.e., internal discussions) processes. An additional 34% of respondents exclusively depend on informal internal discussions, while 12% of respondents employ formal processes only.

Q: Which guides do you consider most beneficial?

According to the survey results, 15% of respondents have implemented informational manuals or procedural documentation to maintain C-of-A fencing; these are listed in Table C5. Also, Figure 25 shows that 26% of respondents think manufacturers' guidelines are the best for C-of-A fencing maintenance, emphasizing the importance of following fencing material manufacturers' specifications and recommendations. Only 9% of respondents find online resources and publications to be beneficial, as they offer current and easily accessible information.

Figure 25. Most beneficial guides for C-of-A fencing maintenance



Results on Design

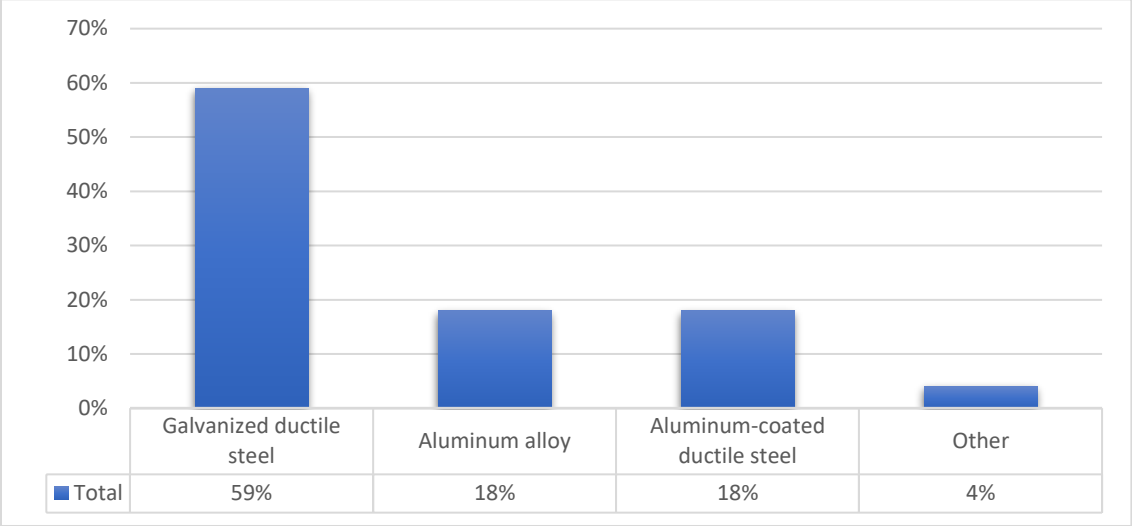
Q: Is chain link fencing used in your jurisdiction for control of access?

According to the survey results, 85% of jurisdictions employ chain link fencing, while 15% do not. This indicates that chain link fencing is a prevalent choice for C-of-A purposes.

Q: What is the material type used for the chain link fencing in your jurisdiction?

Galvanized ductile steel is the most frequently used material for chain link fencing in various jurisdictions, cited by 59% of respondents. 18% of respondents utilize aluminum alloy and aluminum-coated ductile steel, as shown in Figure 26. Tables C6, C7, and C8 provide further context on states that use different specifications for material type, height requirements, and post spacing for chain link fencing.

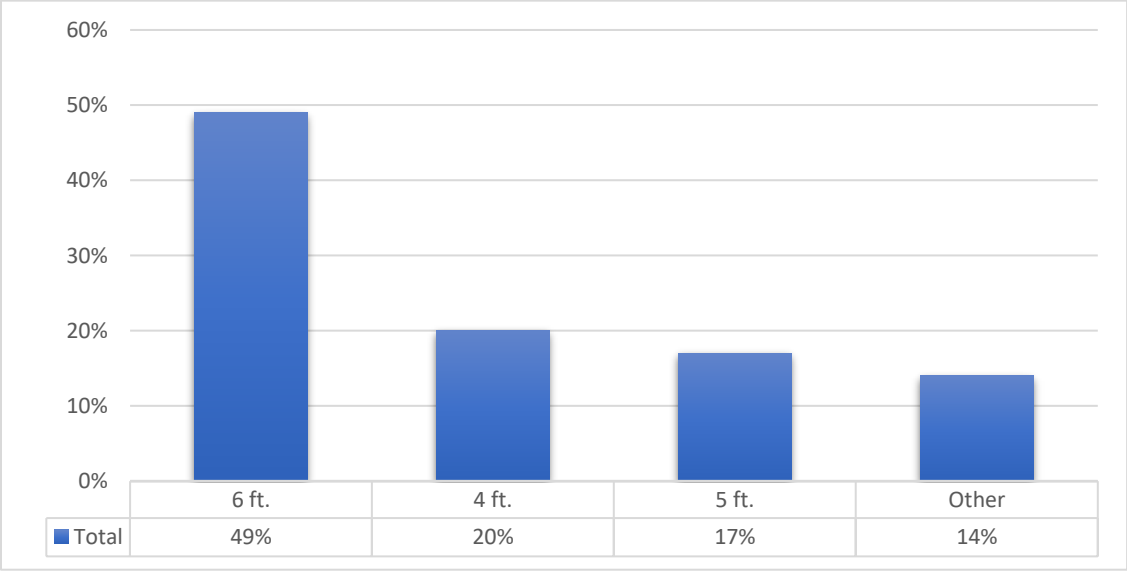
Figure 26. Material types used for chain link fencing



Q: What is the required height for the chain link fencing in your jurisdiction?

Figure 27 shows that 49% of respondents in favor 6 foot fences, 20% require 4 foot fences, and 17% require 5 foot fences. The tables in the Appendix contain additional variations.

Figure 27. Height requirements for chain link fencing



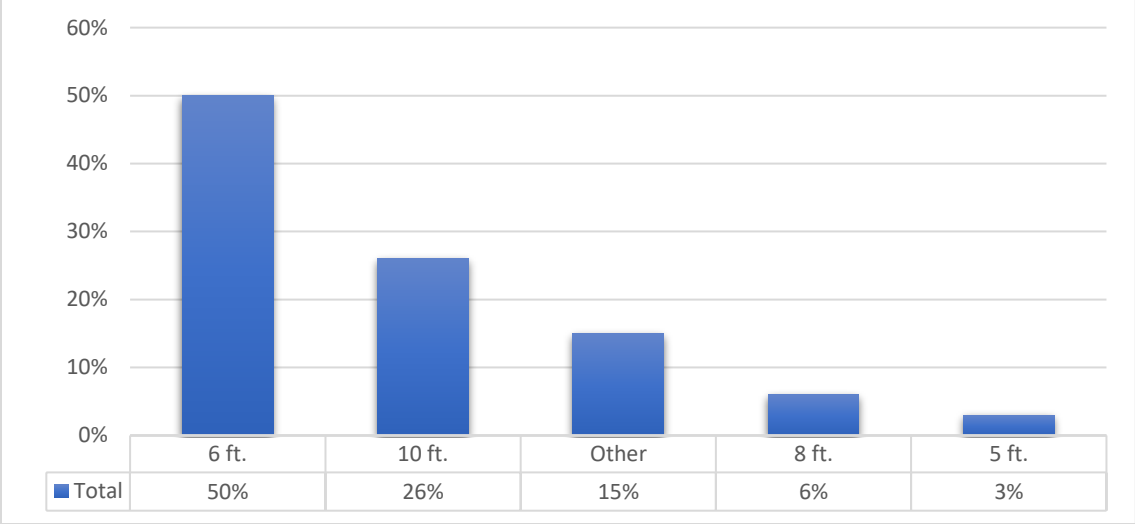
Q: What is the most common post type used with the chain link fencing in your jurisdiction?

Steel posts are the preferred post type for chain link fencing in a variety of jurisdictions, as evidenced by 97% of respondents who reported their use. Only 3% of respondents employed posts made of wood or steel. This indicates that steel posts are the favored choice for supporting chain link fences in most jurisdictions due to their durability and strength.

Q: What is the designated post spacing associated with the chain link fencing in your jurisdiction?

As illustrated in Figure 28, 50% of respondents from the jurisdictions that use chain link fencing utilize 6 foot spacing. More than 25% of respondents reported 10 foot spacing.

Figure 28. Post spacing associated with chain link fencing



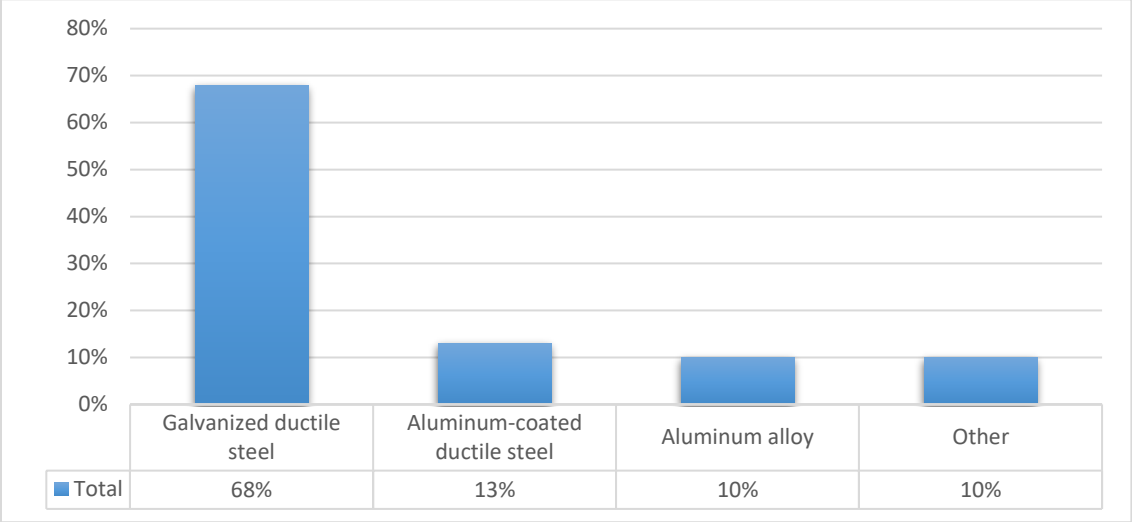
Q: Is woven wire fencing used in your jurisdiction for control-of-access?

According to the survey data on woven wire fencing for access control, 75% of jurisdictions employ it, while 25% do not. This indicates that woven wire fencing is another prevalent choice for C-of-A fencing.

Q: What is the material type used for woven wire fencing in your jurisdiction?

Figure 29 shows the distribution of the various material types used in the jurisdictions that utilize woven wire fencing. The figure illustrates that the most commonly used material is Galvanized Ductile Steel, accounting for 68% of responses. Other reported materials include Aluminum-Coated Ductile Steel (13%) and Aluminum Alloy (10%).

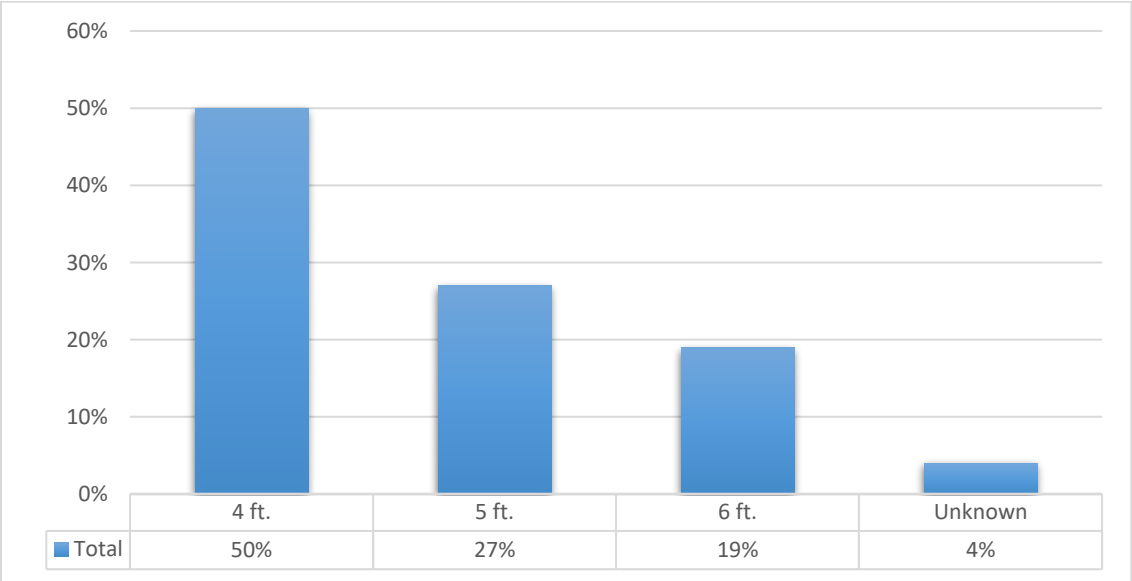
Figure 29. Material type associated with woven wire fencing



Q: What is the required height for the woven wire fencing in your jurisdiction?

Figure 30 shows the distribution of height requirements associated with woven wire fencing in various jurisdictions. Tables C9, C10, and C11 provide further context on states that use different specifications for material type, height requirement, and post spacing for woven wire fencing.

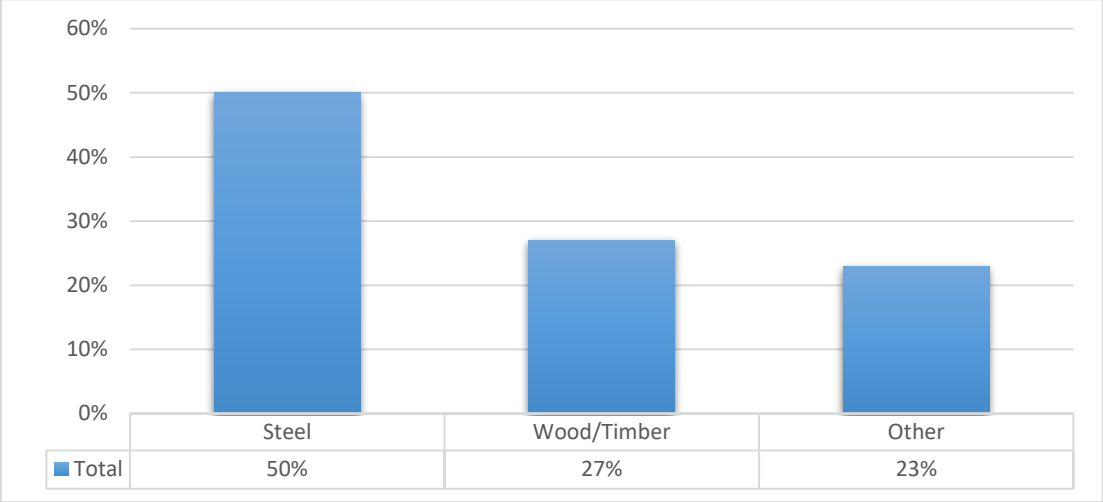
Figure 30. Required height associated with woven wire fencing



Q: What post type is used with woven wire fencing in your jurisdiction?

Figure 31 shows that steel posts are employed by 50% of respondents using woven wire fencing, while 27% of respondents utilize wood or timber posts.

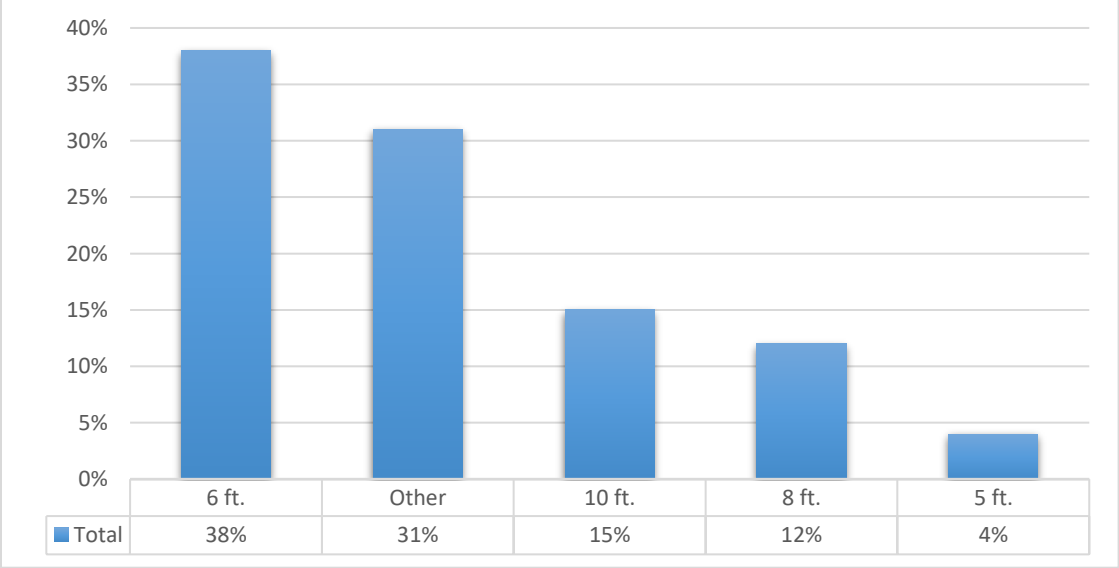
Figure 31. Post type associated with woven wire fencing



Q: What is the designated post spacing for woven wire fencing in your jurisdiction?

Figure 32 shows the designated post spacing for woven wire fencing in various jurisdictions. 38% of respondents from jurisdictions using woven wire fencing utilize 6 foot spacing.

Figure 32. Post spacing associated with woven wire fencing



Q: Is high tensile eight wire fencing used in your jurisdiction for control-of-access?

Survey results show that only 9% of jurisdictions reported using high tensile eight wire fencing for access control, while 91% did not. This suggests that it is not a widely adopted option for C-of-A fencing.

Q: What is the material type used for the high tensile eight wire fencing?

For all three jurisdictions that utilize high tensile eight wire fencing, 100% of respondents reported using galvanized ductile steel for its construction.

Q: What is the required height for the high tensile eight wire fencing?

The required height for high tensile eight wire fencing varies across jurisdictions. 50% of respondents utilized a height of 5 feet, while the other jurisdictions did not specify any height.

Survey data indicated that 29% of respondents used additional categories of fencing in their jurisdictions beyond those addressed previously. This indicates that although most jurisdictions employ chain link, woven wire, and high tensile eight wire fencing for access control purposes, a substantial minority employ other unspecified forms of fencing. This is outlined in Tables C1, C2, C3, C4, and C5, as well as Figure C12.

Conclusions

It is necessary to maintain control-of-access fencing to guarantee the safety, security, and efficient operation of the highway. C-of-A fencing functions as a critical barrier, regulating vehicle movement in designated areas, reducing incidents involving wildlife and pedestrians, and preventing unauthorized access. In many locations near interchanges, C-of-A fences serve the dual role of marking the right-of-way line. Louisiana needs to address the maintenance issues of its C-of-A fencing, much of which requires considerable attention.

Two specific maintenance issues can be highlighted regarding the condition of C-of-A fencing in Louisiana. First, reports indicate damage from run-off-road crashes, particularly near high-AADT urban areas. Second, overgrown vegetation compromises the durability of the fencing, partly due to insufficient regular maintenance. Regarding maintenance strategy, Louisiana currently employs a reactionary approach to regular fence maintenance. This method typically involves responding to requests from local governments and stakeholders and often results in maintenance being handled as a supplementary item to potential construction work.

This report outlined an extensive review of C-of-A fencing practices in a variety of jurisdictions across the U.S., emphasizing the most significant findings and challenges. Galvanized steel, chain link, and woven wire fences are the most frequently employed materials, according to the survey of state DOTs. Although these materials are known for their durability, they are still susceptible to environmental factors, including vandalism, vehicle collisions, and weather conditions.

Numerous state DOTs use reactive maintenance, which means that repairs are only addressed after problems have occurred. Although this reactive approach is widely used, it leads to more frequent structural damage and increases long-term costs. DOTs increasingly acknowledge the advantages of preventive maintenance, which entails routine inspections and the early identification of damage or deterioration. This proactive strategy has the potential to substantially reduce repair costs, extend the lifespan of fencing, and mitigate the safety risks associated with degraded fencing. The lack of sufficient financial resources to address these environmental challenges is a recurring issue for many DOTs, leading to delays in repairs and in some cases worsening the damage over time.

This report documented the results of a survey on best practices for maintaining C-of-A fencing. The survey, which was designed using Qualtrics and distributed to experts responsible for C-of-A fencing in all 50 states, provided a robust response that enabled an analysis of policies and guidelines across these states. Installation practices for C-of-A fencing vary

significantly, as responses indicated a range of approaches from recommended to mandatory installations based on specific circumstances. Some states have comprehensive mandates for fencing along all highway rights-of-way, while others evaluate needs on a case-by-case basis, particularly for interstates. The survey findings also highlight different state directives and administrative policies regarding fencing requirements, reflecting diverse statutory and regulatory environments. Additionally, maintenance responsibilities primarily fall to state DOTs, with occasional shared duties with other entities, emphasizing a predominant state role in fencing maintenance. This comprehensive survey shed light on the varied strategies and criteria states employ to manage and maintain their C-of-A fencing.

Highway safety and infrastructure management are dependent upon the maintenance of C-of-A fencing. The efficiency, durability, and cost-effectiveness of fencing maintenance can be enhanced, although current practices vary significantly across jurisdictions. State DOTs can overcome the financial and physical obstacles presented by environmental degradation, crashes, and budget constraints by implementing preventive maintenance strategies, investigating alternative materials, and standardizing best practices. Additionally, the implementation of more explicit policies regarding ownership and maintenance responsibilities, in conjunction with the implementation of updated technology and enhanced training, will guarantee that C-of-A fencing continues to be a dependable and cost-effective method of regulating access to high-speed highways.

Updating the Louisiana DOTD fencing policy may lead to cost savings by reducing maintenance needs associated with C-of-A fencing damaged in vehicle crashes. Also, using alternative fencing to control access will further reduce maintenance costs while satisfying aesthetic fencing needs.

Recommendations

The key recommendations for ensuring regular and efficient maintenance and management of C-of-A fencing are threefold: Proactive Maintenance for Unscheduled Repair Approaches; Proactive Maintenance for Scheduled Repair Approaches; and Construction Strategies. The state should approach the maintenance of C-of-A fencing as an exclusive item, rather than as a supplementary aspect of construction and maintenance, to ensure the continued effective use of existing and future fences.

Proactive Maintenance for Unscheduled Repair Approaches

- **Expanding the Scope of Damage Identification:** Beyond addressing immediate repairs due to damage from run-off road crashes or other natural calamities, expanding the scope to proactively identify such damages is crucial. Integrating proactive checks with mandatory inspections can significantly enhance the identification and resolution of existing maintenance needs.
- **Targeted Responses to Damage:** For locations with reported damage, it is crucial to adopt a proactive approach to ensure necessary repairs that were not previously scheduled. Instead of approaching these issues merely as supplementary items, identifying areas where no regular maintenance or construction is planned for a specific period should trigger immediate maintenance efforts.

Proactive Maintenance for Scheduled Repair Approaches

- **Routine Inspections:** Conducting routine inspections and proactively addressing issues as they arise goes beyond merely responding to immediate damage. Key factors in ensuring the effectiveness and durability of C-of-A fencing include regular vegetation control, timely restorations such as trimming bushes and cutting lawns, and replacing damaged sections of the fence. Maintenance should also include lubricating hinges and locks, as well as repainting or recoating as needed. These practices are common in a number of states, as highlighted in survey results. As the survey results indicated, vegetation control is the most frequent maintenance issue that is addressed through regular maintenance. From observing the fencing, it is clear that vegetation control should be a major priority, specifically in rural areas. Given that the majority of surveyed states conduct annual maintenance, the state should consider allocating a budget for these activities at least once every year.

- **Comprehensive Maintenance Framework:** Adopting comprehensive maintenance guides based on manufacturer recommendations can enhance fencing management effectiveness. The current Engineering Directives and Standards Manual (EDSM) addresses right-of-way issues concerning the erection, maintenance, and replacement of fencing. However, adopting more specific maintenance guidelines that align with existing resources and budget allocations could improve overall maintenance practices. This maintenance framework can incorporate DOTD's existing policy for roadside vegetation management, prioritizing the stages of vegetation control highlighted in the policy manual. This could include training relevant personnel to adhere to these maintenance strategies, thereby standardizing procedures across the state. A potential roadside maintenance plan can incorporate the maintenance issues of C-of-A fencing.
- **Tracking Maintenance:** Tracking mileage and repair costs effectively documents the potential benefits of maintenance. Monitoring maintenance trends over time helps in assessing progress and informing future improvements in maintenance strategies, such as establishing maintenance thresholds.

Construction Strategies

- **Avoiding Unnecessary Fencing:** It is recommended to strategically identify locations where fencing is unnecessary. Areas with steep gullies, ravines, and rivers naturally prevent access to pedestrians and animals. Fencing should not be installed in those locations.

- **Adjusting Height:** The most common height for chain link fencing is 5 feet; for woven wire fencing, the most common height is 4 feet. This finding aligns with Louisiana's design practice. However, modifications can be made based on damage scenarios, as other states have increased height for larger animals and to deter pedestrians. Similar to height, the spacing of posts in Louisiana also aligns with the conventional design.

- **Targeting Pedestrian Safety Hotspots:** Identifying the locations of frequent pedestrian crashes is essential for determining new areas where installing C-of-A fencing could be beneficial, particularly in urban settings. Utilizing available camera coverage to gather data on pedestrian encroachments can pinpoint hotspots of pedestrian activity. This strategy aims to enhance safety by preventing unintended pedestrian presence and reducing the likelihood of severe crashes. Additionally, this approach should help assess if existing fencing effectively prevents pedestrian access or if enhancements, such as climbing prevention measures, should be considered.

- **Targeting High Animal Activity Locations:** Similar to managing high pedestrian activity in urban areas, identifying animal activity hotspots on rural access-controlled highways can be beneficial. Utilizing current GIS facilities to locate these hotspots ensures the presence and necessity for potential C-of-A fencing on these roadways. Given the relatively lower activity compared to states with higher large-animal activity, the current C-of-A design may be sufficient to prevent animal encroachment. Considering the lack of detection of impact of animal-vehicle collision locations, the maintenance issue may be better managed with the cooperation of the Louisiana Wildlife and Fisheries Department, which tracks large wildlife activities [67].

- **Optimizing Fencing Materials:** Louisiana employs composite fencing, a combination of wood and metal, along with wooden fencing as alternative options. Louisiana is currently using chain link fencing like a majority of U.S. states. Utilizing the availability of alternative materials could reduce the construction and maintenance costs of C-of-A fencing. For instance, since District 7 of Louisiana DOTD has a greater availability of wood, the extensive utilization of wooden fencing can be a cost-effective strategy for both construction and maintenance.

- **Reviewing State-of-Art Knowledge of Construction and Maintenance:** Regular reviews of strategic knowledge on construction and maintenance, including automation and advanced technologies, are crucial for effectiveness. The state should continuously explore newer technologies that could facilitate quick and efficient maintenance and erection of C-of-A fencing.

- **Relying on Manufacturer's Guidelines for Installing and Maintaining Fencing:** The installation and maintenance of fencing should follow the manufacturer's guidelines. This could enhance the longevity of fencing and reduce maintenance costs.

Acronyms, Abbreviations, and Symbols

Term	Description
AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
C-of-A	Control-of-Access
CTDOT	Connecticut Department of Transportation
DOT	Department of Transportation
DOTD	Louisiana Department of Transportation and Development
EDSM	Engineering Directives and Standards Manual
FHWA	Federal Highway Administration
ft.	foot (feet)
in.	inch(es)
LTRC	Louisiana Transportation Research Center
lb.	pound(s)
m	meter(s)
ROW	Right-of-Way
WVDOT	West Virginia Department of Transportation

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Appendix

Appendix A: Survey Details

States Participating in the Survey

Table A1. Alphabetical list of states that participated in the survey

No.	State	No.	State	No.	State
1	Alabama	15	Kentucky	29	Oklahoma
2	Alaska	16	Louisiana	30	Oregon
3	Arkansas	17	Maine	31	Pennsylvania
4	Colorado	18	Maryland	32	Rhode Island
5	Connecticut	19	Massachusetts	33	South Carolina
6	Delaware	20	Michigan	34	South Dakota
7	Florida	21	Minnesota	35	Texas
8	Georgia	22	Mississippi	36	Utah
9	Hawaii	23	Montana	37	Vermont
10	Idaho	24	New Hampshire	38	Virginia
11	Illinois	25	New Mexico	39	Washington
12	Indiana	26	New York	40	West Virginia
13	Iowa	27	North Dakota	41	Wisconsin
14	Kansas	28	Ohio	42	Wyoming

Consent and Information Form

Title of the Study: Best Practices for Maintenance of Control of Access Fencing

Control-of-access relates to a legal status which limits the types of vehicles that can use a highway, as well as a road design that limits the points at which these vehicles can gain access. Control-of-access (C-of-A) fencing is installed on interstates and other freeways to provide protection to the operation of access-controlled highways from outside right-of-way encroachment or interference. Though C-of-A fencing plays an important role in highway safety, its maintenance has been relegated to a supplementary task by most jurisdictions. In an effort to better understand and enhance the maintenance practices of C-of-A fencing, the Louisiana Department of Transportation and Development (DOTD) has commissioned this study.

To this end, a survey questionnaire has been developed to seek input from transportation jurisdictions across the United States as a means to gather information on fencing policies, maintenance practices, and strategies to reduce fencing maintenance budgets. Specifically, the questionnaire seeks to:

- Solicit information on the maintenance of control-of-access fencing
- Understand control-of-access fencing policy and maintenance procedures used across the United States
- Identify alternative fencing and practices that can lower maintenance costs

If you agree to participate, you will be asked to complete a questionnaire consisting of: (1) transportation agency location and role within agency; (2) fencing design; (3) fencing maintenance practices and procedures; (4) fencing policy/procedural documents and procedures; and (5) alternative fencing. The survey will take 15-20 minutes to complete. Your responses will be collected and analyzed for the purpose of the study.

All comments and questions may be addressed to:

Milhan Moomen, Ph.D., Research Assistant Professor
Louisiana Transportation Research Center
4101 Gourrier Avenue
Baton Rouge, LA 70808
Milhan.Moomen@la.gov

Background Information

Name:

Email:

Contact information is only being collected in the event that there is a need to follow up with additional questions.

Please specify the state your transportation agency is located in:

What is your role within the State DOT? (e.g., maintenance manager, operations engineer, traffic engineer, etc.)

How many years of experience do you have in roadside maintenance?

Construction and Maintenance Practices

What is the level of requirement for the installation of control-of-access fencing in your jurisdiction?

- Mandatory
- Recommended
- Required
- Other (Please specify)

If the installation of fencing is required or mandatory, please provide the specific state/local statute, provision or law:

If the installation of fencing is recommended but not required, please describe your organization's approach to determine whether to install fencing. What criteria or considerations are used to make a determination? (Please select all that apply)

- Route AADT
- Proximity to/likelihood of pedestrian traffic
- General need for public safety (deter pedestrian/wildlife access, general deterrent to encroachment)
- Budget/cost considerations
- Other (Please specify)

Who is responsible for the maintenance of the control-of-access fencing in your jurisdiction?

- DOT (including district offices)
- Property owner
- Combination of both
- Other (Please specify)

How often is the control-of-access fencing inspected and maintained for damage or necessary repair?

- Annually
- Every 2 years

- Every 3 years
- Only when reported
- Other (Please specify)

What are the criteria used to prioritize maintenance of control-of-access facilities on existing roads? (Please select two)

- Community priority (including complaints/requests)
- Fence condition (vehicle damage, weather damage, etc.)
- Project feasibility or cost
- Change of right-of-way
- Other implementation opportunities (including "piggybacking" on other projects)

How is damage to the control-of-access fencing typically addressed?

- Immediate repair or replacement (0-3 months)
- Repair or replacement within a few months (3 months or more)
- Only repaired or replaced when there is sufficient funding (e.g., new construction project)
- Other (Please specify)

Which of these factors are most critical when determining maintenance frequency? (Please select two)

- Fencing material
- Age of fence
- Environmental conditions
- Budget and resources
- Vegetation control

Which of the following maintenance activities do you consider most essential for ensuring the longevity and functionality of control-of-access fencing? (Please select two)

- Cleaning and removing vegetation (e.g., trimming bushes, cutting grass)
- Repainting or recoating

- Lubrication of hinges and locks
- Replacement of damaged parts or sections

Are there any other factors that impact the longevity and functionality of control-of-access fencing?

- No
- Yes (If yes, please specify)

Alternative Fencing and Practices

Is there any alternative fencing that has been considered or used to lower maintenance costs?

- Yes
- No

Which alternative fencing options have been considered or used to lower maintenance costs? (Please select all that apply)

- Vinyl Fencing
- Composite Fencing (combination of wood and metal)
- Wooden Fencing
- Natural Barriers (trees/hedges)
- Other (Please specify)

What other strategies or practices have you found to be most effective in reducing overall maintenance costs related to control-of-access fencing? (Please select two)

- Proper installation
- Quality material
- Regular inspection
- Clear vegetation
- Effective drainage
- Prompt repair
- Other (Please specify)

Informational Guide and Policy

Which of the following best describes the process for weighting/inclusion of control-of-access fencing in the budget for maintenance?

- Formal (comprehensive plan)
- Informal (internal discussion)
- Both
- Not known

Have you used any informational guide(s) or procedural documentation for the control-of-access fencing maintenance?

- Yes
- No

Please name or describe the guide or document you utilized for the control-of-access fencing maintenance:

Are there plans to adopt or develop a fencing maintenance guide or document?

Which guides do you consider to be most beneficial? (Please select two)

- Online resources and publications
- Manufacturer’s guidelines
- Government or regulatory agencies
- An internal or in-house informational guide
- Fencing contractors and professionals
- Other (Please specify)

Design

Is chain link fencing used in your jurisdiction for control-of-access?

- Yes
- No

What is the material type used for the chain link fencing in your jurisdiction? (Please select all that apply)

- Aluminum alloy
- Galvanized ductile steel
- Aluminum-coated ductile steel
- Other (Please specify)

What is the required height for the chain link fencing in your jurisdiction?

- 4 ft.
- 5 ft.
- 6 ft.
- Other (Please specify)

What is the post type used with the chain link fencing in your jurisdiction? (Please select all that apply)

- Wood/Timber
- Steel
- Other (Please specify)

What is the designated post spacing associated with the chain link fencing in your jurisdiction?

- 4 ft.
- 5 ft.
- 6 ft.
- Other (Please specify)

Is woven wire fencing used in your jurisdiction for control-of-access?

- Yes
- No

What is the material type used for woven wire fencing in your jurisdiction? (Please select all that apply)

- Aluminum alloy
- Galvanized ductile steel
- Aluminum-coated ductile steel
- Other (Please specify)

What is the required height for the woven wire fencing in your jurisdiction?

- 4 ft.
- 5 ft.
- 6 ft.
- Other (Please specify)

What is the post type used with the woven wire fencing in your jurisdiction? (Please select all that apply)

- Wood/Timber
- Steel
- Other (Please specify)

What is the designated post spacing associated with the woven wire fencing in your jurisdiction?

- 4 ft.
- 5 ft.
- 6 ft.
- Other (Please specify)

Is high tensile eight wire fencing used in your jurisdiction for control-of-access?

- Yes
- No

What is the material type used for the high tensile eight wire fencing? (Please select all that apply)

- Aluminum alloy
- Galvanized ductile steel
- Aluminum-coated ductile steel
- Other (Please specify)

What is the required height for the high tensile eight wire fencing?

- 4 ft.
- 5 ft.
- 6 ft.
- Other (Please specify)

What is the post type used with the high tensile eight wire fencing in your jurisdiction? (Please select all that apply)

- Wood/Timber
- Steel
- Other (Please specify)

What is the designated post spacing associated with the high tensile eight wire fencing in your jurisdiction?

- 4 ft.
- 5 ft.
- 6 ft.
- Other (Please specify)

Is any other type of fencing used in your jurisdiction for control-of-access?

- Yes
- No

If there are other types of fencing used in your jurisdiction that have not been addressed in the previous questions, please specify the type and its associated material.

- Other fence type
- Material type
- Height requirement
- Post type
- Post spacing

Appendix B: Current Design of C-of-A Fencing and Gates in Louisiana

Figure B1. C-of-A for ramp/frontage road interchange

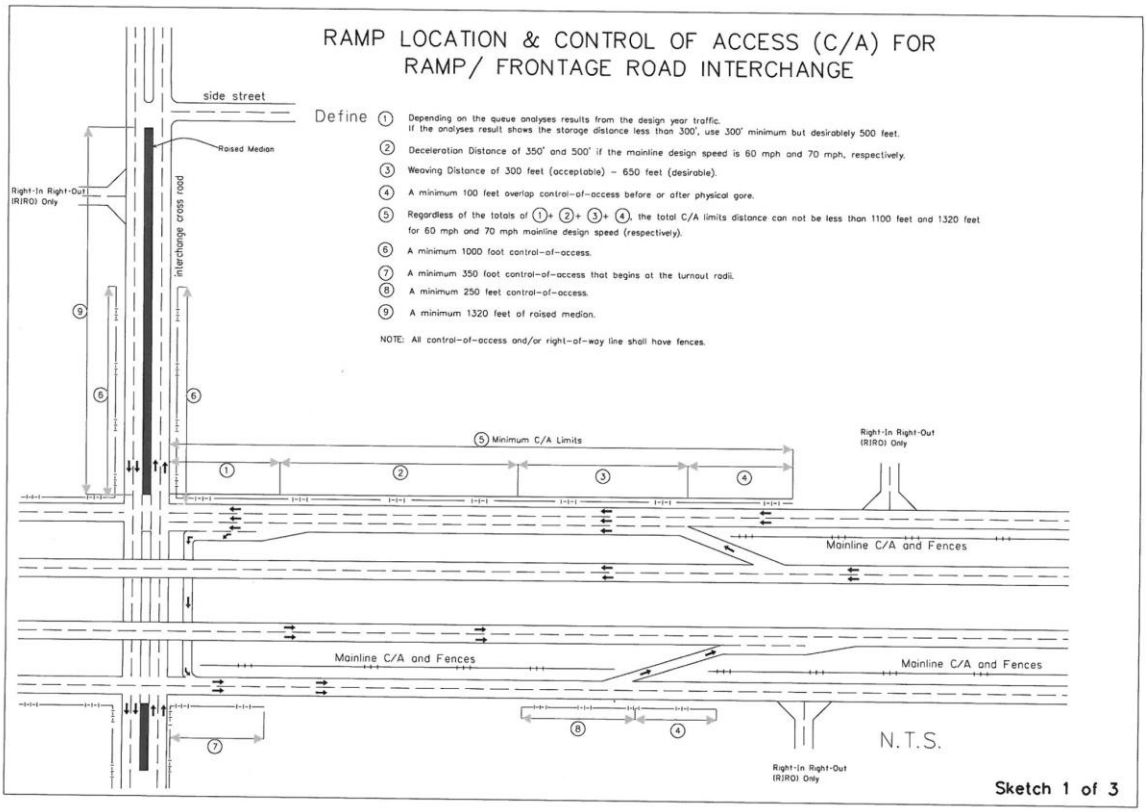


Figure B2. C-of-A for ramp/frontage road interchange

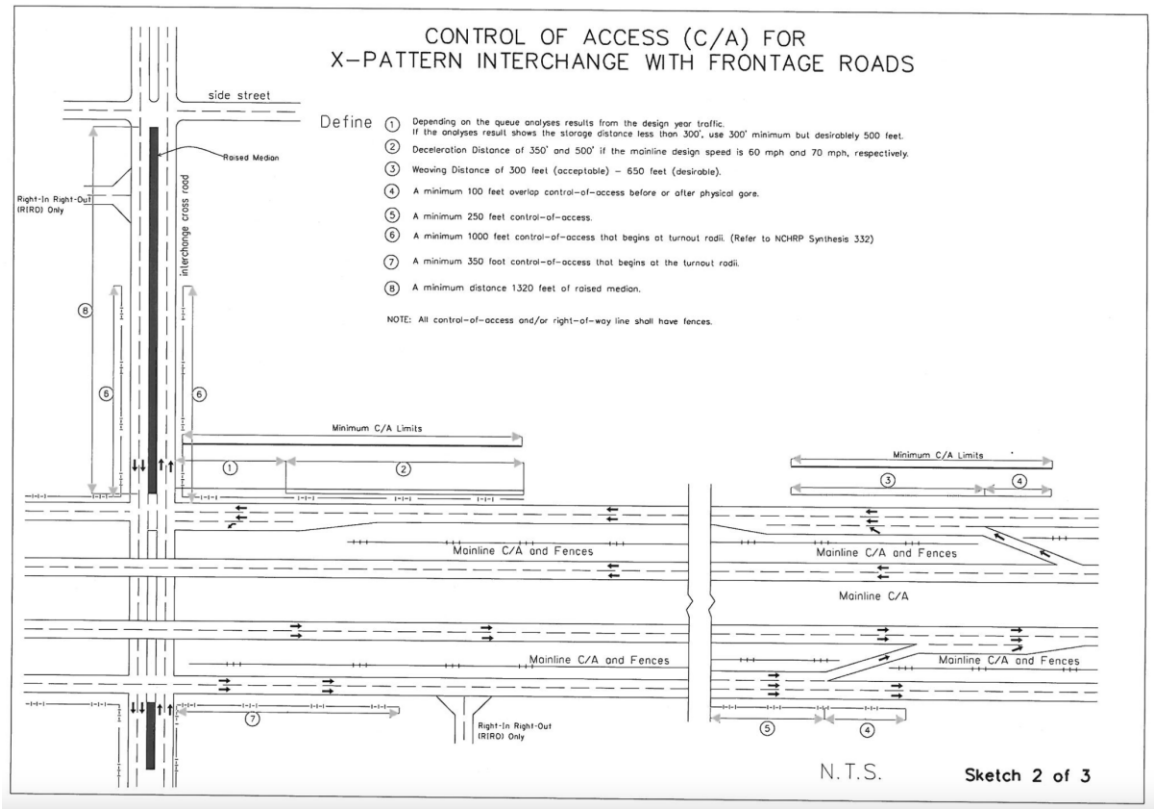
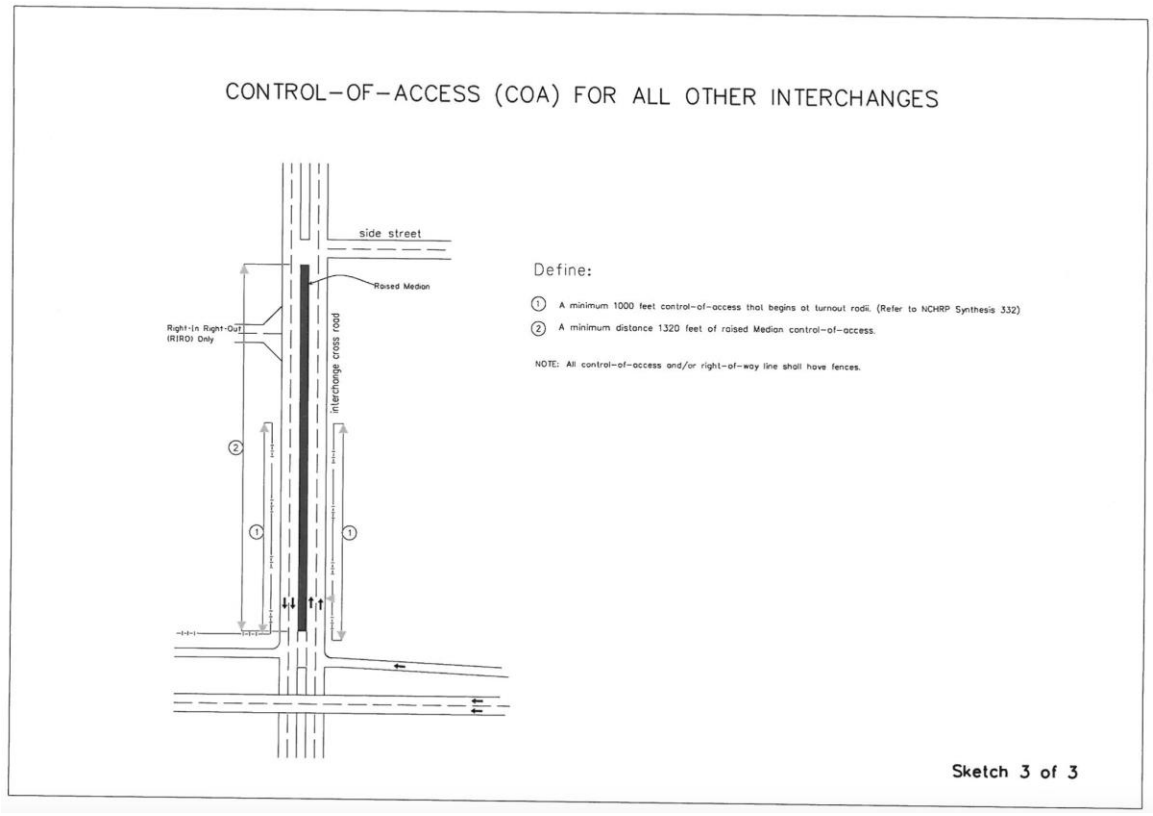


Figure B3. C-of-A for ramp/frontage road interchange



Appendix C: Supplementary Tables of Survey Questionnaire

Table C1 State/local statute, provision, or law if fencing installation is required

Specific state or local statute, provision, or law	State DOT
560.02(2) Limited Access Highways	Washington
All interstate routes	Mississippi
FHWA requirement	Montana
FHWA specifies COA will be fenced for interstate highway systems	South Dakota
It is required by Administrative Policy within the Department as directed by various sections of Idaho Code	Idaho
It is required by design policy	Connecticut
NMDOT Access Control Policy	New Mexico
Not sure	North Dakota
Unknown	Michigan
Standard Specifications Construction or Transportation Systems	Georgia
Title 19	Vermont
I am unsure; it is not handled at my level.	South Carolina
Utah Administration Rule 930-6, Utah Code 72-1-202.	Utah

Table C2 Other requirements for installation of C-of-A fencing

Other Requirements for Installation	State DOT
All highway rights-of-way are fenced where WYDOT deems it appropriate	Wyoming
Case by case basis	New Hampshire
Depends on the right-of-way designation for the route	Pennsylvania
Installation driven by FHWA and projects Maintenance and repair performed as needed	Wisconsin
Interstates mandatory	Oregon
Not known	Oklahoma
Office of Highway Development	Maryland

Other Requirements for Installation	State DOT
Recommended in most applications, but it is mandatory when livestock is present	Colorado
Required for limited access routes	Virginia
Varies	New York
We have driveway-controlled access; however, it is not required	Hawaii

Table C3 Percentages of maintenance activities for ensuring the longevity of C-of-A fencing

Factors that impact longevity and functionality	State DOT
Accidents caused by close proximity to the roadway	Utah
Adjacent property owner land use activities	Arkansas
Budget not available due to other priorities	South Carolina
Crashes	Indiana
Damage from animals such as livestock	Idaho
Damage to the fence from property owner's vegetation and development	Connecticut
Environmental factors are critical in our area	New Mexico
Snow depth, large amounts of snow tend to pull wires down or off fence posts	North Dakota
Snow load, proximity to the public damage	Minnesota
Traffic damage	Connecticut
Trees falling on the fence	North Dakota
Weather condition	South Carolina
Wind and debris	Colorado

Table C4. Other alternative fencing to lower maintenance costs

Alternative Fencing	State DOT
Composite Fencing (combination of wood and metal), Wooden Fencing	Louisiana
Natural Barriers (trees/hedges), Concrete posts, and a single large chain	North Dakota

Alternative Fencing	State DOT
Natural Barriers (trees/hedges), Sound barriers	Connecticut
Single cable fence on guardrail posts	Kansas
Smooth wire woven wire	South Dakota

Table C5. Guides or documents utilized for C-of-A fencing maintenance

Guide(s) or document	State DOT
CDOT M&S standard details	Colorado
GDOT spec book and design policies	Georgia
Maintenance Guidelines	New York
Maintenance Rating Program Handbook	Florida
ND MTCE manual	North Dakota
The department maintenance guide under activity 138 is fence maintenance.	Oregon

Table C6. Other material types for chain link fencing

Chain Link Fence (Material Type)—Other	State DOT
1. Zinc-coated fabric meets the requirements of ASTM A 392, Class 2 (2.0 ounces per square foot) or AASHTO M 181 Type I, Class D. 2. Aluminum-coated fabric meets ASTM A 491 or AASHTO M 181, Type II requirements. 3. PVC coated fabric meeting requirements of ASTM F 668, Class 2b or AASHTO M 181, Type IV, Class B Fused.	Iowa
WisDOT standard specification 616 Property and right-of-way Fence	Wisconsin

Table C7. Other height requirements for chain link fence

Other chain link fence height requirements	State DOT
Height varies depending on location	Arkansas
Replace in kind and height	Washington
Variable, mostly 6-8 ft.	Montana
Varies, it is used in urban areas	Oregon
4-6 ft.	New York

Table C8. Other chain link fence post spacing

Other chain link fence post spacing	State DOT
16 ft.	Pennsylvania
Varies	Wisconsin, Oregon
Varies, based on manufacturer specification	Rhode Island
We don’t have a standard	Idaho

Table C9. Other material types used for woven wire fence

Woven Wire Fence (Material Type)—Other	State DOT
Field fence shall conform to AASHTO M 279 or ASTM A 116 and shall be unless otherwise specified: 1. Type Z, Class 3. 2. Design numbers 1047-6-11 or 939-6-11 for grade 60 wire or design numbers 1047-6-12 1/2 or 939-6-12 1/2 for grade 125 wire. 3. Use galvanized (as determined by visual inspection) steel rod for splicing fence material.	Iowa

Woven Wire Fence (Material Type)—Other	State DOT
Can vary based on design; see standard specification 616.2.2.1 Woven Wire Fabric.	Wisconsin

Table C10. Other post types associated with the woven wire fence

Other woven wire fence post type	State DOT
Steel Line posts End, corner, pull, or braces can be wood or steel	Arkansas
Both wood (corner and brace posts) and steel (line posts).	Iowa

Table C11. Other post spacing associated with woven wire fence

Other woven wire fence post spacing	State DOT
8-14 ft.	Alabama
12 ft.	Montana
14 ft.	Utah
16 ft.	Iowa, South Dakota, Wisconsin
16 ft 6 in.	Wyoming
Unknown	Idaho

Figure C1. Types of fences other than chain link, woven wire, and high tensile eight wire fence

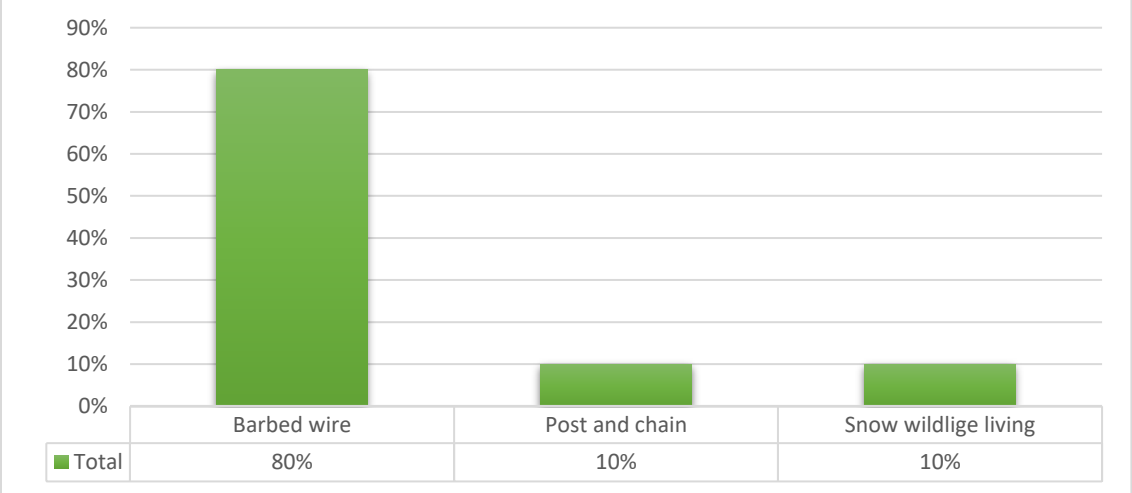


Figure C2. Material type associated with type of fence other than chain link, woven wire, and high tensile eight wire fence

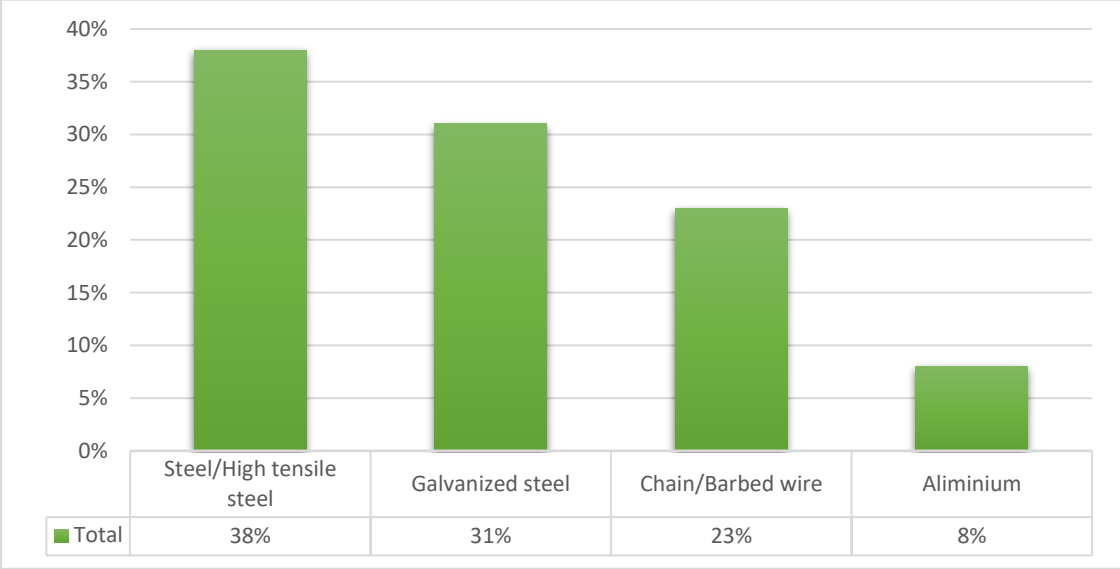


Figure C3. Height requirement associated with type of fence other than chain link, woven wire, and high tensile eight wire fence

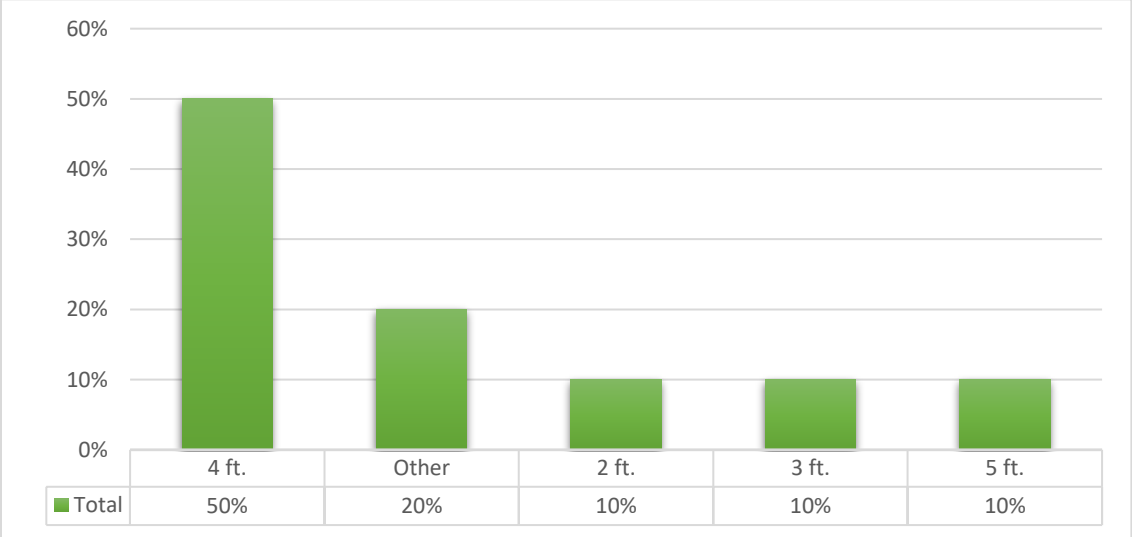


Figure C4. Post type associated with type of fence other than chain link, woven wire, and high tensile eight wire fence

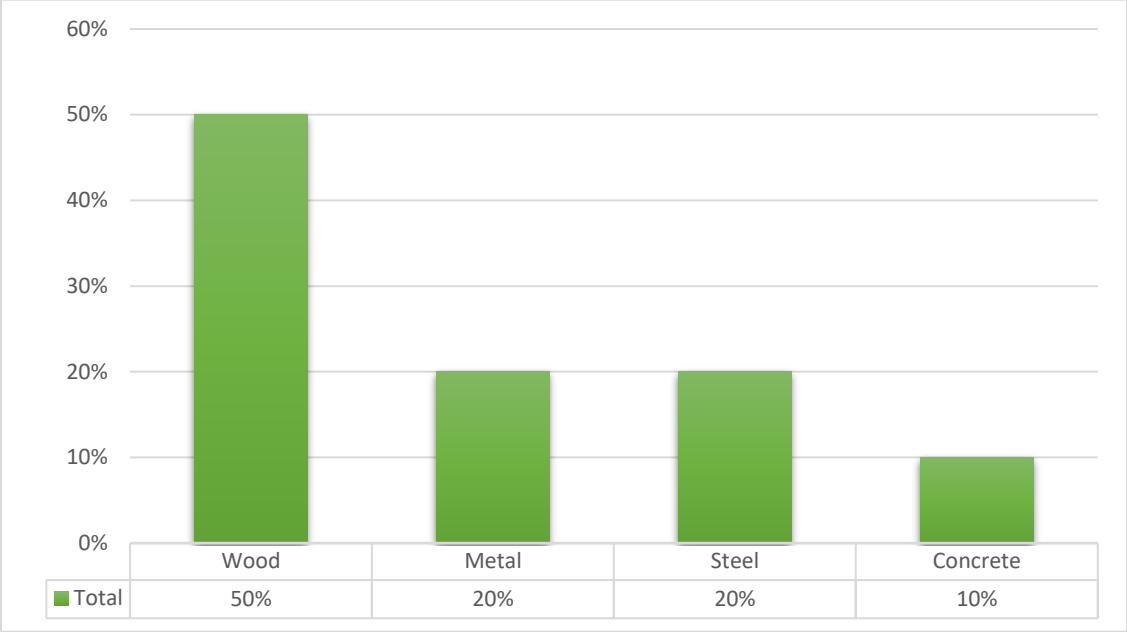


Figure C5. Post spacing associated with type of fence other than chain link, woven wire, and high tensile eight wire fence

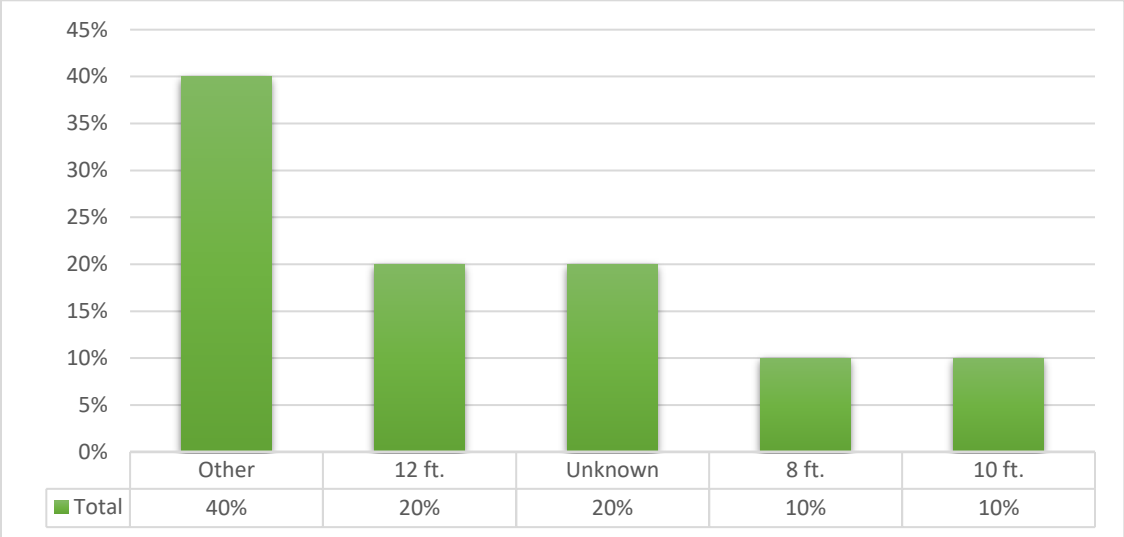


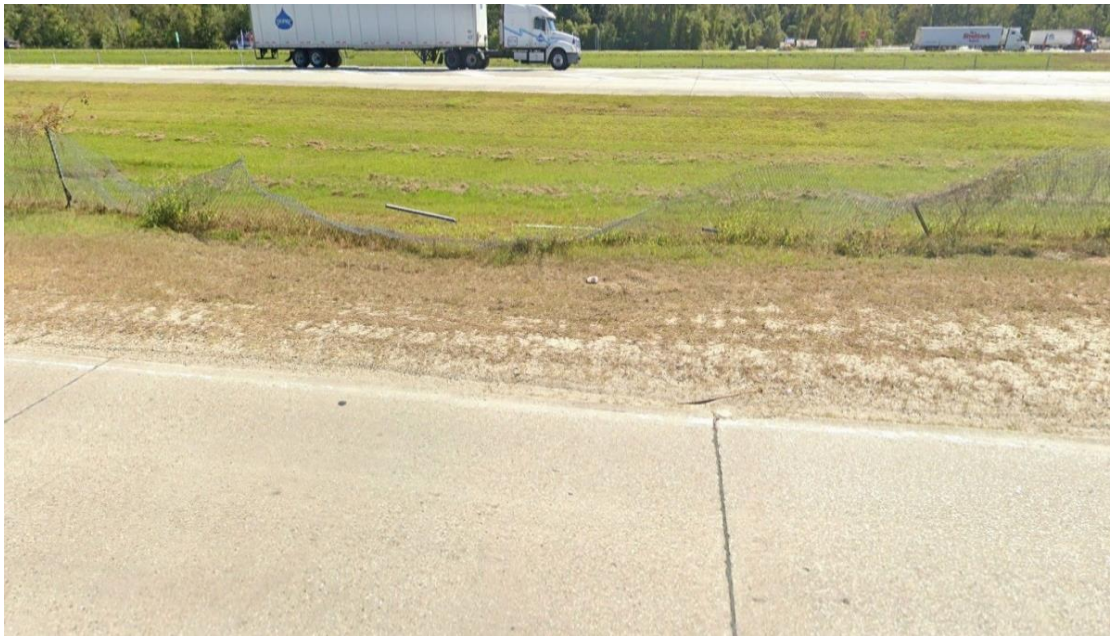
Table C12. Other post spacing associated with type of fence other than chain link, woven wire, and high tensile eight wire fence

Other post spacing associated with other fence type	State DOT
16 ft.	Utah
16 ft.	Wyoming
16 ft.	Colorado
16 ft.	South Dakota

Appendix D: Additional Images for C-of-A Damage

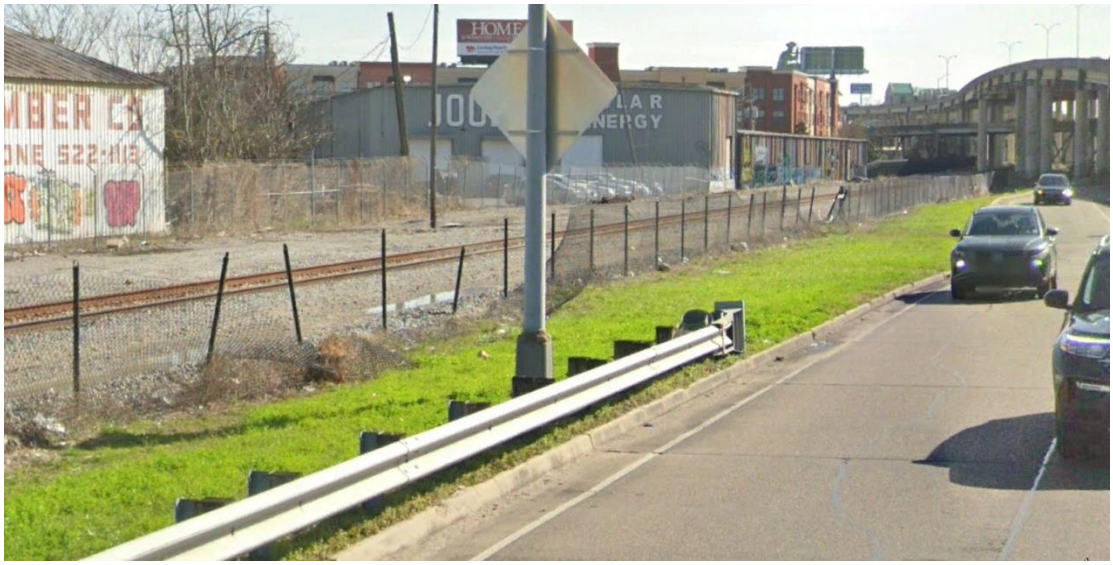
Figure D1. Damage of C-of-A fencing (loose sections) (a), (b), (c) and (d)

(a)



(b)

(c)



(d)