VDOT

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Virginia Department of Rail and Public Transportation

VIRGINIA GRADE CROSSING STATE ACTION PLAN

FEBRUARY 2022

VIRGINIA GRADE CROSSING STATE ACTION PLAN

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- ***Virginia Department of Education (VDOE)***
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- ***CSX***
- ***Norfolk Southern (NS)***
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1 INTRODUCTION

1.1 PURPOSE

According to the Federal Railroad Administration (FRA), there are a total of 3,037 miles of rail lines with 9,409 highway-rail crossings in Virginia. Of this amount, 1,852 are public and at-grade, 2,574 private grade crossings, and 1,852 grade-separated grade crossings, as well as 3,764 closed crossings.

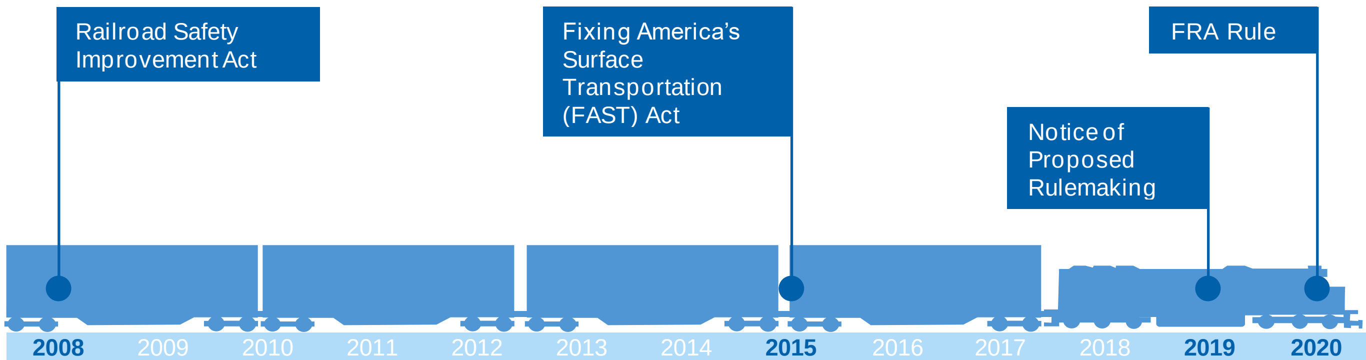
The purpose of the Virginia Grade Crossing Action Plan is to provide the strategies and actions that will improve rail safety throughout the Commonwealth ensuring people, goods, and services arrive at their destinations. A particular focus are the rail-highway grade crossings where trains and vehicles interact, which can lead to dangerous circumstances for all users. This plan was developed with internal and external coordination with several stakeholders in Virginia, including the Virginia Department of Transportation (VDOT), Department of Rail and Public Transit (DRPT), and rail safety stakeholders to align with FRA requirements, noteworthy practices from Federal Highway Administration (FHWA), and other state plans where transportation safety goals and objectives overlap.

State Action Plans provide an opportunity to conduct a systematic review of highway-rail grade crossings for safety risks identification, needs prioritization, safety solutions identification, and strategic actions to improve crossing safety. Combining the quantitative results with stakeholder feedback resulted in the comprehensive identification of issues and concerns regarding highway rail grade crossings, including multiple crossings in close proximity, blocked crossings and challenges in obtaining matching funds for upgrades.

1.2 BACKGROUND

The Railroad Safety Improvement Act (RSIA), passed by the U.S. Congress in 2008, required the 10 states with the highest highway-rail grade crossing accident rates to develop State Grade Crossing State Action Plans (SAP). In 2015, the Fixing America's Surface Transportation (FAST) Act directed the FRA to require the remaining 40 states and the District of Columbia to also develop SAPs. The FRA published a Notice to Proposed Rulemaking (NPRM) in November 2019 requiring all states to create grade-crossing action plans, as well as updates to the 10 states with existing plans. The NPRM was followed by a Final Rule a year later, 49 CFR §234.11, State Highway-Rail Grade Crossing Action Plans.

Figure 1 State Grade Crossing State Action Plans Timeline



1.3 GOALS AND OBJECTIVES

An important part of the Action Plan is establishing goals and objectives. Consideration of goals and objectives determines action- and results-oriented programs and projects structured for and focused on implementation and evaluation. Safety performance measures are the key to ensuring safety issues are considered and addressed throughout the transportation planning process. The goal of Virginia's Rail Safety Action Plan, which provides the why of the plan and the reason it has merit, is to:

Improve safety where railroads interact with other motor vehicles and other modes of transportation over the next five years.

For the plan objectives, five-year rolling averages were used to account for expected variability in the data from year-to-year due to the relatively small frequency of incidents. To achieve that goal, the plan includes six specific objectives that address the highway-rail safety challenges facing the Commonwealth including:

1. Reductions in the number and rate of incidents at passive crossings.
2. Reductions in the number and rate of incidents at active (equipped) crossings.
3. Reductions in the number and rate of crossing incidents involving all modes.
4. Reductions in the number and rate of incidents, injuries and fatalities involving trespassers in the vicinity of at-grade crossings.
5. Reductions in the severity of incidents (fatalities, injuries and property damage) at locations with reoccurring incidents within the last five years.
6. Reductions in the number of incidents on railroad right-of-way that is not an at-grade crossing.

These objectives identify the changes the plan intends to accomplish and address, not only the actual number and rate of incidents at both passive and active crossings across all modes, but also incidents involving trespassers, locations with recurring incidents over the last five years, and railroad right-of-way incidents not directly at at-grade crossings.

The objectives are supported by strategies and action steps, identified in ***Action Plan***, that provide a framework for plan implementation over the next five years. The strategies indicate how the changes will be made, and the actions are the specific tasks or steps that will be undertaken by highway-rail safety stakeholders to implement the strategy and achieve the objectives.

1.4 REQUIRED PLAN ELEMENTS

State Highway-Rail Grade Crossing Action Plans are required to include several key elements. The first element is to identify crossings for improvement. This identification is done by reviewing crossings with at least one incident in the previous three years, those with more than one incident in the previous five years, and other high-risk locations as defined by Virginia. The Plan must also contain an action plan for improving safety, including a discussion of strategies for improving crossings over the next five years, a documented implementation timeline, and the designated official responsible for managing that implementation.

In the final rule, the FRA also designated several high-risk factors in the following table that should be considered, including the data sources used. Most of these locations are considered in the U.S. Department of Transportation (DOT) Accident Prediction and Severity Model (APS). Table 1 lists the required plan elements, risk factors, and location of each plan element.

Table 1 Required State Action Plan Elements and Additional Risk Factors

#	Required Element	Location
(i)	Have experienced at least one accident/incident within the previous 3 years	Pg. 18
(ii)	Have experienced more than one accident/incident within the previous 5 years	Pg. 18
(iii)	Are at high-risk for accidents/incidents as defined in the Action Plan	Pg. 54
	Specific strategies to improve safety over at least four years	Pg. 56
	Provide an implementation timeline	Pg. 56
#	**Minimum High-Risk Factors**	**Location**
(A)	Average annual daily traffic	Pg. 36
(B)	Total number of trains per day	Pg. 36
(C)	Total vehicle collisions during previous 5-year period	Pg. 18
(D)	Number of main tracks at each crossing	Pg. 40
(E)	Number of roadway lanes at each crossing	Pg. 40
(F)	Sight distance	Pg. 52

2

VIRGINIA HIGHWAY-RAIL GRADE CROSSING SAFETY EFFORTS

2.1 INTRODUCTION

Highway-rail grade crossing safety requires a multidisciplinary approach and coordination with the overall transportation planning and safety process. This section summarizes the transportation plans that relate to and align with rail grade crossing safety and the administrative programs that implement these safety improvements. Highway-rail grade crossing safety improvements are funded and implemented through a variety of methods, including the Highway-Rail Crossings (Section 130) Program and local jurisdiction work. Local jurisdiction efforts outside Section 130 include grade separations, quiet zones, and corridor-level planning, which is occasionally supported by state agencies.

2.2 FEDERAL REQUIREMENTS

Public safety at highway-rail grade crossings has been a Federal priority since the early 1900s. Federal grants for states to reduce hazards of highway-rail grade crossings were first established in 1933, and the Railroad Safety Act of 1970 resulted in a study to eliminate and protect grade crossings, an approach which has been carried forward in subsequent legislation. Since 1974, the FHWA's Railway-Highway Crossings Program (Section 130) has provided funds to states for the elimination of hazards at highway-rail crossings. Today, FHWA and other Federal agencies continue to support states to promote safety improvements at or near public highway-rail grade crossings.

Table 2 State Grade Crossing Chronology

Year	Legislation	Description
2008	Railroad Safety Improvement Act	Required 10 states with the highest accident records to develop State Action Plans, including Alabama, California, Florida, Georgia, Illinois, Indiana, Iowa, Louisiana, Ohio, and Texas.
2015	Fixing America's Surface Transportation (FAST) Act	Required the FRA to issue rules for the other 40 states and the District of Columbia to develop State Action Plans.

Year	Legislation	Description
2019	Notice of Proposed Rulemaking	Rulemaking required states to develop or update State Action Plans.
2020	FRA Rule	FRA published the Final Rule that required all states to develop or update State Action Plans.

Section 130 Program

Recent Annual Set-Asides:

- ***FY2016:*** *$350 million*
- ***FY2017:*** *$230 million*
- ***FY2018:*** *$235 million*
- ***FY2019:*** *$240 million*
- ***FY2020:*** *$245 million*

Section 130 of Title 23, United States Code, codifies the Federal Highway Rail Crossings Program (commonly referred to as the Section 130 Program—S130) and specifies the way funds apportioned from this program may be used by state DOTs. The Program is funded as a set-aside from the funds apportioned for the Highway Safety Improvement Program (HSIP) under 23 U.S.C. 148. Safety improvements are implemented along with the rest of the HSIP. This funding was continued under the Moving Ahead for Progress in the 21st Century Act (MAP-21) and under the Fixing America's Surface Transportation (FAST) Act. The funds are apportioned to states by formula. S130 projects are funded at 90 percent Federal share in accordance with 23 USC 130(f)(3).

The FAST Act increased the set-aside amount for each fiscal year. In addition, the Consolidated Appropriations Act of 2016 (Public Law 114-113) provided a one-time increase for fiscal year 2016. Section 130 funds are apportioned to states by a set formula.

Infrastructure and Investment Jobs Act

The Infrastructure and Investment Jobs Act (IIJA), signed into law in November 2021, brings some significant changes to the Section 130 program. Overall Federal funding for the Section 130 program increases to $245 million (nationally) in the first year, significantly higher than the levels seen with the FAST Act. The Federal share for projects is increased from 90 to 100 percent and clarifies that the replacement of functionally obsolete warning devices is an eligible expense. The permissible amount of state incentive payments at-grade crossing closures is raised from $7,500 to $100,000, and the set-aside for compilation and analysis of data is increased as well from 2 percent up to 8 percent.

The IIJA also has a new FRA program called "Railroad Crossing Elimination Grant Program" that will be funded at $600 million annually on a national basis. Grants shall be awarded for projects that make improvements to highway and pathway rail crossings, such as eliminating highway-rail at-grade crossings that are frequently blocked by trains, adding gates or signals, relocating track, or installing a bridge. The program would improve the safety of communities and the mobility of people and goods. At least 20 percent of grant funds are reserved for projects located in rural areas or on Tribal lands.

2.3 VIRGINIA'S APPROACH TO MANAGING AT-GRADE CROSSINGS

Applicable Virginia Statutes

Virginia has several laws and regulations that impact highway-rail grade crossings:[1]

***§ 33.1-145.1. Grade crossing closing and safety**

It is the public policy of the Commonwealth of Virginia to enhance public safety by establishing safe highway-rail grade crossings; to consolidate and close unsafe, unnecessary, or redundant crossings; and to limit the establishment of new crossings. The Commonwealth Transportation Board (CTB) has the authority to close public highway/rail grade crossings on the system of highways for which it has responsibility.

§ 56-365.1. Closing and or consolidation of grade crossings

Whenever public safety requires that an existing railroad crossing by a public highway at grade be eliminated or that multiple grade crossings be consolidated, either the public road authority or the affected railroad may petition the CTB to request funding for the change. Elimination of the existing grade crossing may also be a condition of receiving the funding.

***§ 56-366.1. Proceedings to avoid or eliminate grade crossings by grade separation or to widen, strengthen, remodel, relocate or replace existing crossing structures on public highways**

The Commonwealth Transportation Board or public road authority will allocate funds for payment of the locality's or state's portion of the cost of constructing overpass or underpass structures or for widening, strengthening, remodeling, relocating or replacing an existing structure. The Commissioner of Highways or representative of the public road authority will coordinate with the railroad companies involved, on terms and conditions regarding the plans and specifications, the manner of construction and the division of costs and maintenance responsibility of any separation of grade structure.

***§ 56-369. Elimination of public grade crossings by change of alignment of public highways or construction of replacement public highways**

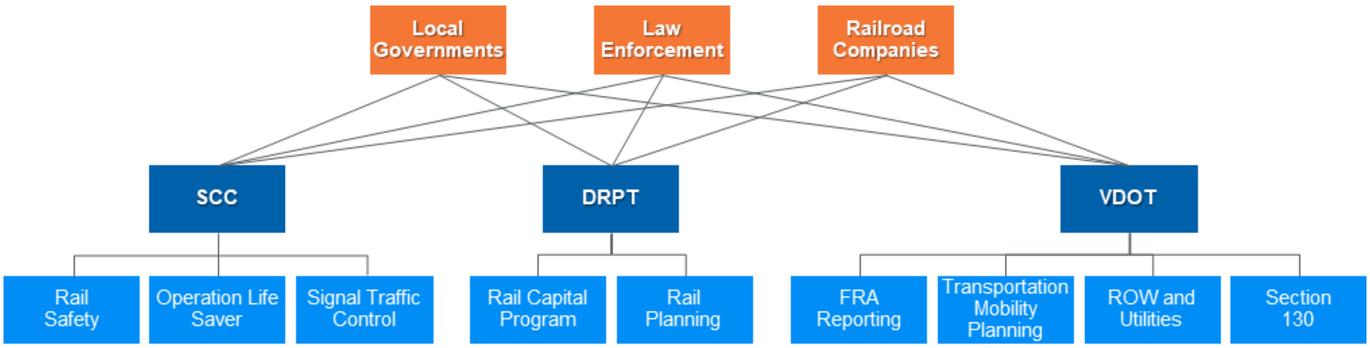
The public road authority will coordinate with the railroad companies involved, on terms and conditions regarding the plans and specifications, the manner of construction and the division of costs and maintenance responsibility of any proposed changes to the alignment of the highway or construction of a highway that would permanently eliminate one or more crossings of a railroad at grade.

Institutional Elements

Virginia's approach to rail grade crossing safety is complex in that the different responsibilities and aspects of grade crossings are spread throughout VDOT, DRPT, and the State Corporation Commission (SCC), making it challenging for any other entity to coordinate on a specific element. The diagram in Figure 2 shows the different aspects for which each organization is responsible and the various lines of coordination that are necessary for local governments, law enforcement, and railroad companies to address rail grade crossing safety.

[1] Compilation of State Laws and Regulations Affecting Highway-Rail Grade Crossings (FRA, 2014).

Figure 2 Virginia's Approach to Grade Crossings



The SCC is involved in Operation Life Saver and works on both Rail Safety and Signal Traffic Control. The Division of Utility and Railroad Safety assists in administering safety programs involving underground utility damage prevention, jurisdictional natural gas and hazardous liquid pipeline facilities, and railroads. The Railroad Regulation section of the Division conducts inspections of railroad facilities to ensure safe operation of Virginia railroads.

Virginia DRPT coordinates with local, regional, state, and Federal governments, as well as private entities, on rail planning, public transportation, and commuter services. They provide support for projects and programs, and they are responsible for managing the Rail Capital Program for the state.

VDOT is the state and responsible for most of the Federal reporting, including FRA Reporting and Section 130 programming/reporting through the HSIP. VDOT also oversees Transportation Mobility Planning and ROW and Utility management.

Virginia's Section 130 Program

Virginia's Section 130 Program allocates $4.5 million annually and is focused on low-cost safety upgrades, lights and gates, and surface improvements. The Section 130 Program funds improvements at passive and active crossings, as well as efforts to close crossings. Improvements at passive crossings include low-cost safety upgrades such as highly reflective signs, while improvements funded at active crossings include upgrading signal systems, 12-inch LED fixtures, and solar-powered pre-warning devices.

3 PLAN DEVELOPMENT PROCESS

3.1 INTRODUCTION

Highway-grade crossing safety requires a multidisciplinary approach in coordination with the overall transportation planning process, supported by the involvement of the railroads, safety organizations, law enforcement, and local, state, and Federal stakeholders. This section summarizes the stakeholder engagement and transportation plans encompassing or related to highway-grade crossing safety.

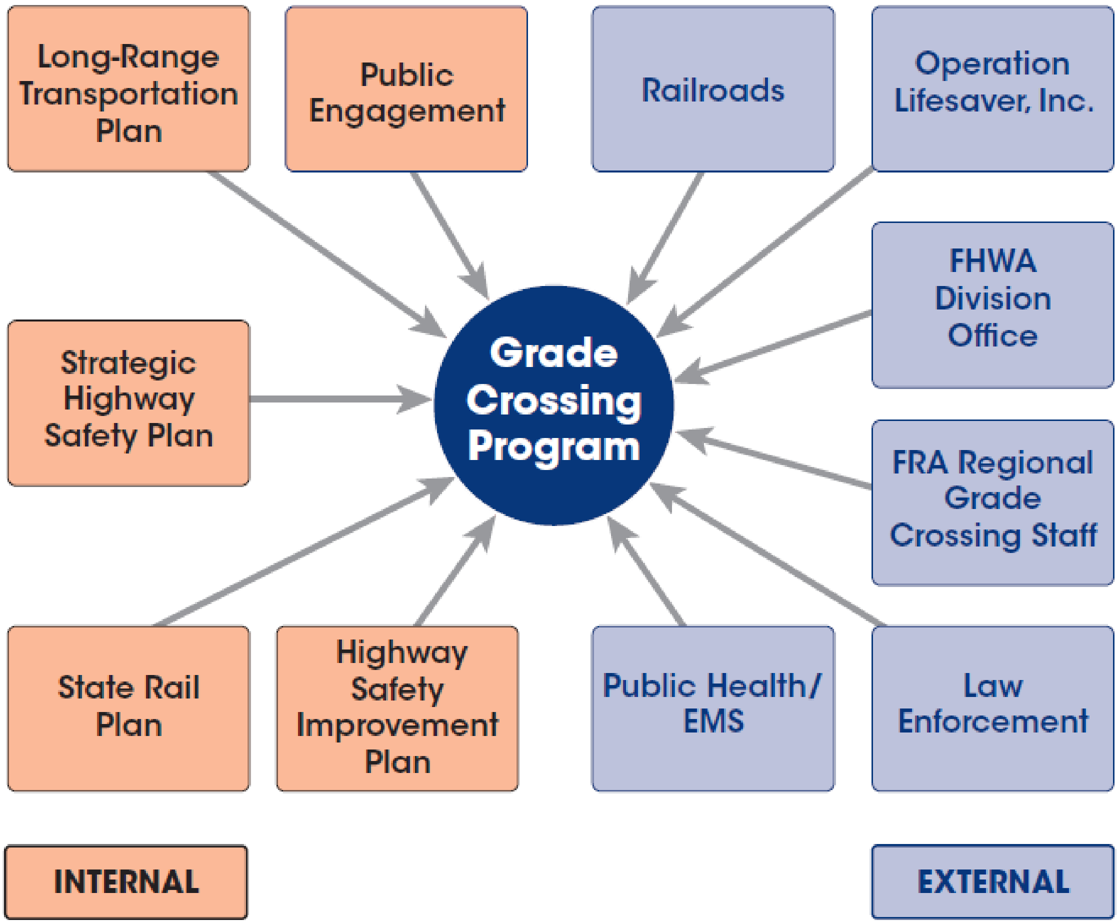
3.2 STAKEHOLDER ENGAGEMENT

The agencies most closely involved in the development of the Virginia Grade Crossing State Action Plan (SAP) are VDOT, DRPT, and the SCC. These agencies worked together to conduct stakeholder outreach through interviews and a webinar with local jurisdictions. This outreach confirmed the data analysis conducted for the plan, provided qualitative context to other elements that were analyzed, and offered ideas for the strategies and actions in the plan.

FRA and FHWA provided some guidance on the stakeholders to be interviewed as did VDOT and DRPT and the implications for the state's particular jurisdiction of roads and tracks. Figure 3 shows the framework for stakeholder outreach that encourages states to develop their own approach in a manner that best addresses their own unique needs. "The implementation program, with cycles for data collection, reporting on strategies and objectives, and mid-term revisions, needs to include provisions for sharing information on the SAP's accomplishments with external stakeholders."[2]

[2] FRA, FHWA (2016). "Highway-Railway Grade Crossing Action Plan and Project Prioritization Noteworthy Practices." https://safety.fhwa.dot.gov/hsip/xings/fhwasa16075/.

Figure 3 Internal and External Resources for the SAP



Source: FRA, FHWA (2016).

The findings from stakeholder outreach activities are categorized by key issues, trends, and problems. These were culled from interviews with 12 key stakeholders, and a webinar that was conducted to engage with local officials. Stakeholder interviews were conducted with representatives from the following organizations.

- **Railroads**
  - CSX
  - Norfolk Southern (NS)
  - Buckingham Branch Railroad (BB)
  - Virginia Rail Express (VRE)
  - Virginia Railroad Association (VRA)
- **Public Safety**
  - Ashland Police Department
  - Virginia Department of Motor Vehicles (DMV) Highway Safety Office

- **Virginia State Agencies**
  - Virginia Department of Transportation (VDOT)
  - Virginia Department of Rail and Public Transportation (DRPT)
  - Virginia State Corporation Commission (SCC)
- **Federal Agencies**
  - Federal Highway Administration (FHWA)
  - Federal Railroad Administration (FRA)

The webinar, conducted on August 26, 2021, attracted 82 attendees, including 43 local and state agency staff across the Commonwealth.

Key Issues, Trends, and Problems

Key issues are topics identified for future discussion. In some cases, these are topics on which to find common understanding, a common solution, or forge a partnership. **Trends** demonstrate areas under development or experiencing change, which could be an increase or decrease in occurrence. **Problems** are harmful matters or concerns that need to be addressed.

Key Issues

Lack of coordination on rail safety improvements. Many respondents expressed a strong desire for better coordination among the involved parties, as they felt that there often is no clear path to engagement among the railroads, local jurisdictions, the state, and law enforcement to address public rail safety issues. The railroads and other participants viewed the development of the SAP and the associated stakeholder engagement as a first step to meeting this objective.

The freight railroads cited a disconnect with Virginia's regulations that impact the Commonwealth's involvement with grade crossings. For example, in 2019, one of the railroads attempted to close three crossings that were good candidates for closure. During that process, they endeavored to engage with public officials for assistance, but they were unsure if they should meet with the VDOT district, with whom they met onsite, the city, or VDOT headquarters. In the end, nothing happened. Another railroad offered an example of a city attorney who would not sign an agreement to provide maintenance funding for a grade crossing at $1,000 per year because they did not want to obligate future city councils to pay.

For commuter train operator VRE, the challenge is that they are only a tenant and thus do not control the tracks over which they operate. Furthermore, VRE's limited resources often hampers their ability to engage with local jurisdictions. There needs to be coordination and accountability to help with engagement. One local law enforcement agency reported that trespassing is an issue that requires immediate, appropriate jurisdictional enforcement. During the webinar, a local jurisdiction participant asked about a rail safety issue. They asked whom to call and were told to reach out to the owner of the crossing, likely a railroad. However, that is not always the case.

Simplify priorities for investment. Discussion on safety technologies generally led to stakeholders resoundingly advising that priorities should be low-cost, low-risk, and high impact.

FRA discussed the previous 10 state SAPs as a template so that there was no need "to reinvent the wheel." Example SAPs cited included Georgia, Indiana, North Carolina, Ohio, and Texas. All of the railroads interviewed agreed that a data-driven approach focusing on locations with high incident frequencies should guide prioritization for improvement. All three freight railroads interviewed also advocated for closing crossings and weighing the costs of doing so against the cost of fatalities and serious injuries caused by incidents. FRA said it was important to have an established plan for closing crossings. The railroads also offered to help with ideas at crossings whether that be medians, high contrast paint markings, or barriers against vehicles going around gates. FHWA also advocated for choosing impactful, achievable, low-cost projects. VRE said in their review of crossings that in some areas, gates do not lower in sync, and just addressing this issue could be impactful.

Operation Lifesaver needs more support. Railroads, enforcement, Federal, and state partners agreed that the revitalization of the OLI program under the SCC is a step in the right direction. However, they suggested more engagement with local jurisdictions and increased stakeholder involvement to include colleges and rural areas, in addition to the K through 12th grade demographic has been a longstanding focus of OLI. OLI's hallmark event of Rail Safety Week in late September has been somewhat limited due to the COVID-19 pandemic.

Trends

Land use associated with some private crossings is increasingly averse to safety. This was an issue primarily discussed by the railroads. Many private at-grade crossings were established generations ago when traffic volumes were much lower. However, in recent years substantially increased roadway traffic has increased risk exposures at some private crossings. Railroads are interested in the local jurisdictions' land use plans to mitigate the following trends.

- **Private crossings can have traffic volumes comparable to public crossings.** However, because they are owned by private landowners and often bound by old access agreements, the railroads are not able to address rail safety concerns in a straightforward manner.
- **Land use changes can exacerbate the issue.** One carrier described an example where a farm had been redeveloped into a recreational vehicle (RV) campground, increasing traffic substantially. There was another example in Dumfries where real estate development occurred around a private crossing with a nearby marina and restaurant.

Operation of long trains (over 8,000 feet) is a relatively recent phenomenon, particularly in the east where this practice only has become widespread since 2017. Is this a safety hindrance or safety benefit? This question was added after stakeholder interviews had begun so the question was not asked of every respondent. VRE said long trains increase the time it takes for emergency medical services (EMS) response. One respondent conceded the extra time it takes for train operating personnel to resolve enroute incidents, which can result in extended crossing blockages. However, both Class I railroads serving the state said that the longer trains reduce the frequency of interactions between trains and road users, and thus are a net safety benefit. A 2019 U.S. Government Accountability Office (GAO) report found that additional information is needed to assess the impact of longer trains.[3]

[3] U.S. GAO (2019). "Rail Safety: Freight Trains Are Getting Longer, and Additional Information Is Needed to Assess Their Impact." https://www.gao.gov/products/gao-19-443.

Problems

Trespassing. All stakeholders acknowledged that trespassing is a big problem. However, not all trespassing is the same. There is a difference between bicyclist, pedestrian, or off-road vehicle (ORV) users trespassing as a shortcut or for recreation versus suicides. Railroads offered that mental health awareness must be a component of public outreach. OLI advocates against romanticizing trains in media. They also conduct outreach nationally with fishing and hunting associations to spread the word. Enforcement is necessary but can be complicated by jurisdictional issues. Physical barriers and signs are another avenue but require careful consideration to avoid exacerbating high-risk situations. These were potential solutions offered across the board, with acknowledgment that it is a problem nationwide.

Photo: Spencer Whitman

Educating public, drivers, and law enforcement on rail safety. Law enforcement cited the need for public education on rail safety, railroads cited the need for driver and law enforcement training, and the DMV noted that driver training on rail safety is limited. There may be opportunities to update driver training and partner with OLI on this effort. For FHWA, it is important to look at behavior from the point of the road user that is using a short cut or possibly avoiding some other danger when trespassing, citing the lack of sidewalks in many Virginia communities.

Hot spots. The following specific jurisdictions were cited in the answers given by stakeholders:

- North 7th, Valley Road and Hospital Street in Richmond (CSX)—This skewed crossing is one of the most dangerous crossings in the Nation, according to FRA statistics. CSX acknowledged that improving this location is complicated by the presence of African American burial grounds and environmental justice issues; thus, there must be a more intentional process to addressing safety at the crossing.
- Suffolk (NS)—OLI has concentrated its public outreach where incidents continue to be an issue. NS shared a list of crossings in Suffolk where they see many incidents.
- Manassas (NS) and Dumfries (CSX)—VRE cited the urban, high-road user volume as being a major issue for at-grade crossings located in these communities. Manassas is a town with a lot of festivals. The volume is highly localized. According to CSX, it is the prospect of ongoing development in Dumfries that makes it a hot spot that will only get worse.
- Fredericksburg (CSX)—VRE cited this town as a place where gates at crossings do not come down in unison.
- CSX recommended closure of the following highway-rail crossings:
    - Petersburg (CSX)—There are two crossings: one at Lincoln Street and one at Grimes Road, both of which are county roads.
    - Isle of Wight (CSX)—The crossing at Old Carrsville Road.

Conclusion

The stakeholder outreach identified key issues, trends, and problems. An analysis of interviews and the webinar results paired with the risk assessment to inform the SAP. The next section is devoted to the detailed results of stakeholder activities.

3.3 ALIGNMENT WITH OTHER STATE PLANS

Multiple transportation plans in Virginia reference highway-rail grade crossing safety. State rail plans are also multiyear, data-driven plans for state investments in passenger and freight railroad services. FRA has issued guidance for the content and format of state rail plans, which include rail safety policies from the state rail system inventory. Highway-rail grade crossing statistics and funding programs are usually reviewed in state rail plans but not in the same level of detail as rail state action plans. This section documents the review of the following plans to identify overlapping goals and objectives related to highway-rail grade crossing safety. Three of the four plans reviewed are currently being updated.

VTrans 40

VTrans is Virginia's Transportation Plan that is prepared for the CTB by the Office of Intermodal Planning and Investment (OIPI). OIPI collaborates with VDOT and the DRPT staff to help guide the work and outputs of the VTrans. Their hands-on engagement throughout the process encourages strong coordination among key agency departments and divisions to help ensure a successful VTrans outcome. The plan is currently being updated. However, the published VTrans 40 (2017) highlights rail safety in many ways. Though there is not a specific reference to rail at a high level, safety is discussed throughout the document and is more formally referenced in the Virginia Freight Element. VTrans 40s guiding principle is “Ensure Safety, Security, and Resiliency: Provide a transportation system that is safe for all users, responds immediately to short-term shocks such as weather events or security emergencies, and adapts effectively to long-term stressors such as sea level rise.” This guiding principle cascades to its goal of “Safety for All Users.”

Virginia Freight Element

Within VTrans40, the Virginia Freight Element (VFE) is devoted to rail safety and an associated subsection is devoted to highway-rail grade crossings. The section describes data trends and factors in incidents. According to VTrans 40, “funding for the Section 130 program varies by year, but averages about $4.5 million annually. The number of projects completed depends on the type and cost of the projects, but typically between 15 and 40 projects are completed in a year.”[4]

Virginia State Rail Plan

This plan is being updated with an expected completion in 2022. The latest published plan was developed by DRPT in 2017 under the guidance of the CTB Rail Committee. It has as its second goal to “Ensure Safety, Security and Resiliency.”

[4] VTrans 40. (2017.) pp. 7-11. https://icfbiometrics.blob.core.windows.net/vtrans/assets/docs/VTrans2040-Freight-Element.pdf.

Virginia Strategic Highway Safety Plan

Virginia's 2022-2026 Strategic Highway Safety Plan (SHSP) is expected to be published in January 2022. The latest version of the document (2017-2021 SHSP) was developed in a joint effort between VDOT and Virginia Department of Motor Vehicles (DMV). Traffic safety was summarized in terms of infrastructure-related (such as intersections and roadway departures) and behavioral-related (such as speeding and impaired driving) crashes. Rail safety was discussed under the intersection emphasis area in the strategy to "Improve user comprehension of and compliance with intersection and interchange traffic control devices." The action that supports crossing safety is to "assess best practices and develop an action plan for passive and active public highway-rail grade crossings, including grade separations, intersection warning and signing, gating, and signalized intersection interconnection."

4.1 INTRODUCTION

This chapter outlines the initial data collection, analysis, and findings for the Virginia State Action Plan. Several documents were reviewed in the development of this analysis, including the FAST Act (section 11401(b)(2)) outlining State Action Plan requirements and Federal Register Vol. 85, No. 240 which covers the rules and regulations of State Action Plans. Other documents such as previous state action plans and best practice guides were also reviewed before conducting this analysis.

Background

Data was analyzed for all the entities that make up Virginia's rail system, including 3,065 Open at Grade Public Highway-Rail Crossings. Virginia is served by eleven freight railroads, eight Amtrak intercity passenger routes, and two VRE commuter routes. The system includes 3,037 miles of rail lines operated by the 11 freight railroads — 2 Class I railroads and 9 shortline railroads. The passenger rail system is comprised of Amtrak long-distance intercity services, intercity services through Amtrak, and VRE commuter rail services. These passenger services operate on rail lines owned by the freight rail companies under negotiated service agreements.

Data Sources

The primary data sources for the data collected were:

- The FRA Highway-Rail Crossing Inventory Crossing Inventory, maintained by the Federal Railroad Administration (FRA), which uses data submitted through FRA Form 6180.71.
- The FRA Highway-Rail Grade Crossing Accident/Incident Database (Form 6180.57) was also used. This database contains information on each reported accident at highway-rail crossings. Information on crossing conditions, vehicle user profile, and incident particulars are reported in this form.

- VDOT Rail Inventory Management System (RIMS)—system used by the rail safety section to maintain accurate and up-to-date information on highway-rail grade crossings in Virginia.
- FRA—Rail Equipment Accident/Incident (6180.54), Operational Accidents (6180.55), Trespasser Casualties.
- Fatal Analysis Reporting System (FARS) database—contains fatal traffic crash data in all 50 states, District of Columbia, and Puerto Rico.
- State System for Accident Reporting (e.g., Traffic Records Electronic Data System (TREDS)).

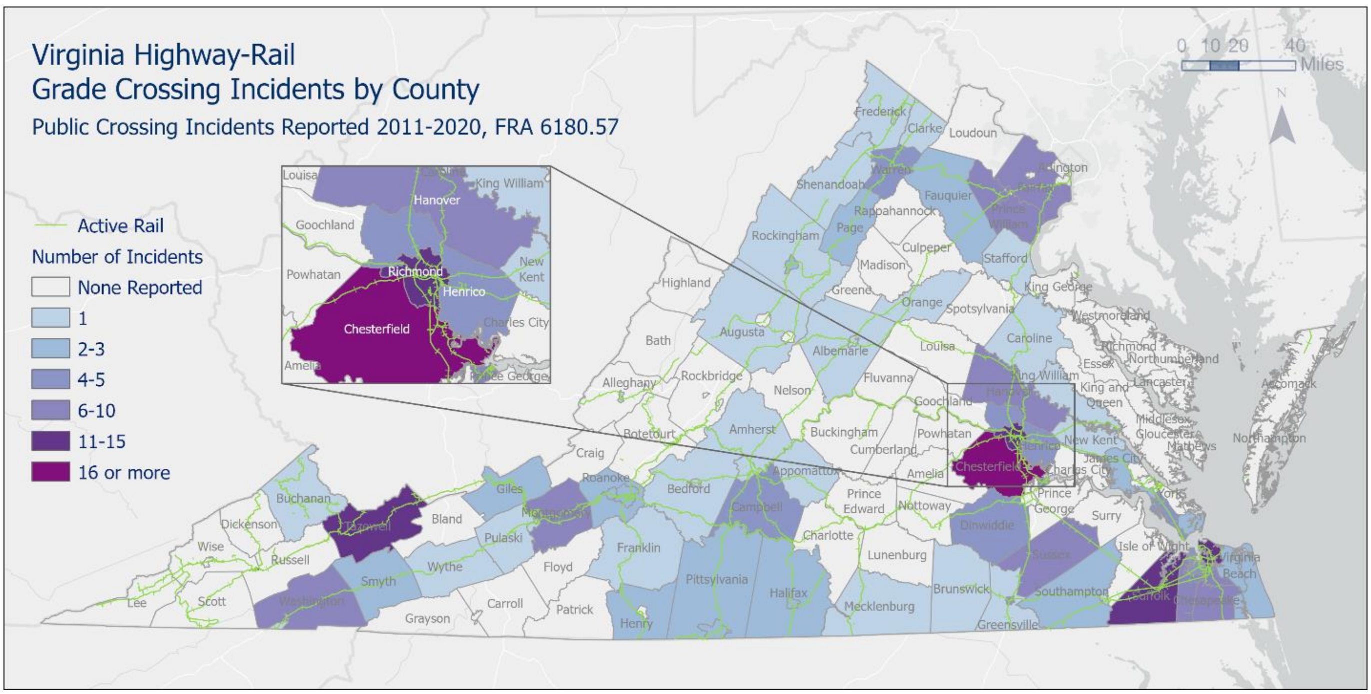
4.2 APPROACH AND SUMMARY

Data Analysis

The maps below represent a spatial analysis of Virginia Highway-Rail Crossing incidents reported at public crossings from 2011–2020, per FRA Form 6180.57. The 10-year approach was considered a means of establishing safety trends for the highway-rail crossing infrastructure with focus on the areas with the most history of incidents.

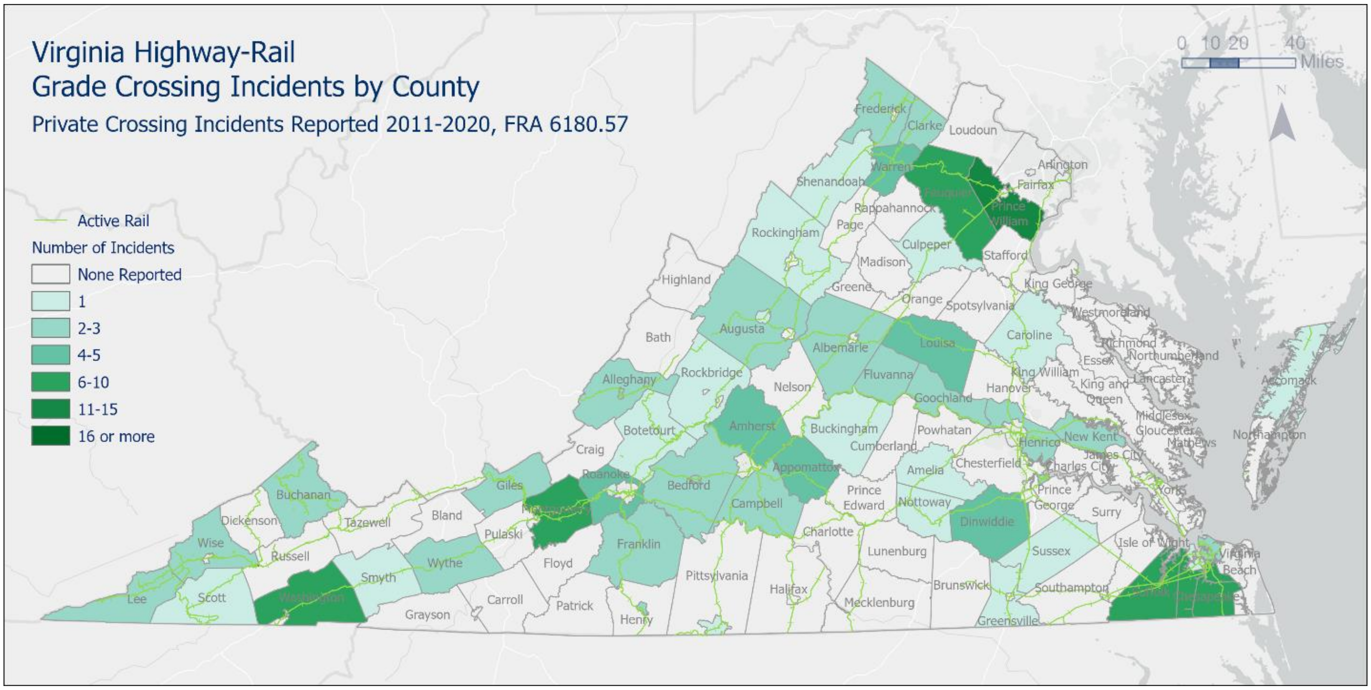
Figure 4 shows the incidents reported between 2011 and 2020 at public crossings in Virginia by County. Chesterfield County had the most incidents (16) at public crossings.

Figure 4 Incidents at Public Crossings by County



Although the Virginia State Action Plan does not emphasize private crossings, Figure 5 represents the monitoring of incidents at private crossings for future trend analysis.

Figure 5 Incidents at Private Crossings by County



By combining both public and private crossings incidents, areas of focus as shown in Figure 6, based on rail corridors and population centers, can be established within the trend analysis.

Figure 6 Incidents at all (both Public and Private) Highway-Rail Crossings by County

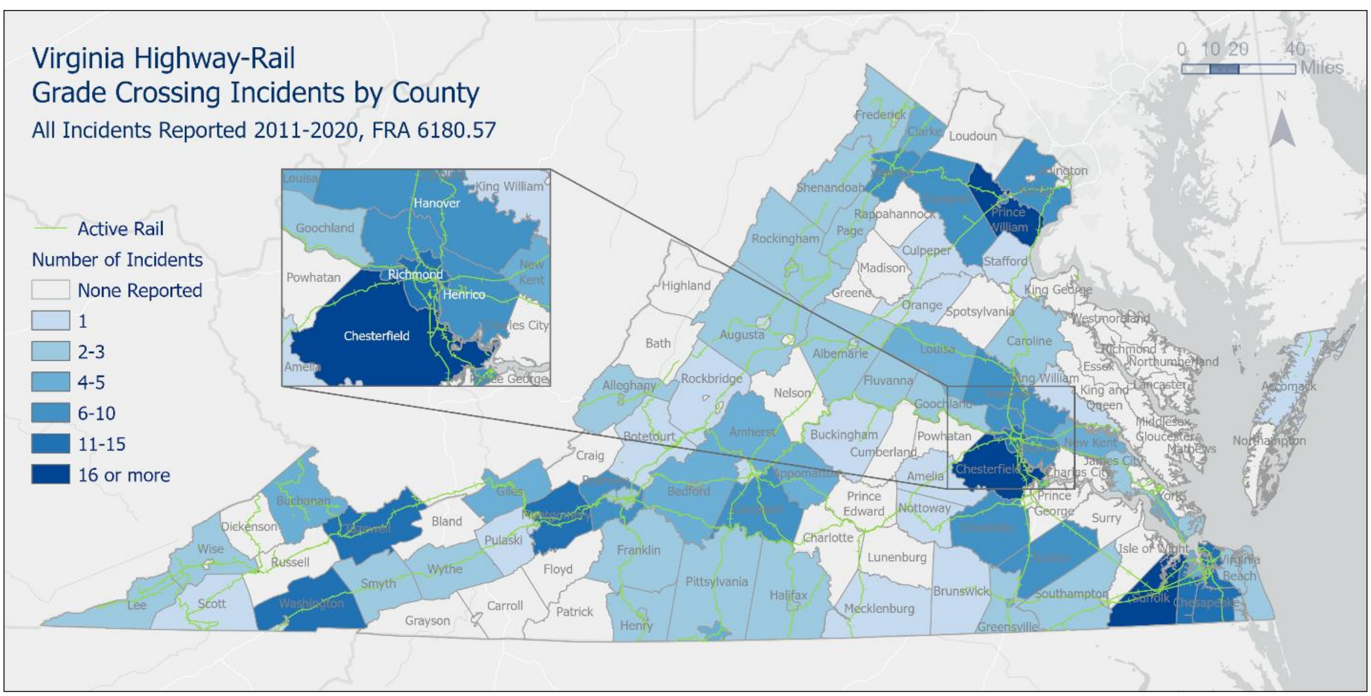


Figure 7 shows that clusters of incidents can be readily identified and established as areas of focus.

Figure 7 Specific Locations of Highway-Rail Crossing Incidents

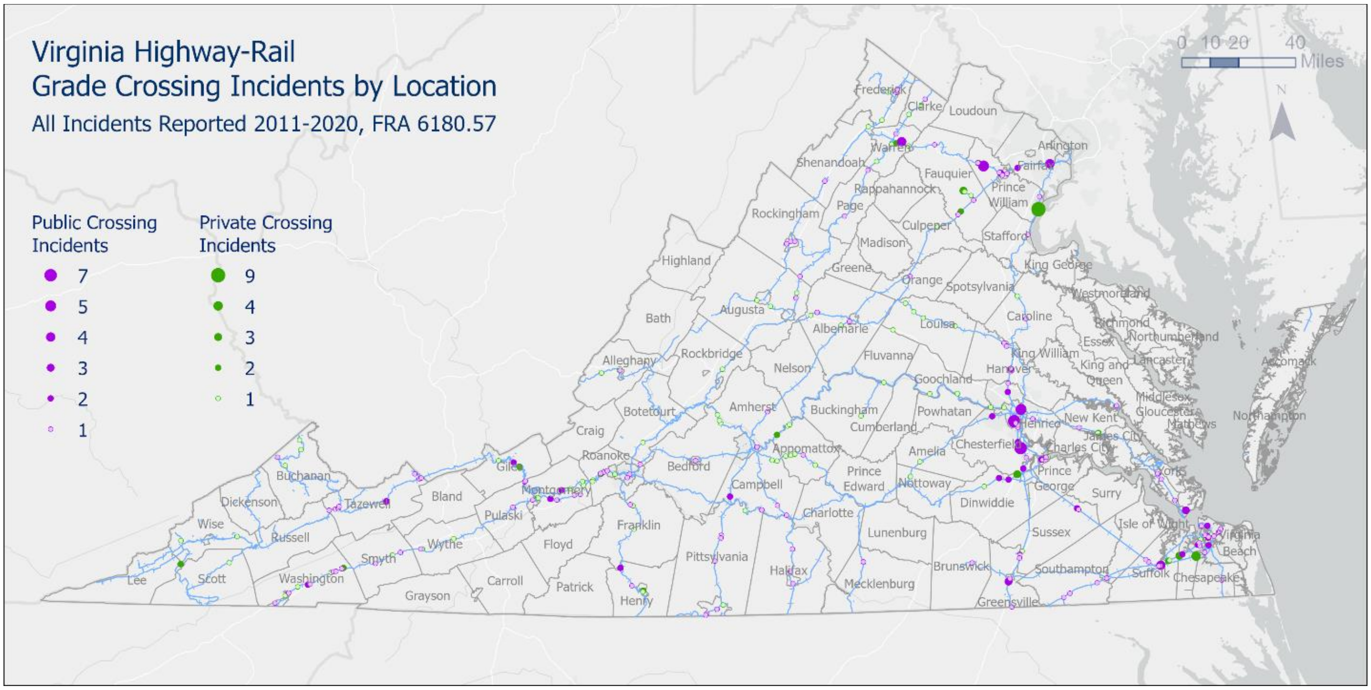
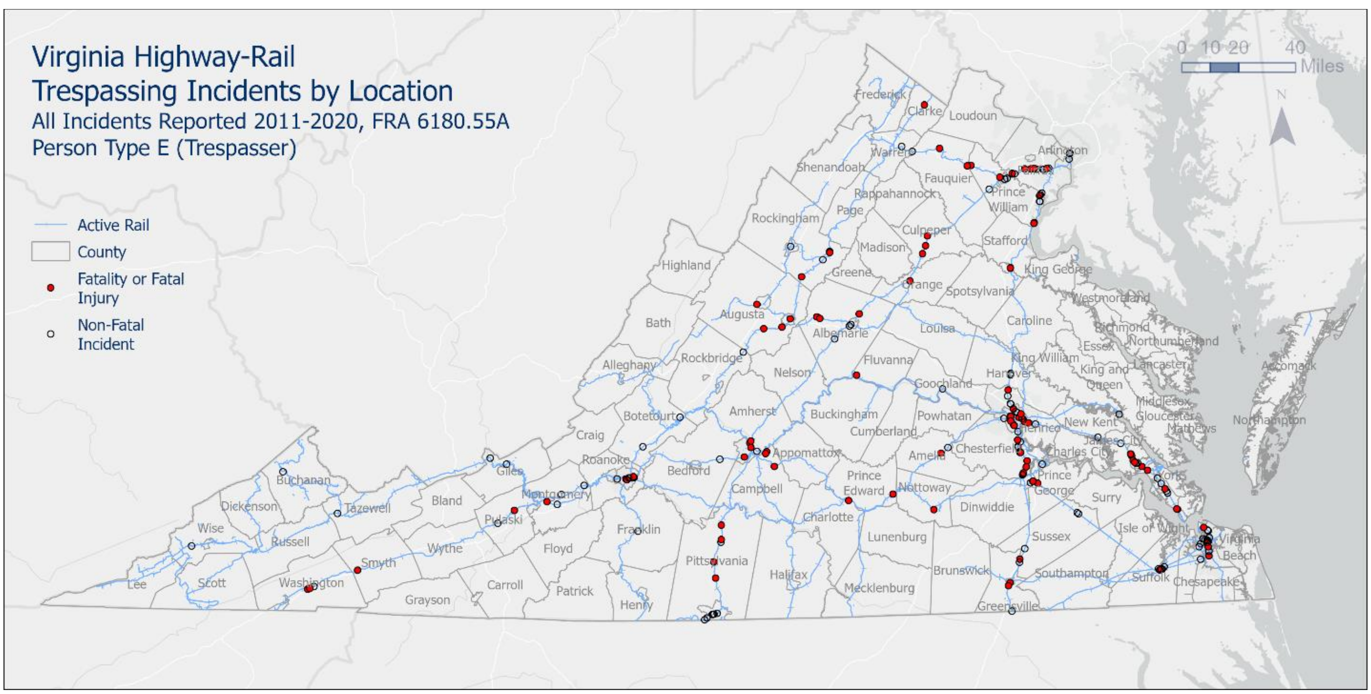


Figure 8 represents area of national focus. FRA is addressing the trespassing issue through implementation of its National Strategy to Prevent Trespassing on Railroad Property.[5]

Figure 8 Trespasser Incidents by Location



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5 https://railroads.dot.gov/national-strategy-prevent-trespassing.

Notable Differences Between Virginia and the National Averages

FRA Highway-Railroad Incident Data (FRA Form 6180.57) was obtained from the FRA for the complete years of 2016 through 2020 for public crossings in Virginia. This data was compared to the same five-year period for the Nation. The information is shown in four categories: crossing, driver, train and temporal information. Key findings are summarized below. These data snap shots represent the initial step in identifying areas of focus for highway-rail crossing enhancement projects. The VDOT Highway-Rail Grade Crossing Safety Program (H-RGCP) selection process will consider the details of each incident.

- A higher number of crossings were illuminated by street or special lights in Virginia compared to national percentages. In Virginia, 47 percent of incident locations were listed as being illuminated versus 38 percent nationally.
- Most crossings (101 of 119 incidents, 85 percent) where incidents occurred already have gates installed.
- A higher number of incidents in Virginia occurred where the vehicle speed was zero, almost 20 percent more than the national average (54.6 percent versus 35.9 percent).
- While the number of fatal injuries is slightly higher than the national percentage of reported incidents (7.9 percent, 8 of 111, versus 6.6 percent nationally), fewer incidents in Virginia have reported injuries (61.5 percent versus78.3 percent nationally).
- A higher percentage of highway users in Virginia went around the gate or stopped on the crossing than the national percentages.
- The time of incident chart is also higher than the national percentages for vehicles being stalled or stuck on the crossing at the time of incident (36.1 percent in Virginia versus 12.6 percent nationally).
- The type of equipment involved in the incident reveals that a higher percentage of passenger train incidents and maintenance or inspection car incidents occur in Virginia over the national percentages.
- A high percentage of incidents (79 percent versus 64.7 percent nationally) are reported by Virginia’s Class I railroads.
- A high percentage of incidents are reported by Virginia’s passenger and commuter rail lines compared to the national percentages.
- Incidents in Virginia are higher at night and at dusk than the national percentages.
- 1,798 public highway at-grade crossings: 1,777 crossings include sight distance data (98.8 percent).

Data Age Analysis

The Virginia highway-rail crossing data was evaluated for accuracy and age. This information was then compared to national averages.

Figure 9 illustrates Virginia crossings with AADT values with an age of 5 to 10 years, which is slightly higher than the national average as shown in Figure 10. Accurate AADT data effects modeling and ultimately the highway-rail crossing enhancement project selection process.

Figure 9 Distribution of AADT Age for VA at Public At-Grade Crossings

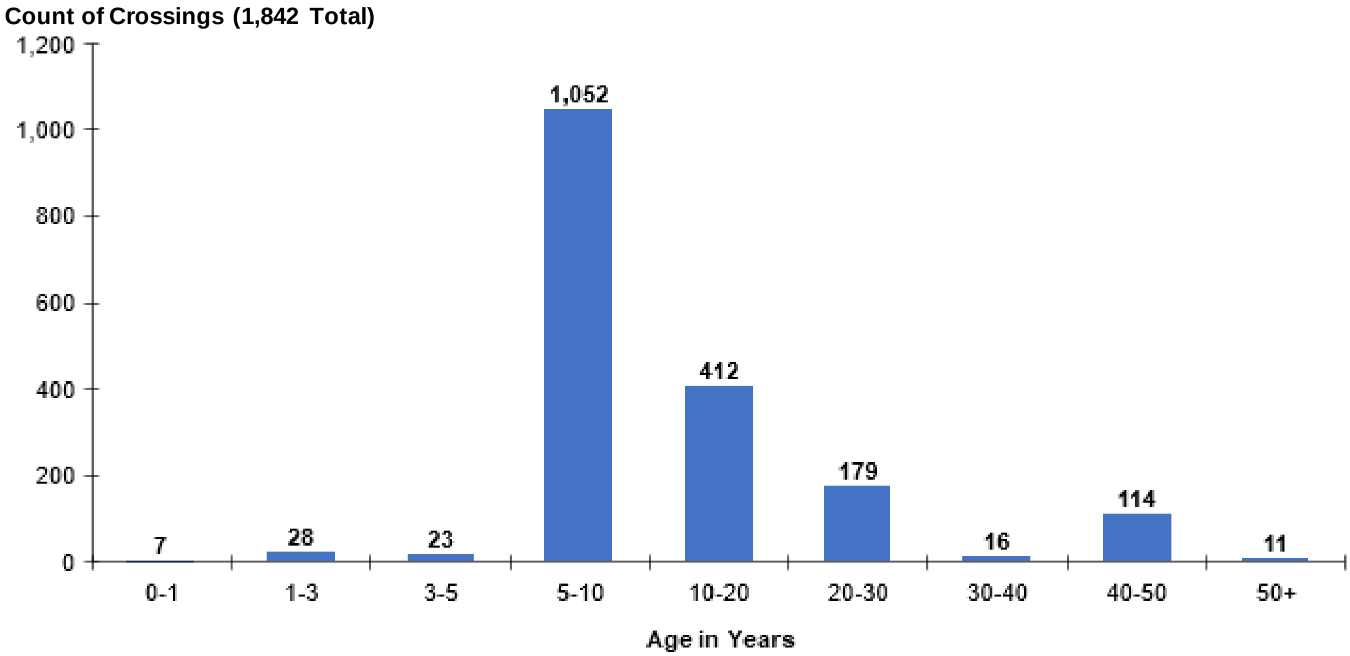


Figure 10 Distribution of AADT Age for U.S. (National Average) at Public At-Grade Crossings

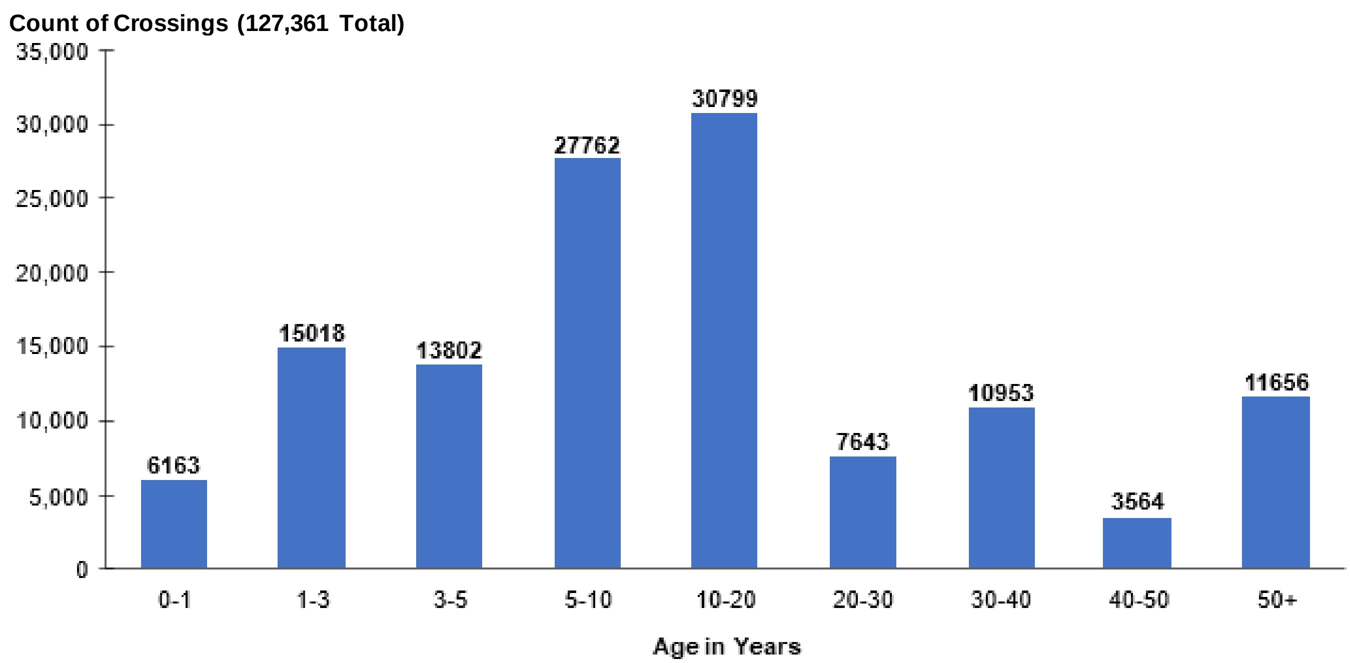


Figure 11 illustrates that Virginia crossings have a high percentage of total train count values with an age of 0 to 5 years, which is well ahead of the total train count age for the U.S. as shown in Figure 12. Accurate train count data affects modeling and ultimately the highway-rail crossing enhancement project selection process.

Figure 11 Distribution of Total Train Count Age for VA, Public At-Grade Crossings

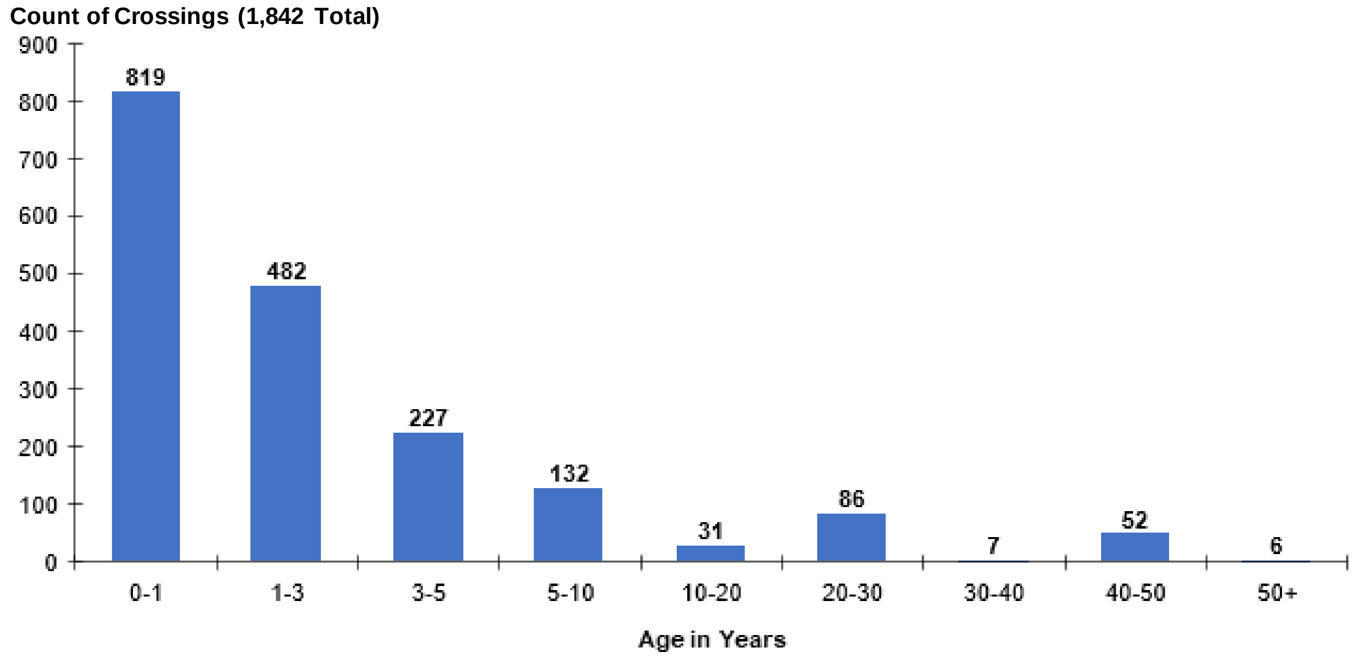
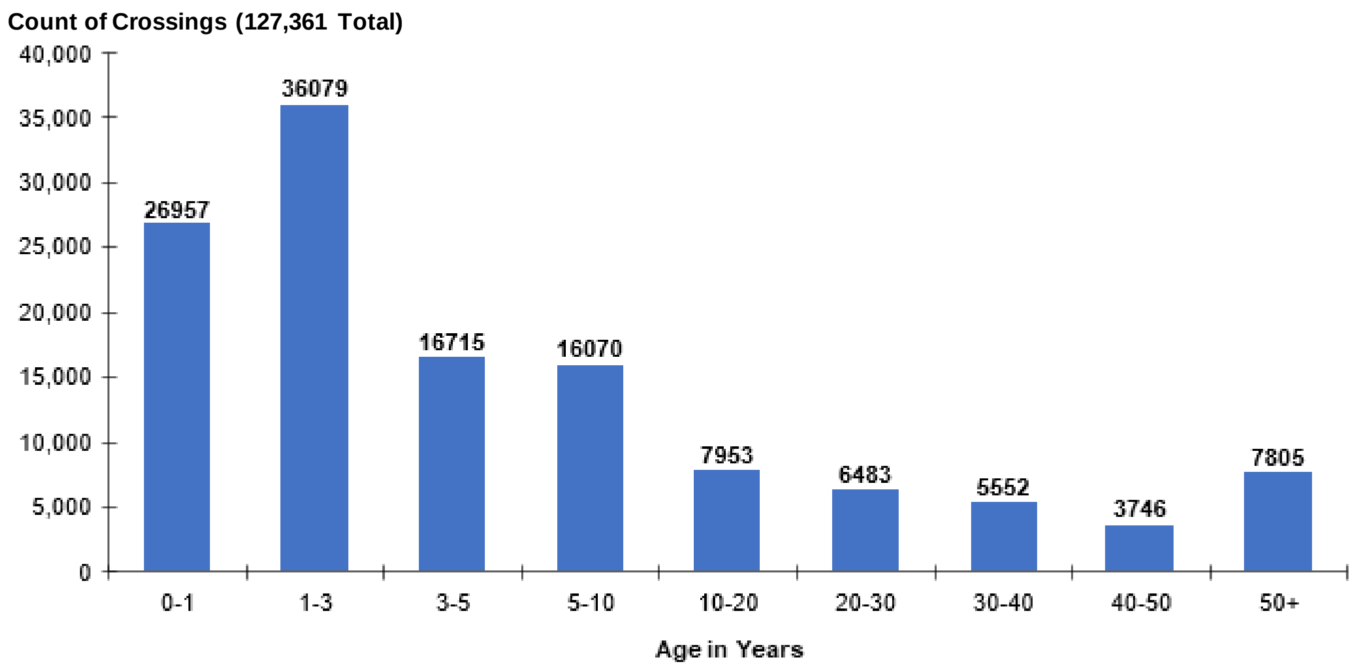


Figure 12 Distribution of Total Train Count Age for U.S. (National Average), Public At-Grade Crossings



4.3 VIRGINIA HIGHWAY-RAIL CROSSING INVENTORY DATA SUMMARY

The following section reflects the inventory data summary for Virginia crossings (database backup dated July 21, 2021). The intent was to establish thresholds for the highway-rail crossings in the state.

Table 3 Rail Crossing Inventory Data Summary[6]

Total Crossings	9,409	Percent of Total
Closed Crossings	3,764	40%
Open Crossings	5,645[1]	60%
Open Public	3,065	54% of Open Crossings
Open Private	2,574	46% of Open Crossings
Open Public Crossings	**3,065**	**Percent of Total**
Public Grade Separated	1,213	40%
Public At Grade	1,852	60%
Public Active Warning Devices At Grade	1,376	74% of Public At Grade
Public Passive Warning Devices At Grade	476	26% of Public At Grade
Open Private Crossings	**2,574**	**Percent of Total**
Private Active Warning Devices At Grade	47	2%
Private Passive Warning Devices At Grade	2,379	92%
Private Active Grade-Separated	148	6%

[1] *Crossing type not defined for six open crossings in GCIS data.*

4.4 VIRGINIA HIGHWAY-RAIL CROSSING SAFETY TREND ANALYSIS

The subsequent information compares collected data on four categories: crossing, driver, train, and temporal information. The basis for the comparison will be Virginia data compared to national averages thus providing perspective in the efficacy of the Virginia crossing safety approach between 2016 and 2020. In addition, a baseline was established for use by the VDOT rail safety section for future trend analysis.

Crossing Information

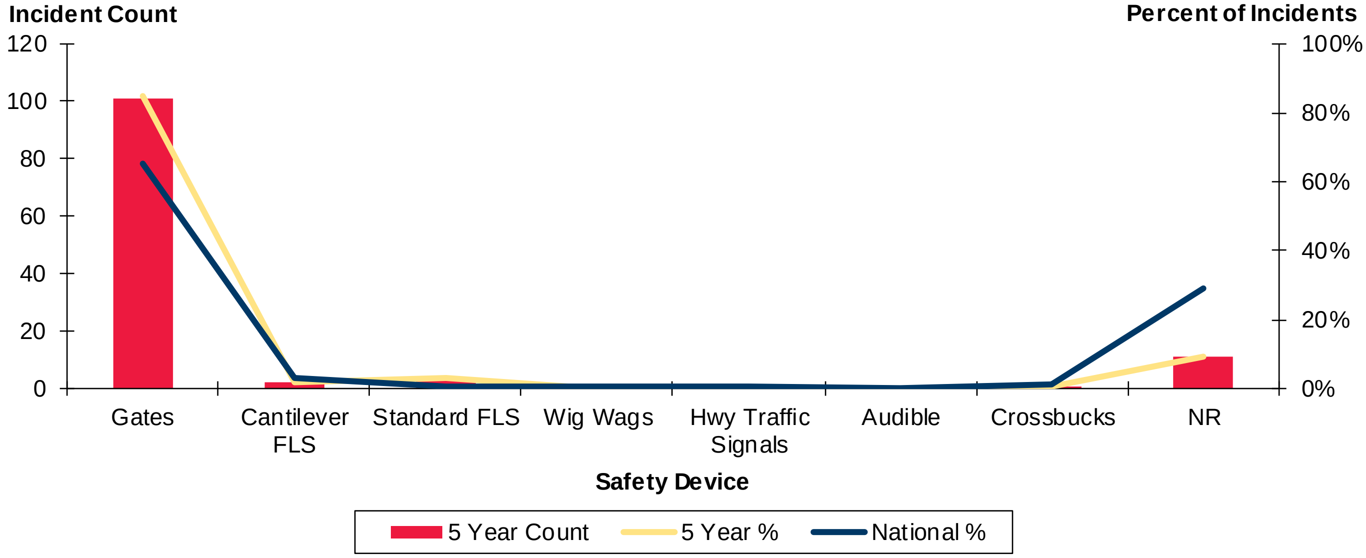
Gates are present at crossings where most of the incidents occurred—101 of 119 incidents or 85 percent of crossings.

Figure 13 reflects that 65 percent of at-grade crossing incidents occur at gated crossings. All other incidents at the respective safety devices are less than 3 percent.

[6] FRA GCIS database backup dated July 21, 2021.

Figure 13 Crossing Signals

2016–2020 Public, At-Grade Crossing Incident Data

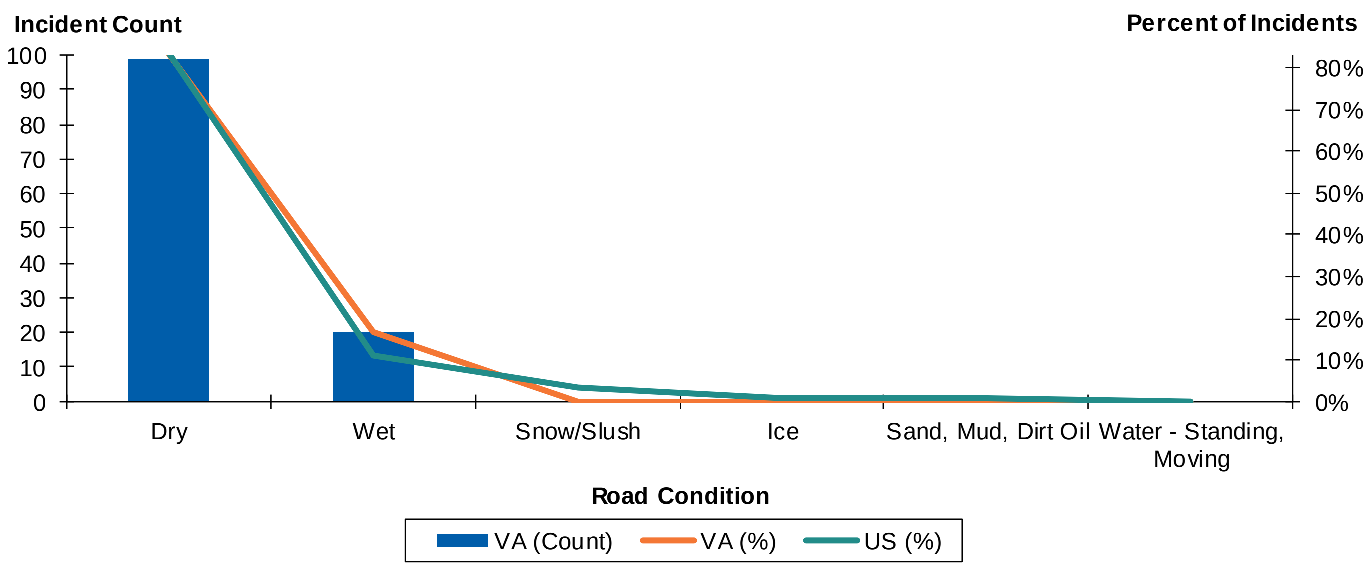


Most crossings provided a minimum of a 20-second warning (114 of 119 incidents or 95 percent). Four incidents (three percent) occurred at crossings alleged to have warnings that were greater than 60 seconds. These findings are similar in the national dataset.

Road conditions at the time of incident in Virginia were like those on the national level. Ninety-nine of the incidents (83 percent) occurred in dry conditions, similar to 83 percent on the national level. The values for wet conditions were similar (17 percent in Virginia versus 11 percent nationally), the remaining national incidents occurred with snow/slush, ice or sand/mud/dirt/oil conditions. Figure 14 indicates that most incidents in Virginia occur in dry conditions.

Figure 14 Road Conditions

5-Year, Public, At-Grade Crossing Incident Data



Incidents in Virginia and nationally reported similar numbers for being interconnected to highway signals (16.8 percent interconnected in Virginia versus 16.9 percent nationally, 76.4 percent not interconnected versus 73.8 percent nationally). A higher number of crossings were illuminated by street or special lights in Virginia compared to the national percentages. In Virginia, 47.0 percent of incident locations were listed as being illuminated versus 38.0 percent nationally.

Driver Information

A higher number of incidents in Virginia occurred where the vehicle speed was zero, almost 20 percent more than the national average (54.6 percent versus 35.9 percent). The data shows that the vehicle position at time of incident chart is also higher than the national percentages for vehicles being stalled or stuck on the crossing at the time of incident (36.1 percent in Virginia versus 12.6 percent nationally). Vehicles stopped or moving over were lower than the national percentages. This data combined with the number of incidents at gated crossings may require additional diagnostics at the respective crossings to determine ultimate cause and effect, and additional safety solutions.

Figure 15 affirms that most of the incidents occurred while vehicles were stopped at the crossing, while Figure 16 further illustrates Virginia having higher counts of “stalled or stuck on crossing” incidents then the national average.

Figure 15 Vehicle Speed
2016–2020 Public, At-Grade Crossing Incident Data

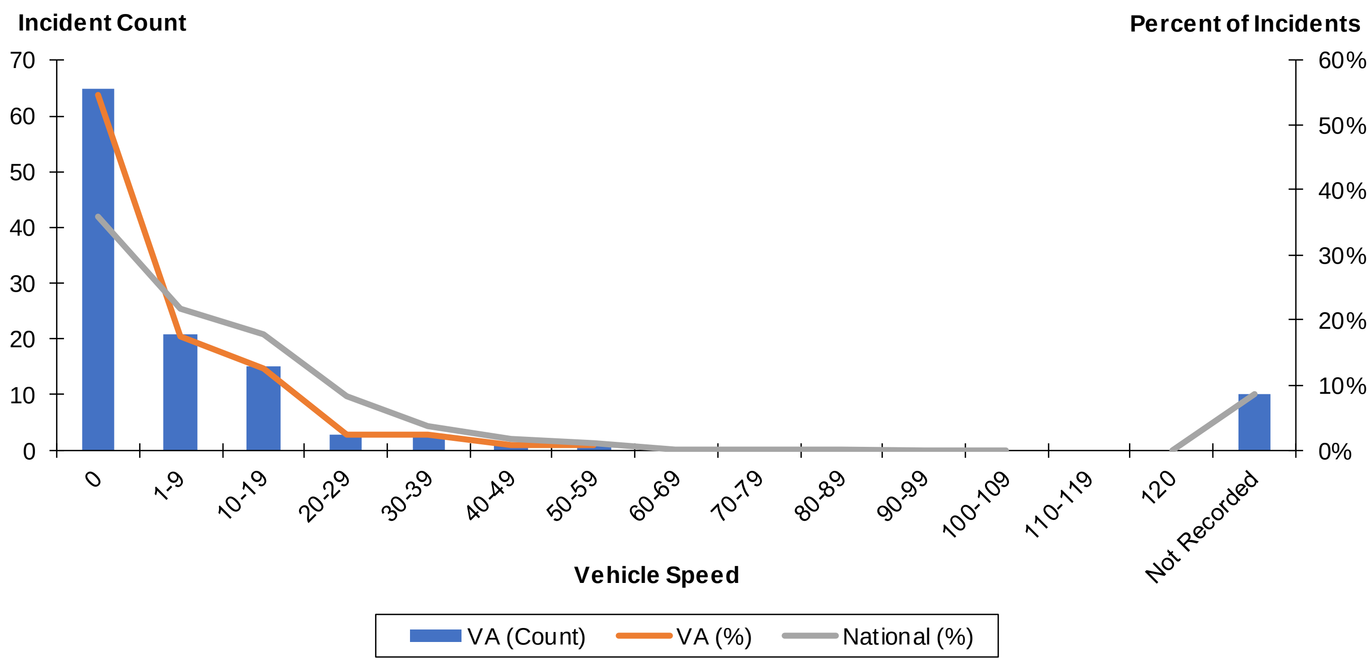


Figure 16 Vehicle Position at Time of Incident
2016–2020 Public, At-Grade Crossing Incident Data

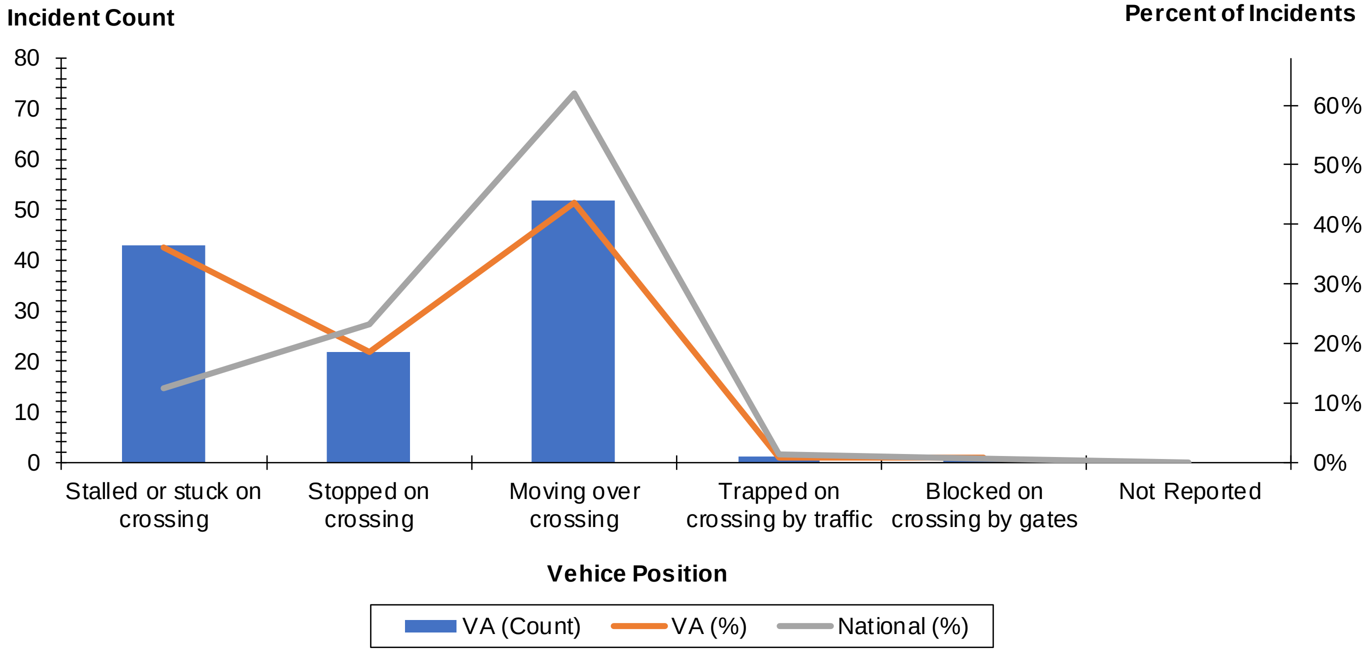


Table 4 Types of Highway Vehicles Involved in Incidents

Type of Highway Vehicle	VA (Count)	VA (%)	National (%)
Auto	73	61.3%	48.2%
Truck	2	1.7%	4.8%
Truck-trailer	7	5.9%	13.3%
Pickup truck	11	9.2%	11.9%
Van	5	4.2%	2.2%
Bus	0	0.0%	0.2%
School bus	0	0.0%	0.1%
Motorcycle	1	0.8%	0.4%
Other motor vehicle	9	7.6%	6.4%
Pedestrian	8	6.7%	9.7%
Other	3	2.5%	2.9%

A low number of incidents in Virginia had obscured views. Of the incidents 113 out of 119 were reported as being "not obstructed." The other six were reported as being obstructed by the passing train (2), highway vehicles (3), or other (1).

As shown in Table 5, incident damages are reported to be higher in the mid-ranges (over $1,000 to $100,000) for the data at Virginia incidents versus the national percentages.

Table 5 Incident Costs

Incident Estimated Damages ($)	VA (Count)	VA (%)	National (%)
0	9	7.6%	13.9%
1-500	1	0.8%	2.3%
501-1000	7	5.9%	32.0%
1001-5000	42	35.3%	26.2%
5001-10000	40	33.6%	19.8%
10001-50000	19	16.0%	1.3%
50001-100000	1	0.8%	0.4%
100001-500000	0	0.0%	0.1%
Not Reported			4.0%

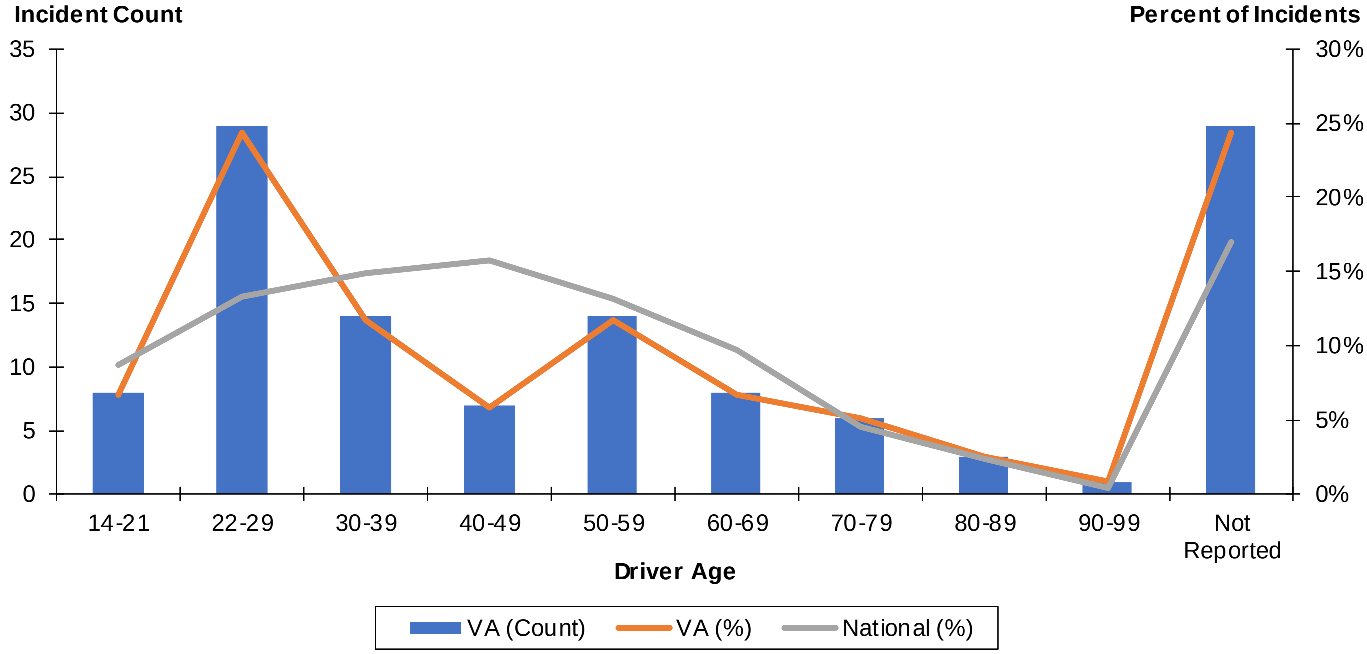
While the number of fatal injuries is slightly higher than the national percentage of reported incidents (7.9 percent versus 6.6 percent nationally), fewer incidents in Virginia have reported injuries (61.5 percent versus 78.3 percent nationally). In fatality incidents, all incidents reported only one fatality per incident. Injury incidents reported one injury in 25 of the 119 incidents and two injuries for two of the incidents.

Table 6 shows that incidents in Virginia are higher than the national percentages for the 22 to 29 age range and 70 to 89 age ranges (graphics illustrated in Figure 17). A higher percentage of ages in Virginia was not reported compared to the national data.

Table 6 Ages of Drivers Involved in Incidents

Driver Age	VA (Count)	VA (%)	National (%)
14-21	8	6.7%	8.8%
22-29	29	24.4%	13.3%
30-39	14	11.8%	14.9%
40-49	7	5.9%	15.8%
50-59	14	11.8%	13.2%
60-69	8	6.7%	9.7%
70-79	6	5.0%	4.6%
80-89	3	2.5%	2.3%
90-99	1	0.8$	0.4%
Not Reported	29	24.4%	17.0%

Figure 17 Ages of Drivers Involved in Incidents
2016–2020 Public, At-Grade Crossing Incident Data



Males drove the vehicles in 66 (55.4 percent) of the incidents in Virginia, while females drove the vehicles in 41 (34.5 percent) of the incidents. Twelve of the incidents did not report the highway user's gender. There is a higher percentage of female highway users (34.5 percent) than the national percentage of 26.2 percent.

Table 7 shows that the percentage of incidents involving the highway user passing a standing vehicle is similar to the national percentage, which is a similar trend for the incidents for when the highway user went behind or in front of a train and was struck by a different train as shown in Table 8.

Table 7 Highway User Passing a Standing Vehicle Incidents

Highway User	VA (Count)	VA (%)	National (%)
Passed as Standing Vehicle	3	2.5%	2.5%
Did Not Pass a Standing Vehicle	103	86.6%	84.4%
Unknown	4	3.4%	3.7%
Not Reported	9	7.6%	9.5%

Table 8 Highway User Going Behind or Around a Train Incidents

Highway User	VA (Count)	VA (%)	National (%)
Went around a train and was stuck	1	0.8%	2.3%
Did not go around a train	111	93.3%	95.6%
Unknown	0	0.0%	0.8%
Not reported	7	5.9%	1.3%

As shown in Table 9, a higher percentage of highway users went around the gate or stopped on the crossing than the national percentages. These values are consistent with the information above, that more incidents in Virginia happened where the vehicle was stopped on the tracks than the national percentages.

Table 9 Highway User Actions Causing Incidents

Highway User	VA (Count)	VA (%)	National (%)
Went around the gate	36	30.3%	18.5%
Stopped and then proceeded	2	1.7%	5.1%
Did not stop	14	11.8%	30.6%
Stopped on crossing	50	42.0%	23.0%
Other	14	11.8%	14.9%
Went around/through temporary barricade	0	0.0%	0.3%
Went through the gate	3	2.5%	5.2%
Suicide, attempted suicide	0	0.0%	2.3%
Not reported	0	0.0%	0.1%

Train Information

Incidents in Virginia were similar to those of the national percentage for track type as shown in Table 10.

Table 10 Incident by Track Type

Track Type	VA (Count)	VA (%)	National (%)
Main	106	89.1%	90.0%
Yard	4	3.4%	3.8%
Siding	0	0.0%	0.7%
Industry	9	7.6%	0.0%

Table 11 shows the slight differences in railroad equipment in the Virginia percentages versus the national trends.

Table 11 Types of Equipment VA Versus National

Railroad Equipment	VA (Count)	VA (%)	National (%)
Train (units pulling)	95	79.8%	78.8%
Train (units pushing)	8	6.7%	9.0%
Train (standing)	2	1.7%	1.6%
Car(s) (moving)	6	5.0%	2.6%
Car(s) (standing)	1	0.8%	0.3%
Light loco(s) (moving)	6	5.0%	4.6%
Light loco(s) (standing)			0.1%
Other	1	0.8%	0.7%
Train pulling—RCL			0.3%
Train pushing—RCL			0.5%
Train standing—RCL			0.0%
EMU Locomotive(s)			1.0%
DMU Locomotives(s)			0.5%

The type of equipment involved in the incident reveals that a higher percentage of passenger train incidents and maintenance or inspection car incidents occur in Virginia over the national percentages as shown in Table 12. The number of incidents involving an Amtrack train is higher for Virginia as well (17.6 percent of incidents versus 7.1 percent nationally).

Table 12 Type of Equipment Involved in Incident

Type of Equipment	VA (Count)	VA (%)	National (%)
Freight Train	78	65.5%	71.6%
Passenger Train—Pulling	23	19.3%	7.8%
Commuter Train—Pulling	2	1.7%	2.9%
Work train	2	1.7%	0.5%
Single Car			0.0%
Cut of Cars			0.1%
Yard/Switching	6	5.0%	4.2%
Light loco(s)			4.6%
Maint./Inspection Car	8	6.7%	1.1%
Spec MoW Equip			2.2%
Passenger Train—Pushing			1.7%
Commuter Train—Pushing			1.7%
EMU			1.0%
DMU			0.5%

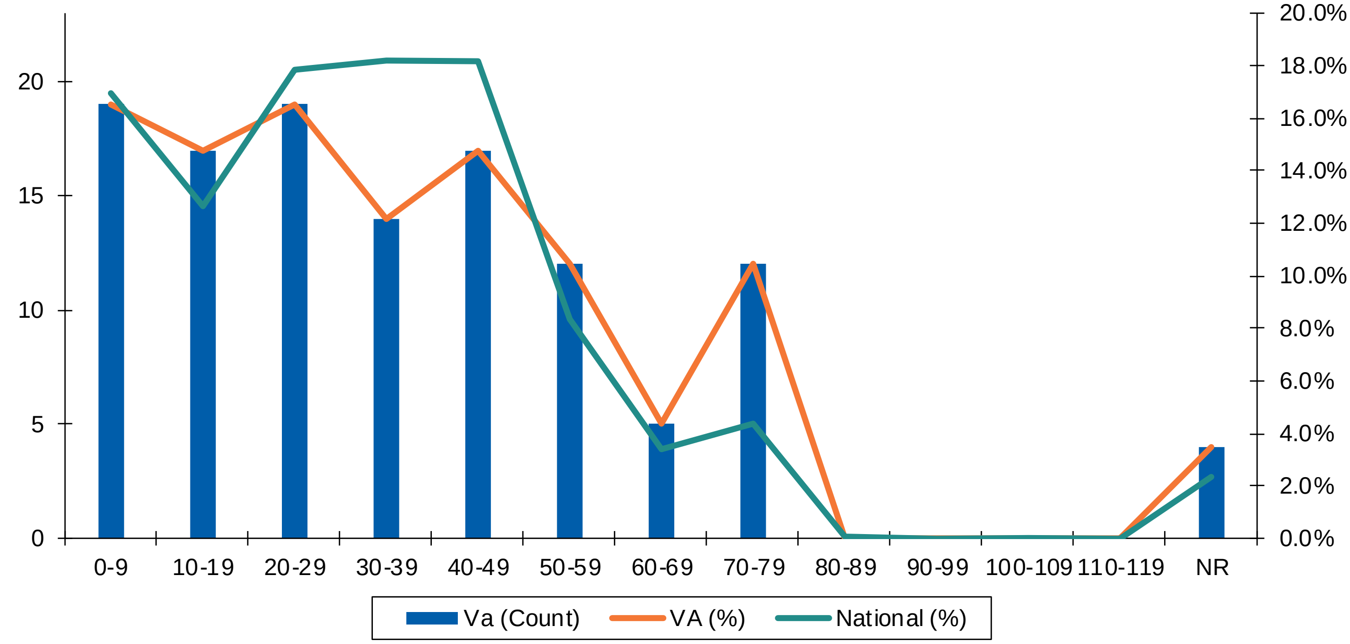
Table 13 shows that a high percentage of incidents (79.0 percent versus 64.7 percent nationally) are reported by Virginia's Class I railroads. A high percentage of incidents are reported by Virginia's passenger and commuter rail lines compared to the national percentages.

Table 13 Railroad Involved in Incident

Reporting Railroad	VA (Count)	VA (%)
Norfolk Southern (NS)	59	49.6%
CSX	35	29.4%
Amtrak (ATK)	21	17.6%
Virginia Railway Express (VREX)	2	1.7%
Bay Coast Railroad (BCR)	1	0.8%
Norfolk Portsmouth Beltline RR (NPB)	1	0.8%

The speed of the trains involved in incidents, as shown in Figure 18, varies from those of the national percentages. Incidents in Virginia are higher than national percentages in the 10 to 19 mph and 50 to 79 mph ranges.

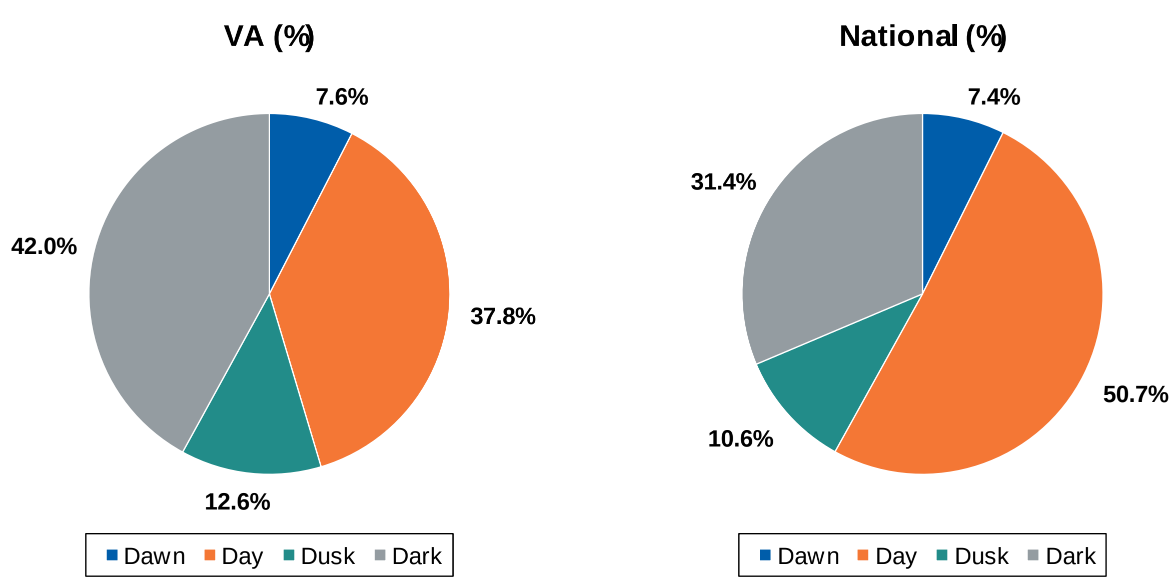
Figure 18 Train Speed at Time of Incident
2016–2020, Public At-Grade Crossings



Temporal Information

Figure 19 shows that incidents in Virginia are higher at night and at dusk than the national percentages. Most incidents happened while the weather visibility was clear.

Figure 19 Time of Day of Incident



The average temperatures in Virginia range from 60 to 71 degrees Fahrenheit as shown in Figure 20. A majority of temperatures at the time of incident fall near this range.

Figure 20 Temperature at Time of Incident
2016–2020, Public At-Grade Incidents

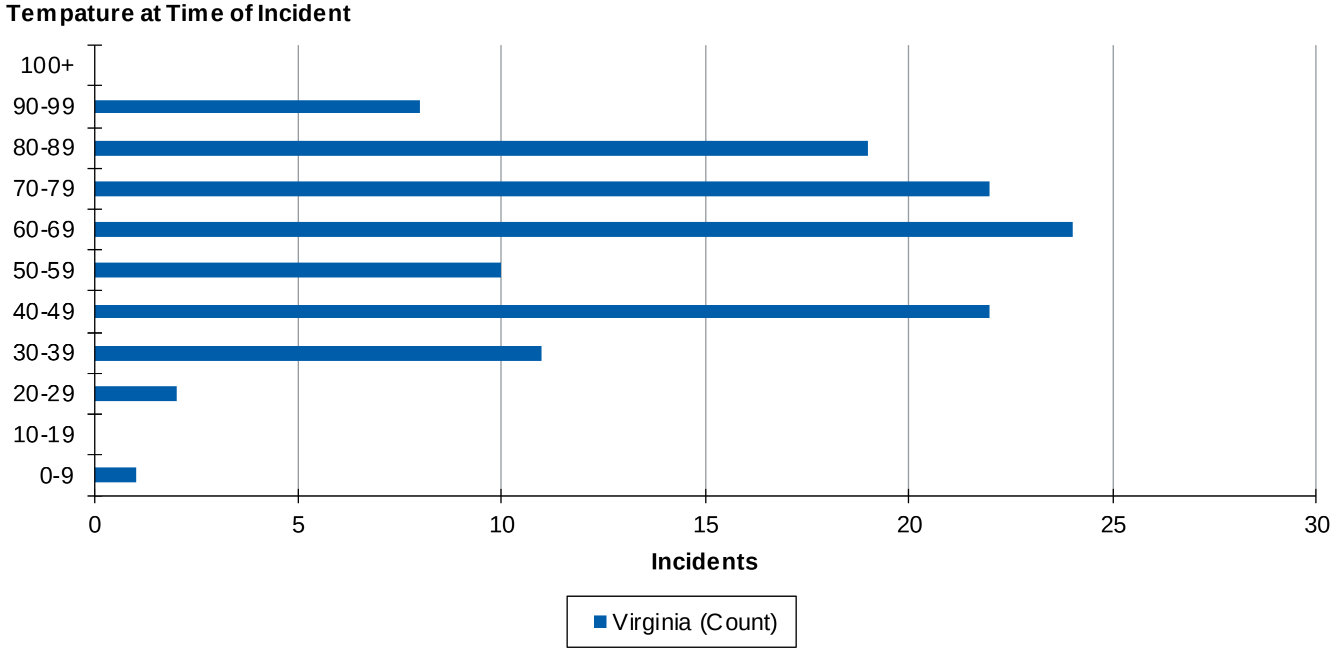


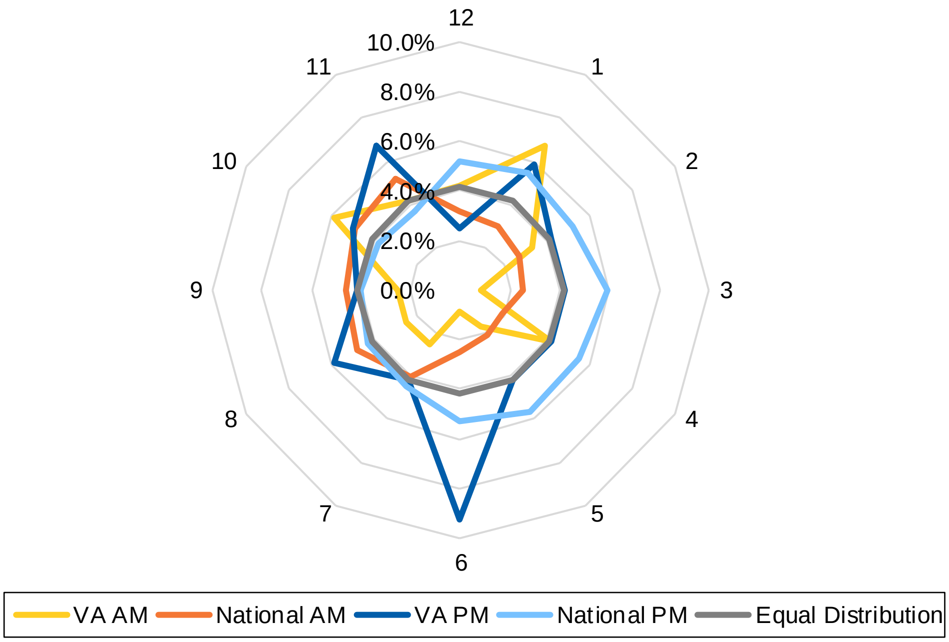
Table 14 shows that the weather/visibility is similar to that of the national percentages, with the exception that slightly more incidents happened in rainy weather (10.9 percent versus 7.6 percent nationally). The difference in percentages is accounted for by weather types that are less common in Virginia such as snow and sleet.

Table 14 Weather Conditions at Time of Incident

Conditions	VA (Count)	VA (%)	National (%)
Clear	80	67.2%	68.6%
Cloudy	25	21.0%	19.9%
Rain	13	10.9%	7.6%
Fog	1	0.8%	1.2%
Sleet	0	0.0%	0.2%
Snow	0	0.0%	2.3%

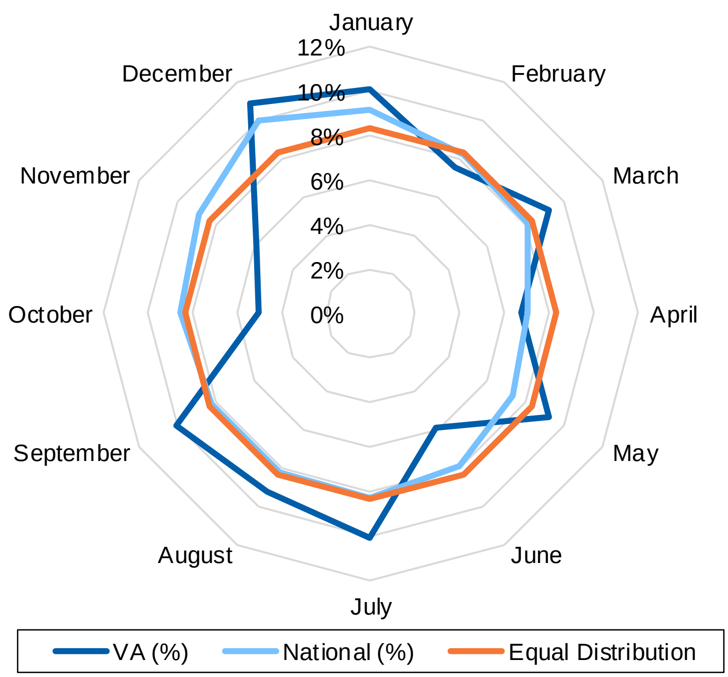
The peak times for incidents, shown in Figure 21 and based on the incident data are the hours between 6 and 7 p.m., 11 and 12 midnight and 1 and 2 a.m. These differ greatly from the national percentages as seen below. The equal distribution data represents a whole (1) divided into 24 equal parts.

Figure 21 Incident Time of Day



The month of the year incident data shown in Figure 22 loosely follows the national percentage data. Trends for more accidents in December and January are similar, but higher for Virginia. Values are also higher for Virginia from mid-summer through early fall.

Figure 22 Incident Percentage by Month



5 RISK ASSESSMENT

5.1 INTRODUCTION

This chapter outlines the process used to analyze collision statistics and applies a methodology of assessing risk at crossings in Virginia. Determining the risk associated with individual crossings can lead to better understanding state trends, and aid in developing processes for crossing improvement selections. To fully understand how risk is calculated, this report outlines the probability formulas and cost methodology used to quantify risk at each crossing.

To understand the current trends in rail-grade crossing collisions, crossings with collision history were analyzed. The characteristics and costs associated with collisions at public at-grade crossing collisions within Virginia were investigated and risk factors were identified. Knowing the characteristics of crossings and overall risk factors will help Virginia identify safety guidelines and implement safety improvements at public crossings.

The probability of crossing collisions was also calculated during this analysis. Several probability models were used to calculate the probability of a collision and the probability of a fatal, injury, or property damage only (PDO) collision. The study team used the following models: the FRA model, the methodology described in the GradeDec reference manual,[7] the 2020 update to the FRA model[8], and Virginia's Priority Indexing Model.

To properly assess the risk posed at each crossing, the costs associated with a collision were calculated. The cost calculations are based on methodologies identified in the NCHRP 755 report, which captures both primary and secondary costs. Section 5.5 describes more detailed differences between the primary and secondary costs.

By calculating the probability and expected collision cost, the risk associated with the crossings could be determined and used to identify at-risk crossings. The at-risk crossings were determined to be crossings that had high annual expected costs associated with them. Other metrics were also reviewed, such as the net present value

[7] https://railroads.dot.gov/sites/fra.dot.gov/files/2021-09/GradeDecNET%202019%20Reference%20Manual.pdf.
[8] https://railroads.dot.gov/sites/fra.dot.gov/files/2020-10/GX%20APS-A.pdf.

of upgrading the warning devices for crossings without existing gates, and the identification of crossings where closure could be investigated. Crossings were ranked using these metrics and then compared to Virginia's Priority Index Value.

In this analysis, not all crossings have the available data needed to calculate probability and cost. Data on the expected number of collisions in Virginia was taken from the FRA's Web Accident Prediction System and compared to a full list of public at-grade crossings taken from the FRA's inventory form. Comparison of the two data sources saw that 89 percent of the crossings from the inventory file had matching data from the FRA's Web Accident Prediction System, and enough complete data to calculate probabilities and crash costs.

5.2 INITIAL DATA ANALYSIS

This section describes an analysis of the reported data associated with historical collisions. By examining previous collisions that have occurred at public at-grade crossings in Virginia, trends were identified for further investigation. While the data used in this analysis does not show the causes of collisions, the trends identified in this section can be used to develop more targeted programs, such as reaching at-risk demographics or identifying shared characteristics of crossings with previous collisions. These analyzed metrics have been statistically reviewed to determine their significance.

Several documents were reviewed in the development of this analysis, including the FAST Act (section 11401(b)(2)) outlining State Action Plan requirements, and Federal Register Vol. 85, No. 240, which covers the rules and regulations of State Action Plans. Other documents such as previous state action plans and best practice guides were also reviewed before conducting this analysis.

Data Sources

For this analysis, two primary sources of data were used:

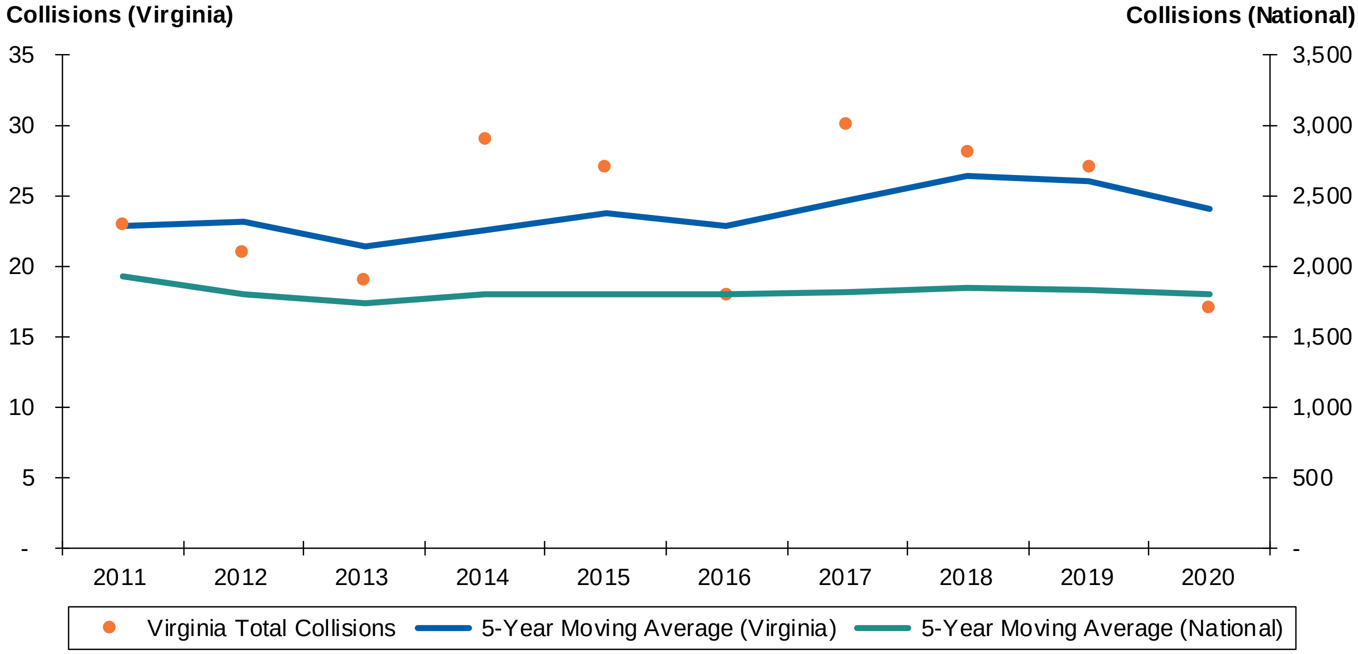
- The Crossing Inventory maintained by the Federal Railroad Administration (FRA), which uses data submitted through FRA Form 6180.71. This database consists of all railroad-highway crossings in the U.S. and lists characteristics for each crossing.
- The FRA Highway-Rail Grade Crossing Accident/Incident Database (Form 6180.57) was also used. This database contains information on each reported accident at highway-rail crossings. Information on crossing conditions, vehicle user profile, and incident particulars are reported in this form.

Using the information from these two databases, the initial analysis was conducted by analyzing crossing information from Form 6180.57 and Form 6180.71 to find trends and patterns in the State of Virginia's single collision and multi-collision highway-rail crossings.

Analysis of Collisions

The analysis began by examining all Virginia public crossing collisions and comparing to all U.S. public crossing collisions over 10 years (2011 to 2020). These figures were graphed, and a five-year moving average was added to illustrate any high-level trends that were occurring. As seen in Figure 23, the moving average has fluctuated but there was a slight trend upward in the number of collisions seen in Virginia between 2016 and 2018. This contrasts with the national moving average, which shows that collisions at the national level have remained relatively stagnant since 2014.

Figure 23 Five-Year Moving Average of Public Collisions in Virginia Compared to National Average *2011 to 2020*



In addition to analyzing collisions at public crossings, special focus was given to collisions involving pedestrians. Pedestrian collisions made up seven percent of collisions at grade crossings in the state of Virginia between 2011 and 2020. For context, the national average for pedestrian-involved collisions is nine percent of all collisions. To better understand conditions in Virginia, all the percentage of pedestrian collisions for all 50 states were analyzed and ranked. Using this method, it was found that Virginia has the 33rd lowest percentage of pedestrian collisions. Additional analysis should be completed on these incidents to better understand their cause(s).

After establishing an overview of collisions at public crossings and the percentage of collisions involving pedestrians, more specific insights were derived. This included looking into the severity of reported collisions, which was done in conjunction with other categories such as type of train and reported train speed at the time of the collision. By looking into the severity of collisions and comparing the findings to the national figures, it is possible to establish a deeper understanding of collision trends within Virginia.

Identifying statistically significant characteristics associated with collision severity in the state of Virginia allows further investigation into potential causes behind these collisions. A statistical approach was used, which analyzed each of the categories related to the collisions by conducting chi-squared or Fisher's Exact tests. The results of these statistical tests, shown in Table 26, identified any characteristics of collisions that are statistically significant in Virginia compared to the Nation overall.

Virginia has many types of train traffic such as freight, passenger, commuter, and work equipment. Table 15 shows the type of train traffic involved in collisions at public crossings in the past ten years. The table also shows the percentage of collisions attributed to each type of train traffic. The table reveals that freight trains in Virginia account for 70 percent of all collisions, below the national average. Passenger trains account for 15 percent of the total collisions in Virginia. The national average of collisions involving passenger trains is seven percent. The statistical analysis determined that the train types involved in Virginia collisions at a public crossing are statistically significant and merits further investigation into the cause(s).

Table 15 Count of Train Type Involved in Collisions[1]
2011 to 2020

Type of Train Traffic	Virginia	National	Virginia %	National %
Freight Train	166	13,156	70%	73%
Passenger Train	35	1,504	15%	8%
Yard/Switching	4	798	2%	4%
Maintenance/Inspection Car	2	229	1%	1%
Light Loco(s)	16	824	7%	5%
Commuter Train	3	771	1%	4%
Spec. Maintenance of Way Equip.	10	349	4%	2%
Electric Multiple Unit	–	167	–	1%
Work Train	2	91	1%	1%
Cut of Cars	–	12	–	–
Single Car	–	5	–	–
Diesel Multiple Unit	–	86	–	–

[1] *Underlined values signify key findings.*

Collision severity by train type and movement was also examined. The values in Table 16 represent public crossing collisions by train type and the percentage of those collisions resulting in a fatality, injury, or property damage only (PDO). In comparison to the national average, a higher percentage of passenger train collisions in Virginia resulted in a fatality or injury. This is important to note given the higher rate of passenger trains involved in collisions in Virginia than the Nation. Another noticeable insight is a higher percentage of freight train collisions result in PDO compared to the national average, with a lower percentage of collisions resulting in an injury or fatality. The statistical analysis concluded incident severity by train type is a statistically significant characteristic. Examining the causation of these collisions will benefit the implementation of safety guidelines at public crossings in Virginia.

Table 16 Percentage of Collisions by Train Type and Severity Compared to National Average
2011 to 2020

Train Type	PDO-Virginia	PDO-National	Injury-Virginia	Injury-National	Fatality-Virginia	Fatality-National
Freight Train	79%	60%	18%	29%	3%	11%
Passenger Train	31%	36%	34%	32%	34%	32%
Yard/Switching	75%	76%	25%	23%	–	1%
Maintenance/Inspection Car	50%	64%	50%	35%	–	–
Light Loco(s)	56%	64%	38%	29%	6%	7%
Commuter Train	100%	43%	–	23%	–	34%
Spec. Maintenance of Way Equip.	60%	69%	40%	30%	–	1%
Electric Multiple Unit	–	26%	–	40%	–	34%
Work Train	50%	69%	–	25%	50%	5%
Cut of Cars	–	75%	–	25%	–	–
Single Car	–	40%	–	60%	–	–
Diesel Multiple Unit	–	44%	–	28%	–	28%

Reported train speeds at the time of the collision were compared to the severity of the collisions. In Table 17, trends emerge regarding the average severity of train collisions occurring at various speeds. Trains in Virginia traveling under 20 miles per hour follow the national trends closely. For trains traveling between 21 and 59 miles per hour, Virginia has a higher percentage PDO incidents when compared to the national average. Collisions in Virginia involving speeds over 60 miles per hour are mostly in line with national trends, but with a higher rate of fatalities. Based on the statistical analysis, the speed of trains at the time of the collision in relation to incident severity is statistically significant. Further insight on the matter of these collisions should be evaluated.

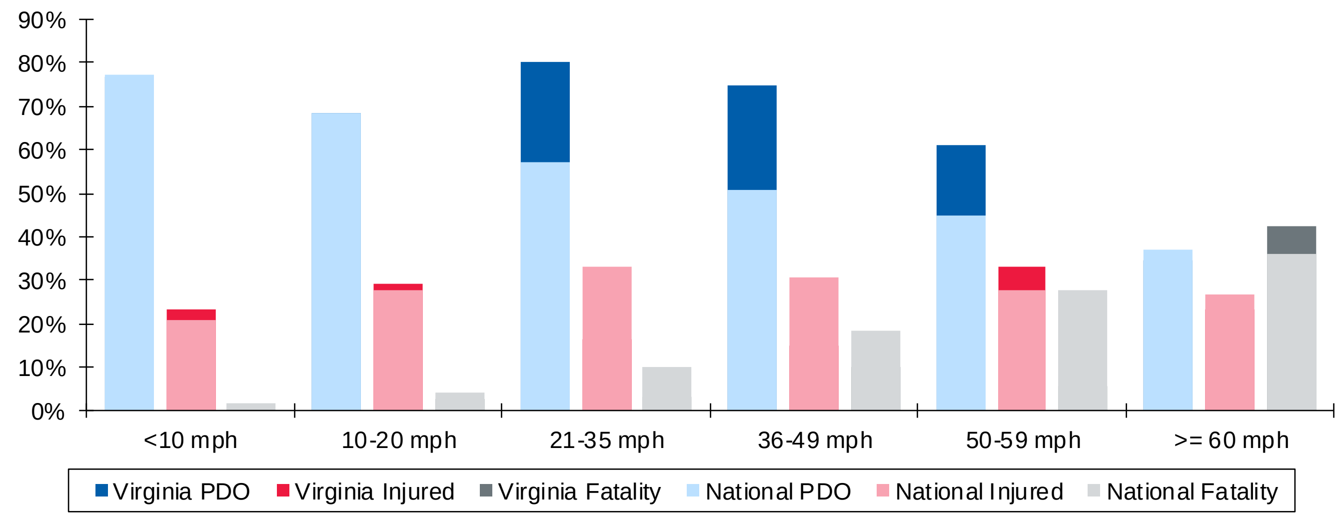
Table 17 Percentage of Collisions by Train Speed and Severity Compared to National Average[1]
2011 to 2020

Train Speed at Collision	PDO-Virginia	PDO-National	Injury-Virginia	Injury-National	Fatality-Virginia	Fatality-National
<10 mph	77%	77%	23%	21%	–	2%
10-20 mph	68%	68%	29%	28%	2%	4%
21-35 mph	<u>80%</u>	<u>57%</u>	16%	33%	3%	10%
36-49 mph	<u>75%</u>	<u>51%</u>	15%	31%	10%	19%
50-59 mph	<u>61%</u>	<u>45%</u>	33%	28%	6%	28%
>= 60 mph	35%	37%	23%	27%	<u>42%</u>	<u>36%</u>

[1] *Underlined values signify key findings.*

Figure 24 illustrates the distribution of collision severity by train speed reported in Virginia compared to the national average. The solid bars in Figure 24 represent the percentages of severity of collisions by train speed in Virginia, while the outlined bars represent the national average percentages. Collisions under 60 mph had a higher rate of PDO incidents. There is a higher rate of injuries or fatalities with train speeds over 50 mph. These findings should be reviewed when allocating resources for safety improvements as fatal incidents.

Figure 24 Collision Severity by Train Speed (Virginia)



To further develop an overview of Virginia's collision trends, several other categories were examined at a high level. One of the metrics measured was the position of highway users when the collision occurs. Table 18 shows that there is a higher rate of stalled or stuck vehicles in public crossing collisions in Virginia compared to the national average. The statistical analysis showed the position of a highway user at the time of the incident is statistically significant. A deeper understanding of the factors that lead to vehicles becoming stalled or stuck on these crossings would help Virginia understand how to address a larger percentage of collisions.

Table 18 Position of Highway User at Time of Collision Compared to National Average[1] *2011 to 2020*

Position of Highway User	Virginia	National
Moving over crossing	46%	62%
Stalled or stuck on crossing	<u>32%</u>	<u>13%</u>
Stopped on crossing	19%	23%
Blocked on crossing by gates	1%	1%
Trapped on crossing by traffic	2%	2%

[1] *Underlined values signify key findings.*

User action during collisions was also considered as a valuable insight to shape future programs to lower collision rates at Virginia crossings. Table 19 shows that several categories of user action are equal to or below the national average. Users who stop on the crossings and those that go around the gates are the exception, and these values are higher than the national average—warranting further investigation. There is also a lower percentage of collisions that resulted from not stopping. Results from the statistical analysis on user action during collisions show user action is statistically significant in collisions. The data in Table 18 and Table 19 support the need for further investigation into these trends.

Table 19 User Action Compared to National Average[1] *2011 to 2020*

User Action During Collision	Virginia	National
Went around the gate	<u>21%</u>	<u>17%</u>
Stopped on crossing	<u>44%</u>	<u>25%</u>
Stopped and then proceeded	3%	5%
Did not stop	19%	32%
Went through the gate	2%	4%
Suicide/attempted suicide	0%	2%
Went around/thru temporary barricade	–	0%
Other	11%	15%

[1] *Underlined values signify key findings.*

Other data points were analyzed to better understand collision characteristics outside of train traffic and user actions. Vehicle user age and gender and collision time of day were analyzed to expand the understanding of collisions in Virginia compared to the U.S. overall. Table 20 shows the percentage of crashes vehicle operator age and gender compared to national averages. For both male and female drivers under 26 years of age, the rate of collisions is higher than the national average. Other age groups appear to be equal to or slightly lower than the national averages, except for male and female drivers between the ages of 56 and 69 who are involved in a higher percentage of collisions in Virginia. The statistical analysis on the age and gender of the vehicle user was inconclusive. Although Table 20 shows a difference between the percentages of collisions by gender and age of operator for Virginia and the national average, this difference is not statistically significant. Focusing on age individually, the analysis on collisions by age was also inconclusive, indicating that vehicle user age is not a factor in the occurrence of a collision. The analysis on collisions by gender shows the gender of the operator is statistically significant in collisions at public crossings in Virginia.

Table 20 Percentage of Collisions by Operator Gender and Age[1]
2011 to 2020

Age	Female Percentage —Virginia	Female Percentage—National	Male Percentage—Virginia	Male Percentage—National	Both Genders—Virginia	Both Genders—National
<26	30%	27%	24%	20%	26%	22%
27-39	20%	22%	23%	24%	22%	24%
40-55	24%	26%	25%	30%	24%	29%
56-69	18%	16%	20%	18%	20%	17%
70-79	4%	6%	5%	5%	5%	5%
80-89	4%	3%	3%	3%	4%	3%
All Ages	35%	28%	65%	72%	26%	22%

[1] *Underlined values signify key findings.*

Figure 25 shows the distribution of collisions by gender and age in Virginia during the analysis period. The solid bars represent the percentages of collisions by gender and age of the operator in Virginia, while the outlined bars represent the national average percentages. This figure illustrates the trends in ages and gender. For example, a larger percentage of female drivers between the ages of 0-26 account for a higher percentage of collisions than males in the same age group.

Figure 25 Distribution of Collisions by Gender and Age (Virginia)

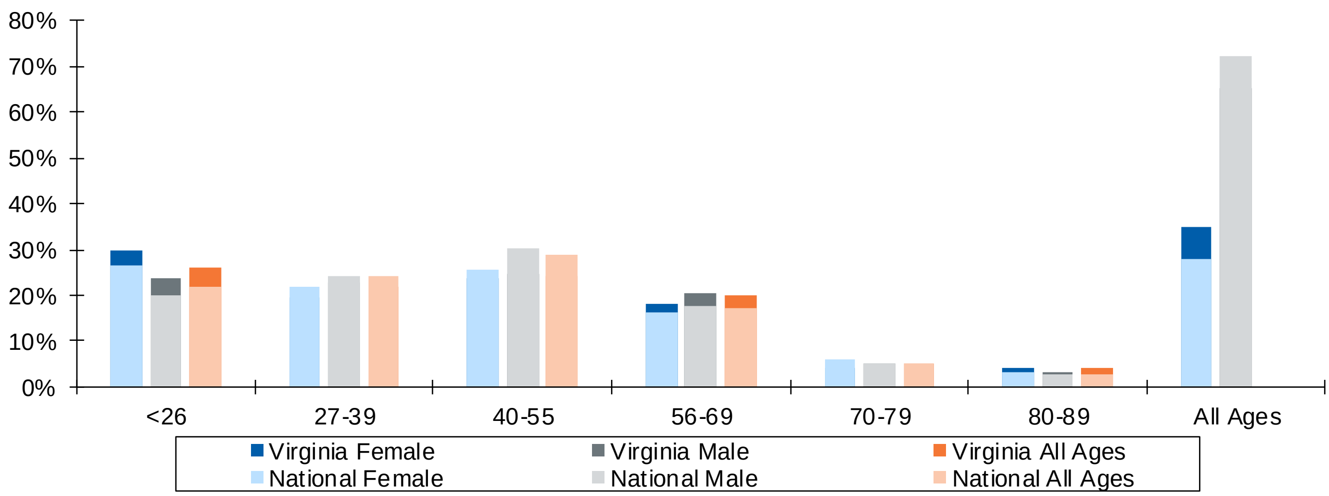


Table 21 shows the percentage of collisions that take place within various periods throughout the day. The data in this table shows that Virginia follows national trends throughout the day but has a higher percentage of collisions between 7:00 PM and 6:00 AM. The time at which the collisions occurred is statistically significant, supported by the results from the statistical analysis. The data shows possible correlations but will require further investigation before causes or solutions can be proposed.

Table 21 Percentage of Collisions Occurring within Time Periods[1]
2011 to 2020

Time of Collision	Virginia	National
12 am—5:59 am	21%	15%
6 am—8:59 am	6%	11%
9 am—11:59 am	14%	16%
12 p.m.—3:59 p.m.	19%	22%
4 p.m.—6:59 p.m.	17%	17%
7 p.m.—11:59 p.m.	23%	19%

[1] *Underlined values signify key findings.*

Single Collision Crossings (2018 to 2020)

An added focus has been given to crossings that have experienced a single collision within the past three years of complete data. In the State of Virginia, 56 public crossings experienced at least a single collision from 2018 to 2020. The crossing identification (ID) of these crossings was extracted from FRA Form 6180.57 and then matched with information from the crossing inventory to develop a profile of the typical crossing involved with at least one collision. These crossings had an average maximum timetable speed of 48 miles per hour and had an average of one main track. The tracks at these crossings have an average of six trains per daytime period and an average of seven trains at night. Crossings in Virginia that are active (open crossing with at least one train per day/night period) had an average of five trains per day and five trains per night, showing that the crossings with higher day and night trains will have a higher chance of collisions. The highways at these crossings saw an average of 4,455 average annual daily traffic (AADT) and all the crossings that reported this metric were paved with an average of two (2.4) traffic lanes, compared to the state average of two (2.1) lanes. A list of these crossings is provided in Appendix A.

Table 22 shows the collisions occurring on various types of roads. The table shows that 41 percent of all crossings with at least one collision in the past three years were intersected by local roads. When compared to the total makeup of road types in the state, this value is considerably lower than the 58 percent of roads that are classified as local. Major collector roads and minor arterial roads have higher percentages of collisions compared to the percentage of crossings they make up in the state. The statistical analysis indicates that the reported road type at crossings where single collisions occurred is statistically significant.

Table 22 Count and Percentage of Reported Road Type at Crossings[1]
2018 to 2020

Road Type	Single Collision	Single Collision %	Statewide Crossing %
Local	23	41%	58%
Major Collector	16	29%	22%
Minor Arterial	14	25%	11%
Minor Collector	2	4%	4%
Other Principal Arterial	1	2%	3%

[1] *Underlined values signify key findings.*

Table 23 shows the percentage of crossings located in urban and rural regions of Virginia. Rural crossings made up 64 percent of all collisions between 2018 and 2020 and urban crossings accounted for 36 percent. Results from the statistical analysis also indicate the region type where single collisions occur in Virginia are significantly different from crossings statewide and should be investigated further.

Table 23 Percentage of Single Collision Crossings in Urban and Rural Regions[1]

Region Type	Single Collision	Single Collision %	Statewide Crossing %
Urban	36	<u>64%</u>	<u>62%</u>
Rural	20	36%	38%

[1] *Underlined values signify key findings.*

Multiple Collision Crossings (2016 to 2020)

Developing strategies to address crossings with multiple collisions in the past five years will be a central focus of the State Action Plan. Crossings with multiple instances of collisions represent an opportunity to determine factors that may lead to a higher probability of collisions. In the past five years of data, there have been 19 public crossings with multiple collisions. These collisions occurred on rail crossings with an average maximum timetable speed of 56 miles per hour and had an average of two main tracks. On these tracks there was an average of eight trains per daytime period and an average of nine trains per nighttime period. This is higher than the average trains per day/night periods seen in single collision crossings. Crossings with higher day and night trains should be investigated further when analyzing multiple collisions at crossings. A list of these crossings is provided in Appendix A.

The roadways moving over these crossings had a higher AADT when compared to those seen in single collision crossings. The average AADT at crossings with multiple collisions was 5,700, compared to 4,455 at single collision crossings (2016-2020). The roadways did have similar average number of traffic lanes with two (2.4) lanes of traffic. Table 24 shows the types of roads at each crossing with multiple collisions in the past five years. When compared to road types involved in single collisions, there is a difference in that major collector roads account for the most multiple collision crossings, making up 42 percent. Within the state of Virginia, these roads account for only 22 percent of all crossings. Another noticeable insight is that 84 percent of crossings with multiple collisions are intersected by urban roads, while only 62 percent of all crossings are in urban areas. The statistical analysis on the reported road type where multiple collisions occurred in Virginia was inconclusive. Although there is a difference between the multiple and statewide collision percentages in Table 24, this difference is not statistically significant. Results from the statistical analysis conducted on Table 25 indicate the region type where multiple collisions occur is statistically significant and merits further investigation.

Table 24 Count and Percentage of Reported Road Type at Multi-Collision Crossings[1] *2016 to 2020*

Road Type	Multiple Collision Crossings	Multiple Collision Crossing %	Statewide Crossing %
Local	5	26%	58%
Major Collector	8	<u>42%</u>	<u>22%</u>
Minor Arterial	4	<u>21%</u>	<u>11%</u>
Minor Collector	1	5%	4%
Other Principal Arterial	1	5%	3%

[1] *Underlined values signify key findings.*

Table 25 Percentage of Multiple Collision Crossings in Urban and Rural Regions

Region Type	Multiple Collision	Multiple Collision %	Statewide Crossing %
Urban	16	84%	62%
Rural	3	16%	38%

Statistical Analysis Summary

Table 26 shows the results of the statistical analysis performed on the characteristics of collisions at public crossings in the state of Virginia by order of significance. The statistical methods used to measure these variables were a chi-squared or Fisher's Exact test. For this analysis, the assumption was made that any p-value less than or equal to 0.05 was considered significant and anything above that was insignificant. This allows for a deeper understanding of which variables are significant to collisions at these crossings and merits further investigation into the causation.

Table 26 Order of Collision Characteristics by Significance

Order	Table Number	Significance	P-Value
1	Table 25 Percentage of Multiple Collision Crossings in Urban and Rural Regions	Significant	0.0000885
2	Table 23 Percentage of Single Collision Crossings in Urban and Rural Regions	Significant	0.0001195
3	Table 15 Count of Train Type Involved in Collisions[1] *2011 to 2020*	Significant	0.0004998
4	Table 16 Percentage of Collisions by Train Type and Severity Compared to National Average *2011 to 2020*	Significant	0.0004998
5	Table 17 Percentage of Collisions by Train Speed and Severity Compared to National Average[1] *2011 to 2020*	Significant	0.0004998
6	Table 18 Position of Highway User at Time of Collision Compared to National Average[1] *2011 to 2020*	Significant	0.0004998
7	Table 19 User Action Compared to National Average[1] *2011 to 2020*	Significant	0.0004998
8	Table 22 Count and Percentage of Reported Road Type at Crossings[1] *2018 to 2020*	Significant	0.0079040
9	Table 21 Percentage of Collisions Occurring within Time Periods[1] *2011 to 2020*	Significant	0.0173000
10	Table 24 Count and Percentage of Reported Road Type at Multi-Collision Crossings[1] *2016 to 2020*	Not Significant	0.0951300
11	Table 20 Percentage of Collisions by Operator Gender and Age[1] *2011 to 2020*	Not Significant	0.9565000

5.3 RISK ASSESSMENT CALCULATION

Risk assessment is the combination of the probability of an event occurring and the consequences of the event. Applied to rail crossings, risk assessment is the probability of a collision multiplied by the expected cost of that collision. In statistics the expected value of an outcome is the sum of the probability of each outcome times the value of the outcome. For example, if a wager is made where a gambler is paid $10 if a coin toss results in heads and must pay $10 if tails, the expected value of the coin toss bet is $0, as demonstrated in the following equation

$$\begin{aligned} &\textit{Expected Value of Coin Toss Bet} \\ &\quad = [\textit{Probability of Tails}] * [\textit{Value if Tails}] + [\textit{Probability of Heads}] * [\textit{Value if Heads}] \\ &\quad = 0.5 * (\$10) + 0.5 * (-\$10) = \$0 \end{aligned}$$

The expected cost of a collision at crossing (risk):

$$\textit{Expected Cost of a Crash} = [\textit{Probability of No Crash}] * (\$0) + [\textit{Probability of a Crash}] * [\textit{Crash Cost}]$$

Since the first term is zero, the focus is on the last two terms.

However, there are various potential outcomes if a collision occurs. A more complete specification of the last two terms is shown in Equation 1.

Equation 1 Expected Cost of a Crash—Primary Effect Costs

$$\begin{aligned} &\textit{Expected Cost of a Crash} \\ &\quad = [\textit{Probability of a Crash}] * [\textit{Probability of Property Damage}] * [\textit{Cost of Property Damage}] \\ &\quad + [\textit{Probability of a Crash}] * [\textit{Probability of Injury}] * [\textit{Cost of Injury}] \\ &\quad + [\textit{Probability of a Crash}] * [\textit{Probability of Fatality}] * [\textit{Cost of Fatality}] \end{aligned}$$

This is explained in greater detail below.

A review of literature provided in the NCHRP Report 755[9] categorizes the cost of an at-grade crossing collision in two groups of primary and secondary effects:

- Primary Effect Costs: direct, indirect, and intangible costs associated with property damage, injury, and fatal collisions (more visible at the time of the collision).
- Secondary Effect Costs: costs accrued to delayed travelers and cargo, and to parties beyond the immediate road and rail travelers and service operators (less visible at the time of the collision).

Taking these secondary effects into account, the expected cost of an at-grade crossing collision becomes the equation shown in Equation 2.

9 https://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_755.pdf.

Equation 2 Expected Cost of Crash—Primary and Secondary Effect Costs

$$\begin{aligned} Expected\ Cost\ of\ Crash \\ = [Probability\ of\ a\ Crash] * [Probability\ of\ Property\ Damage] * [Cost\ of\ Property\ Damage] \\ + [Probability\ of\ a\ Crash] * [Probability\ of\ Injury] * [Cost\ of\ Injury] \\ + [Probability\ of\ a\ Crash] * [Probability\ of\ Fatality] * [Cost\ of\ Fatality] \\ + [Probability\ of\ a\ Crash] * [Cost\ of\ Secondary\ Effects] \end{aligned}$$

While primary effect costs are more visible at the time of the collision and consequently easier to capture and measure, secondary effect costs, which often represent most of the total collision cost for PDO collisions, are not as visible and require further investigation. These costs can be estimated based on the usage and characteristics of the transportation system at the location of the collision.

The expected cost equation is therefore outlined in Equation 3.

Equation 3 Simplified Cost of Crash

$$Expected\ Cost\ of\ a\ Crash = [Probability\ of\ a\ Crash] * ([Primary\ Effect\ Costs] + [Secondary\ Effect\ Costs])$$

The rest of this section will elaborate on estimation of collision probabilities as well as measuring primary and second costs of the collision.

Collision Probability Formula

The U.S. Department of Transportation (DOT) formulas were used to estimate the probability of a public at-grade crossing collision occurring in Virginia. This section uses the terms ‘accident’ for collisions to remain consistent with U.S. DOT terminology outline in the *GradeDec.Net* manual. This report also investigates the updated 2020 FRA accident prediction model and how it calculates the probability of collisions at crossings. The U.S. DOT model includes the accident history at these crossings for the previous five years. The equations used to calculate the FRA models can be found in Appendix A.

5.4 COLLISION COSTS

As mentioned previously in this report, the probability and expected cost of a collision determine the risk associated with each crossing. Risk assessment is composed of the probability of a collision occurring and the cost associated with that collision. The formula used in this model to calculate risk is defined in Equation 3.

Primary Effect Costs

Collision costs consist of primary effect costs and secondary effect costs. Primary costs include direct, indirect, and intangible costs associated with property damage, injury, and fatalities. Primary effect costs are grouped into two categories:

- Injury Costs: Inputs from the U.S. Department of Transportation Guidance on Benefit-Cost Analysis (2021)[10] were used in calculating the costs of fatal and injury-causing collisions. These values covered fatalities, three levels of injury severity, and costs for PDO incidents.
- Property Damage Costs: The property damage cost of a collision was identified based o n FRA forms 6180.57 and 8180.54 which collect data on highway-rail grade crossing accidents and rail equipment accidents respectively.

The statistical value of life and the associated comprehensive costs are listed by crash severity in Table 27.

Table 27 Statistical Value of Life
U.S. DOT 2021

	Fatal Injury	Type A Injury	Type B Injury	Type C Injury	Type U Injury	Non-Injury Cost
Comprehensive Cost	$10,900,000	$521,300	$142,000	$72,500	$197,600	$3,700

The other primary cost considered in a rail collision is the property damage costs. For this analysis, vehicle damage cost, rail equipment cost, and rail infrastructure costs were analyzed. Where possible, averages were taken based on the severity of the collision. The rail equipment and rail infrastructure costs in Table 28 are estimations due to a damage threshold that does not require rail equipment accidents to be reported if the monetary damage is below a certain amount. For collisions without any reported damages, it was assumed that damage equal to half of that years reporting threshold was incurred.

Table 28 Vehicle and Rail Property Damage Costs
2016 to 2020

Crash Type	Vehicle Damage	Rail Equipment	Rail Infrastructure
Fatal	$13,048	$10,211	$4,185
Injury	$6,513	$5,5366	$2,849
PDO	$6,110	$3,615	$4,903

Secondary Effect Costs

The secondary effect costs can be defined as the costs accrued by delayed travelers and cargo, and to the parties beyond the immediate road and rail travelers and operators. Three primary elements of secondary effect costs according to NCHRP Report 755 are outlined in Table 29.

[10] https://www.transportation.gov/sites/dot.gov/files/2021-02/Benefit%20Cost%20Analysis%20Guidance%202021.pdf.

Table 29 Secondary Effect Costs

Cost Component	Description
Delay and Re-routing Costs	Added operating costs and the monetary cost of the delay to the operators and passengers of the vehicles, trucks, and trains affected by the collision.
Supply Chain Transport Cost	Supply chain delay cost includes the cost to the shippers from the additional time spent in transit. This also encompasses penalty fees and other miscellaneous costs incurred during the delay.
Supply Chain Inventory Cost	Additional inventory carrying cost impacted by the crash to cover depreciation in value or replacement of affected goods.

These secondary costs are driven by the closure of the at-grade crossing caused by the collision. Closures of at-grade crossings will cause passenger vehicles and trucks to spend time and resources finding an alternate route to their destination. This also increases the logistical costs of the cargo being transported. Table 30 provides a summary of values presented in NCHRP Report 755 of the closure times for different types of crashes (Brod, Weisbrod, and Moses). The reported numbers in Table 30 are based on limited reports and may not be statistically significant. No comprehensive research on the closure time caused by at-grade crossing crashes could be found. For more information on the sources of data, refer to NCHRP Report 755.[11]

Table 30 Grade Crossing Crash Effects on Closure and Re-routing

Crash Type	Affected Class	Closure Duration (minutes)	Distance Re-routed (miles)	Average Added Travel Time per Person (minutes)
Fatality	Road Vehicle	765	3	7.2
	Freight Train	284	Not provided	Not provided
	Passenger Train	1285	Not provided	Not provided
Injury	Road Vehicle	125	1.2	3.5
	Freight Train	83	Not provided	Not provided
	Passenger Train	1380	2.45	36
Property Damage Only	Road Vehicle	Not provided	Not provided	Not provided
	Freight Train	Not provided	Not provided	Not provided
	Passenger Train	Not provided	Not provided	Not provided

In addition to the NCHRP 755 Report, a study performed by the Mid-America Transportation Center (Khattak and Thompson)[12] was considered for this report. The report “Development of a Methodology for Assessment of Crash Costs at Highway-Rail Grade” was used as an expert-based approach to estimate the closure and re-routing time. The study uses an average of four hours for closure time and an average detour time of 15 minutes for an at-grade crossing collision. It should be noted that it is possible to calculate re-routing time for individual crossings. However, this requires detailed data and calculations to obtain a reliable value. Therefore, this study uses an assumed value of 15 minutes.

For this analysis, NCHRP 755 closure times for freight trains were used which are reflective of additional time needed for the investigation of more severe collisions. The same closure times have been used for injury and PDO

[11] Table 27 (page 29).

[12] https://digitalcommons.unl.edu/matcreports/19/.

collisions. The re-routing time applied in this analysis is based on the Mid-America Transportation Center study to avoid multiple re-routing times based on the severity of collisions.

Roadway Vehicle Delay and Re-routing Costs

Vehicle delay and re-routing costs are derived from the operational cost and value of passenger and operator costs due to the increase in time spent traveling. Delay and re-routing costs are comprised of the operating cost of vehicles that are affected by the closure, and the value of time that passengers lose. The basis for these costs is the number of passenger vehicles and trucks effected by the closure. To estimate these values, two equations were used:

Equation 4 Affected Vehicles

$$Affected\ Vehicles = \left(AADT * (1 - ADTT\%)\right) * \left(\frac{Closure\ Time}{24}\right)$$

Equation 5 Affected Trucks

$$Affected\ Trucks = (AADT * ADTT\%) * \left(\frac{Closure\ Time}{24}\right)$$

In Equation 4 and Equation 5:

- AADT: Average Annual Daily Traffic.
- ADTT%: Average Daily Truck Traffic (as a percentage of the total traffic).

By establishing an estimate for the affected passenger vehicles and affected trucks, the roadway vehicle delay and the re-routing costs can be calculated. For the following equations, re-routing time is expected to be in hours.

Equation 6 Vehicle Re-routing Cost

$$Vehicle\ Re-routing\ Cost = [Number\ of\ Affected\ Vehicles] * [Re-routing\ Time] * [Cost\ of\ Vehicle\ Operation]$$

Equation 7 Value of Passenger Time

$$\begin{aligned} Value\ of\ Passenger\ Time \\ &= [Number\ of\ Affected\ Vehicles] * [Avg. Number\ of\ Passengers\ per\ Vehicle] \\ &* [Re-routing\ Time] * [Value\ of\ Passenger\ Time] \end{aligned}$$

Truck delay and re-routing costs are comprised of the operating cost of re-routing the affected trucks and the cost of the operator's time during the re-routing period. The following equations utilize the same re-routing time as passenger vehicles assuming trucks and passenger vehicles will be able to use the same route.

Equation 8 Cost of Truck Re-routing

$$Cost\ of\ Truck\ Re-routing = [Affected\ Trucks] * [Re-routing\ Time] * [Truck\ Operating\ Cost]$$

Equation 9 Value of Truck Driver Time

$$Value\ of\ Truck\ Driver\ Time = [Affected\ Trucks] * [Re-routing\ Time] * [Truck\ Driver's\ Hourly\ Wage]$$

Rail Delay Costs

Rail Delay can be measured by estimating various costs including the cost of idling, the value of the train operators' time, and the value of the train passengers' time:

Equation 10 Cost of Train Idling

$$Cost\ of\ Train\ Idling = [Delay\ Time] * [Train\ Idling\ Cost](for\ each\ effected\ train)$$

Equation 11 Value of Train Operator(s) Time

$$Value\ of\ Train\ Operator(s) Time = [Delay\ Time] * [Number\ of\ Train\ Operators] * [Value\ of\ Train\ Operator(s)\ Time](for\ each\ affected\ train)$$

Equation 12 Value of Train Passenger(s) Time

$$Value\ of\ Train\ Passengers\ Time = [Delay\ Time] * [Avg. Number\ of\ Passengers\ per\ Train] * [Value\ of\ Train\ Passengers\ Time]$$

Truck Supply Chain Costs

Supply chain transportation and inventory costs are identified to measure the additional pipeline inventory costs and stock outage/safety stock costs resulting from the delay caused by the at-grade crossing collision. NCHRP 755 attempts to explain the driving forces behind the supply chain costs, however, it does not clearly describe how this information can be applied to a collision for calculating supply chain costs.

This report uses the approach provided by an FHWA (Winston and Shirley)[13] report to measure the congestion costs to shippers as a percentage of cargo value. This report assumes the following congestion costs for freight:

- 0.2 percent cargo value per hour for bulk.
- 0.6 percent cargo value per hour for perishables.
- 0.4 percent cargo value per hour for all other.

Truck supply chain cost depends on the value of the cargo carried by the truck. Due to the lack of visibility on truck cargo carried on different roadways, and average value approach is used to estimate the supply chain costs for both the value of the cargo and the time value of the cargo.

The Freight Analysis Framework (FAF5—2021) was used to estimate the dollar per ton value of the truck cargo. FAF5 uses a base year of 2017 and so these values were adjusted for inflation. Queries used to determine the value per ton for trucks and dollar per ton of rail, multiple modes, and mail are included in Appendix A.

[13] https://www.fhwa.dot.gov/policy/otps/060320d/060320d.pdf.

The 3rd version of FAF (FAF3) was used to estimate the tonnage of the average truck in Virginia. Using this method, the framework estimated that the average value per ton was $619.

Rail Supply Chain Costs

Rail supply chain costs depend on the number of railcars in the train, the average cargo weight of each railcar, and the average value per ton for cargo carried by the trains. Several sources were used in the development of these inputs. The average number of rail cars was calculated by taking the average number of cars attached to trains involved in collisions in Virginia from 2011–2020. Through this method, it was determined that the average train involved in a collision contains 43.5 cars. To determine the average ton per rail car, values from the public waybill samples was used. The public waybill sample is a stratified sample of carload waybills for all U.S. rail traffic submitted by those rail carriers terminating 4,500 or more revenue carloads annually. Using this data, it was determined that the average car moving through Virginia has a tonnage of 69 (2019). This includes all cars terminating and originating in Virginia, and all those that most likely passed through Virginia (origination in northeastern states and termination in southeastern states and vice versa). The average value per ton of cargo carried by rail was determined by using the FHWA's Freight Analysis Framework—Version 5 (FAF5) to calculate the tonnage and total value of cargo moving into or out of Virginia, as well as cargo that most likely traveled through Virginia. Using this method, it was estimated that the average value per ton was $572.

Table 31 summarizes the value of time, operational costs and other factors used in the report to calculate the cost of secondary effects. These costs will be used in conjunction with crossing characteristics such as AADT, truck percentage of AADT, and trains per day, to calculate economic costs incurred if a collision were to take place.

Table 31 Secondary Cost Parameters

Parameter	Value	Source
Vehicle Delay and Re-routing Costs		
Value of Passenger Time	17.90 $ / Hour	U.S. DOT—2021 BCA Guidance
Vehicle Operation Cost	29.96 $ / Hour	
Avg. Number of Vehicle Passengers	1.67 Passengers	
Truck Delay and Re-routing Cost		
Value of Truck Drivers Time	30.80 $ / Hour	U.S. DOT—2021 BCA Guidance
Truck Operating Costs	37.79 $ / Hour	ATRI—Operational Costs of Trucking (2020)
Rail Delay and Re-routing Costs		
Value of Passenger Time	17.90 $ / Hour	U.S. DOT—2021 BCA Guidance
Value of Locomotive Engineer Time	49.40 $ / Hour	
Value of Transit—Rail Operator Time	50.00 $ / Hour	
Train Idling Costs	14.48 $ / Hour	NCHRP-755 (adjusted for inflation)

5.5 VIRGINIA CROSSING RANKINGS

Below is a preliminary list of Virginia's crossings, ranked by the expected collision costs per year as well as expected Net Present Value of installing gates. Two rankings were developed to incorporate possible improvements. The first ranking, shown in Table 32, was calculated based on expected annual collision cost. To determine this value, current FRA and GradeDec probability formulas were used to determine the expected number of collisions per year, as well as the probability of severity for these collisions. Primary and Secondary costs for fatal, injury, and PDO collisions were determined using the cost calculator previously described, and then multiplied against the probabilities of each severity type to determine the expected annual collision cost.

Table 32 Rankings of Crossings based on Expected Costs and Improvement Costs[1]

Rank	Crossing ID	Annual Expected Cost ($)	Current Warning Device
1	623668M	583,538	Gates
2	623683P	477,988	Gates
3	467400K	305,461	Gates
4	714341S	224,423	Gates
5	224233S	209,797	Gates
6	623680U	197,337	Gates
7	467399T	193,927	Gates
8	467405U	187,757	Gates
9	714355A	177,735	Gates
10	860437F	175,612	Gates
11	623739G	160,937	Gates
12	467451V	160,010	Gates
13	467398L	158,201	Gates
14	623687S	157,514	Gates
15	860441V	148,322	Gates
16	860459F	147,459	Gates
17	860581X	136,502	Gates
18	623693V	133,962	Gates
19	467450N	126,621	Gates
20	623740B	124,628	Gates
21	714771C	110,089	Gates
22	713846V	109,222	Gates
23	714356G	106,368	Gates
24	623642K	104,654	Gates
25	467406B	102,877	Gates

[1] *Table includes top 25, full list included in Excel file.*

The second ranking of crossings, Table 33, was calculated based on Net Present Value (NPV) of warning device improvement benefits. The NPV was calculated by subtracting the cost installing a warning device from present value of benefits installing warning device over its useful life. Benefits of warning device installation was calculated by multiplying the initial expected annual collision cost by a collision modification factor that corresponded with upgrading to gates. This new value was subtracted from the initial expected annual collision cost to derive the total benefit a warning device upgrade would have. The cost of gate installation was then subtracted from the benefit to calculate the NPV. These costs were based on values provided by VDOT and Norfolk Southern Railroad. It should be noted that the crossings ranked in Table 33 all currently have flashing lights or passive warning devices, as crossings with existing gates were excluded from the ranking. Further investigation of expected benefits is possible if more information is uniformly available of gate type, medians, existence of overhead cantilevers with flashing lights, etc.

Table 33 Crossing Ranking based on NPV of Gate Improvements[1]

Rank	Crossing ID	Net Present Value	Current Warning Device
1	470522T	(194,085)	Flashing Lights
2	469544W	(233,891)	Flashing Lights
3	925503A	(239,724)	Passive
4	842180A	(248,076)	Passive
5	842198K	(249,824)	Flashing Lights
6	714837A	(256,250)	Flashing Lights
7	468118K	(261,048)	Flashing Lights
8	468150D	(261,457)	Passive
9	467928Y	(271,297)	Passive
10	467958R	(272,457)	Flashing Lights
11	467527Y	(275,361)	Flashing Lights
12	468146N	(275,445)	Passive
13	468190B	(275,673)	Flashing Lights
14	623838E	(276,108)	Flashing Lights
15	935132U	(279,201)	Passive
16	623598A	(279,349)	Flashing Lights
17	714465K	(280,089)	Passive
18	714587P	(281,585)	Passive
19	859983H	(281,789)	Passive
20	470391S	(283,781)	Flashing Lights
21	470509E	(284,122)	Flashing Lights
22	468197Y	(284,167)	Flashing Lights
23	469721Y	(284,480)	Passive
24	714598C	(284,590)	Flashing Lights
25	468158H	(285,570)	Flashing Lights

[1] *Table includes top 25, full list included in Excel file.*

Costs associated with closing crossings were also calculated and compared to the 20-year expected accident cost of each crossing. The calculation has three primary assumptions:

- Closing crossings will have no migrated collisions to nearby crossings.
- All crossings have possible detours of 5, 10, and 15 minutes available.
- Emergency services will not be affected by the closure.

The primary benefits to crossing closures are the reduction in expected collision costs to zero, while the costs are the increased travel time and operating costs caused by possible detours. Using AADT and the percentage of truck traffic reported by the FRA, the added cost was calculated on a yearly basis. If the 20-year cost of closure (Present Value) was smaller than the 20-year expected collision cost (Present Value), then the crossing was flagged. Using this methodology, no crossings were flagged for closure.

5.6 VIRGINIA PRIORITY INDEX

Virginia currently does not utilize a benefit-cost analysis approach in determining the priority of highway-rail crossing safety improvements. This methodology, as outlined in VDOT memo “Highway-Rail Crossing Safety Selection Process 2020,” is used due to the infrequency of train/vehicle collisions at any given location within the state. To determine VDOT’s priority ranking of improvements, the preliminary collision prediction value calculated through the FRA’s probability formula, is multiplied against a sight distance number value. Candidate locations are then sorted by descending order to develop the priority list. The final ranking is developed from the priority list and feedback from safety partners and physical reviews of crossing characteristics. This system of prioritization differs from the process outlined previously in this report. The exclusion of monetary inputs from VDOTs ranking system puts greater emphasis on physical crossing characteristics and historical collisions.

This report has recreated VDOT’s priority index ranking by following the procedure outlined in VDOT memo “Highway-Rail Crossing Safety Selection Process 2020.” To calculate the multiplier, the two roadway sight distances (one for each direction of traffic) were matched with their respective crossing IDs. Then the lower of the two values was selected as the crossings primary sight distance value to produce the most accurate results. It should be noted that sight distances under 50 feet were excluded from the analysis, as sight distances less than 50 feet are likely to be intersections.

With the primary sight distance values determined, the recommended sight distance for each crossing was calculated. This value was taken from the Railroad-Highway Grade Crossing Handbook (Second Edition).[14] The table bases the recommended sight distance on the maximum highway speed at the crossing. These values were attributed to each crossing and then the actual sight distance was divided by the recommended sight distance. This produced a percentage, which could then be used to assign the multiplier. Table 34 shows how multipliers were applied based on this percentage.

Table 34 Sight Distance Multipliers

SD Percentage	Multiplier
x <25%	5
25%<= x <50%	4
50%<= x <75%	3
75%<= x <100%	2
x > 100%	1

Using the process outlined above, the Priority Index Value could be determined by multiplying the initial FRA probability with the assigned multiplier.

Table 35 shows the highest ranked crossings based on their Priority Index Value and compares this to the ranking conducted based on expected crash cost in Table 32.

[14] Table 32, https://railroads.dot.gov/sites/fra.dot.gov/files/fra_net/1464/HRGXHandbook.pdf.

Table 35 Ranking of Crossings Based on Priority Index Value[1]

Crossing ID	Priority Index Value	FRA/NCHRP 755 Rank
224233S	0.6994	5
623683P	0.6193	2
859983H	0.5095	154
935045R	0.3920	28
842244J	0.3679	285
623668M	0.3675	1
469432X	0.3338	56
714356G	0.3091	23
468775B	0.3017	375
467402Y	0.2685	27
467399T	0.2576	7
713935M	0.2570	37
469509H	0.2482	48
714771C	0.2214	21
470702R	0.2102	36
623530L	0.2049	32
469735G	0.2002	88
467400K	0.1999	3
469795R	0.1883	54
860459F	0.1741	16
468556M	0.1722	67
469417V	0.1720	73
714355A	0.1720	9
856051B	0.1697	428
469598C	0.1591	109

[1] *Table includes top 25, full list included in Excel file.*

6 PRIORITY LOCATIONS

Virginia's Rail-Highway Grade Crossing Plan identifies priority actions based on a variety proactive and historic analyses. The crossing data analysis presented in Section 4 and the risk analysis summarized in Section 5 provide the foundation used to identify the greatest priority locations for this plan.

6.1 NON-GATED CROSSINGS

Table 36 shows the top 25 crossings that do not currently have gates, based on their expected annual crash cost. The methodology described in Chapter 5 was applied to all crossings that currently have flashing lights or passive safety measures. These crossings were then sorted by cost to determine the ranking. The ranking of crossings based on net present value (NPV) is also included in the table. NPV can be used to determine priority in cases where the expected annual crash costs are similar.

Table 36 Non-Gated Crossings Ranked using NCHRP 755 methodology[1]

Crossing ID	Street Name	City/County	NCHRP 755 Rank	NPV Rank
714465K	KING ST	SHENANDOAH	1	17
925503A	DIUGUIDS LN	SALEM	2	3
859983H	PLEASANT HILL RD	HARRISONBURG	3	19
623598A	DANVILLE ST	HOPEWELL	4	16
842180A	STOVER DR	ROCKINGHAM	5	4
470522T	EDMUNDS ST	HALIFAX	6	1
714463W	QUEEN ST/PARK RD	SHENANDOAH	7	29
623835J	CROSS KEY RD	SOUTHAMPTON	8	28
468835H	DIAL ROCK RD	TAZEWELL	9	27
468150D	POOR CREEK LN	AUGUSTA	10	8

Crossing ID	Street Name	City/County	NCHRP 755 Rank	NPV Rank
842244J	PEAR ST	HARRISONBURG	11	36
467928Y	CAMPBELL CROSSING RD	PRINCE EDWARD	12	9
469544W	TANNERY RD	GILES	13	2
842198K	PENN LAIR DR	ROCKINGHAM	14	5
468190B	RIVERSIDE RD	ROCKBRIDGE	15	13
468775B	ROANOKE BLVD	SALEM	16	44
935132U	DEPOT AVE	WARREN	17	15
714466S	WASHINGTON ST	SHENANDOAH	18	48
468782L	MAIN ST	SALEM	19	49
468118K	OAK LN	WAYNESBORO	20	7
857678R	HAMPTON BLVD	NORFOLK	21	54
714837A	COEBURN AVE	NORTON	22	6
224884E	ABERDEEN RD	HAMPTON	23	47
467498R	FIFTEENTH AVE	HOPEWELL	24	52
469721Y	LAKE MT AIRY RD	WYTHE	25	23

[1] *Table only includes the top 25.*

7 ACTION PLAN

7.1 INTRODUCTION

The strategic action plan is key for guiding Virginia towards achieving the grade crossing safety goal and objectives. Strategies and action steps were developed for each plan objective to provide a framework to achieve the plan's goal. Strategies indicate how changes will be made, and the actions are the specific tasks or steps that will be undertaken by rail-highway safety stakeholders to execute the strategy and measure incremental progress.

7.2 STRATEGIES AND ACTION STEPS

The plan identifies four key focus areas (coordination/outreach, engineering, enforcement, and data) to categorize the strategies and actions that Virginia will follow to achieve the plan's objectives. Each table in this section includes actions within each of the key strategies within the focus areas, as well as lead organization, supporting agencies, and timeline to implementation. The timeline to implement each action is shared relative to the plan (short term—within one year of submitting the SAP, medium term—one to two years, long term—two to four years, or ongoing).

Coordination/Outreach

Table 37 Strategy: Conduct education, coordination and outreach to railroads, local agencies, and the public

Actions	Lead Organization	Supporting Organization(s)	Implementation Timeframe
Inform Local Assistance Division and LTAP about the rail-grade crossing program and suggest they provide information to cities and towns.	VDOT	LTAP; VDOT Local Assistance	Ongoing
Provide updates to railroad company contacts on planned roadway improvements at or near crossings.	VDOT	VDOT Districts, TED and ROW Division	Ongoing
Conduct rail safety presentations at appropriate conferences such as the Governor's Transportation Conference and the Virginia Highway Safety Summit.	VDOT		1–2 Years
Work with Operation Lifesaver to deliver an education program for K-12 and college students which addresses dangers at grade crossings and trespassing along railroad rights-of-way.	SCC	Department of Education; DMV	Ongoing
Review information in the current driver's education curriculum on rail-highway grade crossing safety including information on pedestrians, non-motorized vehicles, and trespassing and determine the need for updates.	Department of Education	SCC; DMV	Ongoing

Table 38 Strategy: Promote Operation Lifesaver in the Commonwealth

Actions	Lead Organization	Supporting Organization(s)	Implementation Timeframe
Identify opportunities to increase volunteering opportunities with Operation Lifesaver; Leverage existing communication channels.	SCC	VDOT, DRPT	Ongoing
Identify opportunities for Operation Lifesaver presentations on rail and highway safety for the public and professional drivers.	SCC	VDOT, DRPT, Department of Education	Ongoing
Disseminate educational material to elected officials for their constituents on rail-highway safety and trespassing.	SCC	VDOT, DRPT	Ongoing

Table 39 Strategy: Develop and communicate a framework for coordination among railroads, VDOT, SCC, DRPT, Operation Lifesaver, local jurisdictions, MPOs, and state police with support from FHWA and FRA

Actions	Lead Organization	Supporting Organization(s)	Implementation Timeframe
Create a Steering Committee comprised of VDOT, DRPT, railroad company representatives, local agencies, law enforcement, and Operation Lifesaver.	SCC; VDOT	DRPT	Within 1 Year of Submitting SAP
Develop policies and procedures for addressing rail-highway at-grade crossings needs that align with SMART SCALE project development process in coordination with the Virginia Freight Advisory Committee.	VDOT		Ongoing
Assess and adopt best practices in grade crossing safety improvements by engaging with AASHTO/U.S. DOT information exchanges for applicable practices in Virginia.	VDOT		Within 1 Year of Submitting SAP

Engineering

Table 40 Strategy: Implement site improvements at passive and active crossings, particularly those with recurring incidents over the last five years; address operational and/or maintenance needs at active crossings

Actions	Lead Organization	Supporting Organization(s)	Implementation Timeframe
Periodic review of crash data over the last 10 years and collect anecdotal information on safety issues from law enforcement, railroad companies, and others.	VDOT		Ongoing
Update a prioritized list of rail-highway grade crossing improvements and review on a regular basis to determine progress on implementation.	VDOT		Ongoing
Evaluate the status of current warning systems and signage and identify locations that require improvements.	VDOT	SCC, Railroad Companies	Ongoing
Prioritize hotspots and low-cost improvements for crossings to achieve maximum impact on reducing incidents at crossings.	VDOT	Railroad Companies	Ongoing
Identify and promote low-cost countermeasures for improving rail-highway crossing safety.	VDOT	SCC	Ongoing
Continue ongoing periodic inspection program to identify safety problems early on.	SCC	FRA	Ongoing

Table 41 Strategy: Install active warning devices per crossing safety program

Actions	Lead Organization	Supporting Organization(s)	Implementation Timeframe
Consider signage with a warning message at locations with high number of incidents.	VDOT		Ongoing
Review rail-highway grade crossings to identify those where active warning devices may be needed.	VDOT		Ongoing
Explore the use of smart technologies or physical barriers to deter or detect trespassing at grade crossings.	VDOT	Railroad Companies, DRPT	Ongoing
Explore treatments to improve the safety of pedestrians at rail-highway grade crossings with risk for pedestrian safety issues.	VDOT	Railroad Companies, DRPT	Ongoing

Table 42 Strategy: Reduce the overall number of public grade crossings in Virginia

Actions	Lead Organization	Supporting Organization(s)	Implementation Timeframe
Identify funding to analyze rail-highway at-grade crossings for potential closure in consultation with railroad companies, law enforcement, other partners, and the communities affected to identify and prioritize locations where it would be possible to close public rail-highway grade crossings including the list developed as part of the SAP.	VDOT	DRPT	1–2 Years
Identify funding to develop and execute standard process for advancing closure of identified crossings, including coordination across stakeholders, public outreach and input, and funding needs.	VDOT	DRPT, Railroad Companies	Ongoing

Enforcement

Table 43 Strategy: Promote active enforcement of traffic laws related to rail-highway grade crossings and on railroad right-of-way

Actions	Lead Organization	Supporting Organization(s)	Implementation Timeframe
Provide the Virginia State Police rail crossing safety information that can be used by the Virginia State Police to make enforcement decisions in areas of high or repeat crash incidences.	VDOT	Virginia State Police; SCC; Virginia Association of Chiefs of Police	Annually
Provide similar information as is provided to the Virginia State Police to VDOT Districts for distribution to local stakeholders (including law enforcement) to work with law enforcement in communities where highway-rail grade crossing incidents are a safety issue.	VDOT	Virginia State Police; SCC; Virginia Association of Chiefs of Police	Annually

Table 44 Strategy: Conduct outreach and education on rail-highway grade crossing safety

Actions	Lead Organization	Supporting Organization(s)	Implementation Timeframe
Coordinate with DMV and Operation Lifesaver on updates to driver training materials and curriculum.	VDOT	Virginia State Police; SCC; FRA	Ongoing

Data

Table 45 Strategy: Improve data inventory, data collection processes, and data accuracy

Actions	Lead Organization	Supporting Organization(s)	Implementation Timeframe
Encourage data to be captured by active crossing systems be made available to VDOT, as part of grant agreements.	VDOT	VDOT; DRPT; SCC; Railroad Companies	Ongoing
Determine where there is a lack of adequate data, such as an inventory of warning devices and signage at rail-highway grade crossings.	VDOT		Ongoing
Review crash reporting form to verify that rail-highway grade crossing crashes are being properly recorded and that information on non-motorized incidents are captured and noted as a rail trespassing violation.	VDOT	DMV	Ongoing

Table 46 Strategy: Conduct data and preliminary field reviews of crossings with high non-motorist activities and multi-crash locations

Actions	Lead Organization	Supporting Organization(s)	Implementation Timeframe
Determine railroad at grade crossings with pedestrian and bicycle crashes.	VDOT		1–2 Years
Prioritize the rail grade crossing locations that have pedestrian and bicycle crashes and determine if countermeasures are needed.	VDOT		2–4 Years

8 IMPLEMENTATION AND EVALUATION

8.1 INTRODUCTION

This section clearly identifies the responsible parties for tracking implementation of the plan, reporting of performance measures related to the objectives of the plan, and timeline for future state action plans. VDOT, DRPT, and their partners have mapped out key steps and implementation strategies to employ upon the completion of this plan update. The same multidisciplinary approach used to update the plan will be leveraged in its implementation, with the goal of integrating these strategies into the department's operational practices. It is important to designate these roles and drive implementation efforts of this collaborative plan to reach Virginia's goal of improving safety where railroads interact with other modes over the next five years.

8.2 DESIGNATED OFFICIAL MONITORING AND COMMUNICATION

VDOT's Traffic Engineering Division will monitor progress of the Virginia Grade Crossing SAP on an annual basis. This process will include reviewing the objectives, strategies, and action steps included in the plan to determine if the objectives have been met, which action steps have been completed, and any outcomes or lessons learned. VDOT will provide progress updates on achieving the objectives identified. If the proposed schedule will be impacted, additional coordination and outreach will take place to determine potential causes and any necessary adjustments.

8.3 MEASUREMENT AND REPORTING

VDOT will measure progress toward the SAP objectives and goal annually by reviewing the grade crossing accident/incident data including fatalities, injuries, and trespassing incidents. Updated trends and analysis will be included in the respective Highway Safety Improvement Program Section 130 reporting process and in the annual

Highway Safety Plan each year. The results will also be shared with the SHSP Steering Committee. The strategic action plan is designed to be a “living document” and will be used to track the state’s progress in reducing grade crossing fatalities and injuries. This allows action steps and strategies in each focus area of the action plan to be updated as needed to address progress, as well as changes impacting the action or timeline for implementation.

8.4 FUTURE STATE ACTION PLANS

For future updates to the the Virginia Grade Crossing State Action Plan, VDOT will start by assessing feedback on the SAP goal, objectives, and strategies for future iterations of the plan. Coordination with other transportation plan goals and objectives will also be used to determine what is working, what processes can be improved, and what opportunities for collaboration should be leveraged to further advance grade crossing safety in Virginia.

APPENDIX A. VIRGINIA DOT HAZARD RATINGS

A.1 FRA MODEL CALCULATIONS

U.S. DOT Formula

The U.S. DOT formula includes a normalizing constant for each warning device at a crossing (passive, flashing lights, and flashing lights and gates), represented as *Adj* in Equation 13. The formula used to calculate the predicted number of collisions at a crossing is as follows:

Equation 13 Predicted Number of Accidents at the Crossing U.S. DOT Formula

$$a = k \times EI \times DT \times MS \times MT \times HL \times HP$$

$$T_o = \frac{1}{0.05 + a}$$

$$NA = \frac{(a * T_o) + N}{T_o + 5} * Adj$$

Table 47 Variable Descriptions for Each Type of Grade Crossing

Variable	Type of Grade Crossing		
	Passive	Flashing Lights	Lights and Gates
k	0.0006938	0.0003351	0.0005745
EI	$\left[\frac{Expose + 0.2}{0.2}\right]^{0.37}$	$\left[\frac{Expose + 0.2}{0.2}\right]^{0.4106}$	$\left[\frac{Expose + 0.2}{0.2}\right]^{0.2942}$
DT	$\left[\frac{dthru + 0.2}{0.2}\right]^{0.1781}$	$\left[\frac{dthru + 0.2}{0.2}\right]^{0.1131}$	$\left[\frac{dthru + 0.2}{0.2}\right]^{0.1781}$

Variable	Type of Grade Crossing		
MS	$e^{0.0077*ms}$	1	1
MT	1	$e^{0.1917*tracks}$	$e^{0.1512*tracks}$
HL	1	$e^{0.1826*(lanes-1)}$	$e^{0.142*(lanes-1)}$
HP	$e^{-0.5966*(paved-1)}$	1	1
Adj	0.5086	0.3106	0.4846

Where:

- a: initial collision prediction, collisions per year at the crossing
- k: regression coefficient
- EI: factor for exposure index based on product of highway and train traffic
- DT: factor for number of through trains per day during daylight
- MS: factor for maximum timetable speed
- MT: factor for number of main tracks
- HL: factor for number of highway lanes.
- HP: factor for highway paved (yes or no)
- *NA*: predicted number of accidents per year at the grade crossing
- *N*: number of accidents in previous five years at grade crossing
- *Adj*: coefficient to normalize predicted accidents in year with actual counts
- *Expose*: daily exposure with time-of-day correlation
- *dthru*: number of through trains per day
- *ms*: maximum timetable speed at crossing, miles per hour
- *tracks*: number of main tracks
- *lanes*: number of highway lanes
- *paved*: if highway is paved, paved = 1; if unpaved then paved = 2

The calculation for daily exposure was outlined in the *GradeDec.Net* manual. This formula takes in the average annual daily traffic that occurs at crossings and the time-of-day correlation of traffic to determine the daily exposure in this model.

Equation 14 Daily Exposure with Time-of-Day Correlation

$$Expose = 1.35 * EF * AADT * TV$$

Where:

- *Expose*: base year daily exposure with time-of-day correlation, effective daily exposures
- *EF*: time-of-day exposure correlation factor
- *AADT:* average annual daily traffic on the highway at the crossing
- *TV:* average daily trains at the crossing

Equation 14 uses the time-of-day correlation factor, derived by Equation 15, between train and highway vehicle types at crossings to determine the impact of the daily exposure. The percentage for daily exposure is then compared to what it would be if the time-of-day correlation was equivalent to the national average's correlation. The U.S. DOT model uses the results of a surveyed expert to determine the percentage of daily exposure for the correlation calculation. The value 1.35, represented in Equation 14, indicated there is 35 percent more daily exposure for the time-of-day correlation between train and highway vehicle types at the crossings than the national average's correlation.

Equation 15 Time-of-Day Exposure Correlation Factor

$$EF = \frac{\sum_i \left(\sum_k \alpha_k a_{ik} \sum_j \beta_j b_{ij}\right)}{Max\left(\sum_i \sum_k (\alpha_k a_{ik})^2, \sum_i \sum_j \left(\beta_j b_{ij}\right)^2\right)}$$

Where:

- *EF*: time-of-day exposure correlation factor
- *i*: an index designating the hour of the day
- *j*: an index of highway vehicle type
  - » Auto
  - » Truck
  - » Bus
- *k*: an index of train types
  - » Passenger
  - » Freight
  - » Switch in the corridor model or through and switch in the regional model
- a_{ik}: the share of daily trains of train type k at the crossing in the ith time-of-day period
  - » $\sum_i a_{ik} = 1$
- b_{ij}: the share of daily traffic of vehicle type j in the ith hour of the day
  - » $\sum_i b_{ij} = 1$
- α_k: the share of train type k of total trains
  - » $\sum_i \alpha_k = 1$
- β_j: the share of vehicle type j in daily highway traffic
  - » $\sum_i \beta_j = 1$

When evaluating the time-of-day exposure correlation factor, the numerator in Equation 15 calls for the sum of all train and highway vehicle types for the designated hour of the day. First, it takes the sum of the share of each train type multiplied by the share of daily trains for each train type in the designated time-of-day period and evaluates it for each train type. Similarly, it takes the sum of the share of each highway vehicle type multiplied by the share of daily traffic for each vehicle type in the designated time-of-day period and evaluates it for each highway vehicle type. These two sums are then evaluated for each hour of the day to determine the total train and highway vehicle types at crossings. The denominator in Equation 15 calls for the maximum between the squared sum value of all the train and highway vehicle types for the designated hour of the day. From here, the time-of-day correlation was determined and incorporated in calculating the daily exposure with time-of-day correlation for the model.

Fatality Probability

The predicted number of fatal accidents per year at the grade crossing, denoted as FA, is estimated using Equation 16.

Equation 16 Predicted Number of Accidents at Crossing for Fatal Accidents

$$FA = \frac{NA}{1 + KF * MS * TT * TS * UR}$$

Where:

- *FA*: predicted number of fatal accidents per year at the grade crossing
- *NA*: predicted number of accidents per year at the grade crossing
- *KF*: formula constant = 440.9
- MS: factor for maximum timetable speed
- *TT*: factor for through trains per day
- *TS*: factor for switch trains per day
- *UR:* factor for urban or rural crossing

The model takes the total number of fatal accidents divided by the total number of accidents resulting in a fatality, injury, or PDO to calculate the fatality probability.

Casualty Probability

The predicted number of casualty accidents per year at the grade crossing, *CA*, is calculated as follows:

Equation 17 Predicted Number of Accidents at Crossing for Casualty Accidents

$$CA = \frac{NA}{1 + KC * MS_{CA} * TK * UR_{CA}}$$

Where:

- *CA:* predicted number of casualty accidents per year at the grade crossing
- *FA*: predicted number of fatal accidents per year at the grade crossing
- *KC:* formula constant = 4.481
- MS: factor for maximum timetable speed
- *TK:* factor for number of tracks
- *UR:* factor for urban or rural crossing

Injury Probability

The predicted number of injury accidents per year at the grade crossing, denoted *IA*, is calculated in Equation 18:

Equation 18 Predicted Number of Accidents at Crossing for Injury Accidents

$$IA = CA - FA$$

Where:

- *IA:* predicted number of injury accidents per year at the grade crossing
- *CA:* predicted number of casualty accidents per year at the grade crossing
- *FA*: predicted number of fatal accidents per year at the grade crossing

The model calculates the injury probability by taking the total number of injury accidents divided by the total number of accidents resulting in a fatality, injury, or PDO.

PDO Probability

The predicted number of PDO accidents per year at the grade crossing, *PA*, is calculated as follows:

Equation 19 Predicted Number of Accidents at Crossing for PDO Accidents

$$PA = NA - FA - IA$$

Where:

- *PA:* predicted number of PDO accidents per year at the grade crossing
- *NA*: predicted number of accidents per year at the grade crossing
- *FA*: predicted number of fatal accidents per year at the grade crossing
- *IA:* predicted number of injury accidents per year at the grade crossing

The model takes the total number of PDO accidents and divides it by the total number of accidents resulting in a fatality, injury, or PDO to calculate the PDO probability.

2020 FRA Accident Prediction Model

The FRA has released a 2020 update to the accident prediction model and the accident severity model. The 2020 models were both considered in this analysis to calculate collision probabilities. The 2020 FRA accident prediction model calculates the predicted number of accidents at a crossing, while the 2020 FRA accident severity model determines the probability of a collision resulting in a specific severity type given a collision occurred. The 2020 accident prediction model is composed of two parts: the Zero-Inflated Negative Binomial (ZINB) regression model and the Empirical Bayes (EB) method. The ZINB regression is used to model count data that displays overdispersion and excess zeroes. The excess zeroes in the data indicate no history of accidents occurring in the past five years at the crossing. The assumptions for the ZINB model are the following:

- Each crossing has a probability greater than zero of being a no-risk crossing.
- Each crossing has an expected number of annual accidents.
- Accident counts for the population of crossings conform to a negative binomial distribution (the standard deviation of accidents for the population is greater than the mean, indicating overdispersion).

The ZINB count model calculates the predicted number of accidents at crossings. This formula does not include crossings that contain excess zeroes in the accident history for the last five years.

Equation 20 The ZINB Count Model

$$N_{CountPredicted} = e^{[\beta_0+\beta_1*lExpo+\beta_2*D_2+\beta_3*D_3+\beta_4*RurUrb+\beta_5*XSurfID2s+\beta_6*lAadt+\beta_7*lMaxTtSpd]}$$

Where:

- $N_{CountPredicted}$: predicted accidents of count model
- $lExpo$: exposure, equal to average annual daily traffic times daily trains
- D_2: if warning device type is lights = 1, 0 otherwise
- D_3: if warning device type is gates = 1, 0 otherwise
- $RurUrb$: if rural = 0, if urban = 1
- $XSurfID2s$: timber = 1, asphalt = 2, asphalt and timber or concrete or rubber = 3, concrete and rubber = 4
- $lAadt$: average annual daily traffic
- $lMaxTtSpd$: maximum timetable speed (integer value between 0 and 99)

The ZINB zero-inflated model calculates the probability that the grade crossing is an “excess zero,” indicating crossings with an effectively zero crossing accident risk.

Equation 21 The ZINB Zero-Inflated Model

$$P_{InflatedZero} = \frac{z}{1+z}$$

$$z = e^{[y_0+y_1*lTotalTrains]}$$

Where:

- $P_{InflatedZero}$: probability that the grade crossing is an “excess zero”
- $lTotalTrains$: total number of daily trains

The ZINB combined model determines the predicted number of accidents at crossings, including those with excess zeroes.

Equation 22 The ZINB Combined Model

$$N_{Predicted} = N_{CountPredicted} * (1 - P_{InflatedZero})$$

Where:

- $N_{Predicted}$: predicted accidents after accounting for excess zeroes
- $N_{CountPredicted}$: predicted accidents of count model
- $P_{InflatedZero}$: probability that the grade crossing is an "excess zero"

The Empirical Bayes (EB) method is incorporated into the 2020 accident prediction model to account for the accident history at the crossings and correct for any bias in the ZINB regression calculation. The EB adjustment will make the expected value of accidents at crossings either closer to zero or the actual value depending on the accident history. The formula below calculates the expected number of accidents at the crossing.

Equation 23 The Empirical Bayes Adjustment Formula

$$N_{Expected} = w * N_{Predicted} + (1 - w) * N_{Observed}$$

Where:

- $N_{Expected}$: the adjusted number of predicted accidents
- $N_{Predicted}$: number of predicted accidents from the ZINB regression procedure
- $N_{Observed}$: the number of observed accidents

The weighting factor in Equation 24 accounts for the accident history at the crossing. This weighted factor allows for a better approximation of the expected number of accidents at crossings.

Equation 24 The Empirical Bayes Weighting Factor Formula

$$w = \frac{1}{1 + \frac{V[N_{Predicted}]}{N_{Predicted}}}$$

Where:

- w: weighting factor
- $N_{Predicted}$: number of predicted accidents from the ZINB regression procedure

The variance of the predicted number of accidents at the crossings is calculated as follows:

Equation 25 The Variance of Crossing's Predicted Number of Accidents Formula

$$V[N_{Predicted}] = N_{Predicted} * 1 + [N_{Predicted} * \left(P_{InflatedZero} + \frac{1}{\theta}\right)$$

Where:

- $N_{Predicted}$: number of predicted accidents from the ZINB regression procedure
- $P_{InflatedZero}$: probability that the grade crossing is an "excess zero"
- $\frac{1}{\theta}$: the inverse of the overdispersion parameter α from the ZINB regression
  - » $\theta = 0.7716$

2020 FRA Accident Severity Model

As previously mentioned in this report, the updated 2020 accident severity model was considered in this analysis to calculate crash probabilities across each severity category (fatal, injury and PDO) at grade crossings.

The 2020 accident severity model determines the probabilities that given an accident at the grade crossing, the accident will result in a fatality, injury, or PDO. In a probability distribution, each probability represents the likelihood of an event occurring, where each probability is composed of a value between zero and one. The sum of these probabilities will always equal to one. The following formula is used to verify that the probabilities calculated for each category of severity sum to one.

Equation 26 Constraint that Severity Probabilities Sum to 1

$$1 = P(acctype = fatal \mid A) + P(acctype = injury \mid A) + P(acctype = PDO \mid A)$$

Where:

- $P(acctype = fatal \mid A)$: the probability of a fatal accident given an accident A
- $P(acctype = injury \mid A)$: the probability of an injury accident given an accident A
- $P(acctype = PDO \mid A)$: the probability of a PDO accident given an accident A

The 2020 accident severity model uses multinomial logistic regression, which is used to predict the probability of an accident type occurring at a crossing based on the severity type. This model uses the accident type "fatal" as the reference level in the regression analysis.

The calculation for the probability of an injury relative to a fatal accident is as follows:

Equation 27 Accident Severity Model—Injury Relative to Fatal

$$ln\left(\frac{P(acctype = injury \mid A)}{P(acctype = fatal \mid A}\right) = \beta_{20} + \beta_{21} * lMaxTdSpd + \beta_{22} * lTrains + \beta_{23} * RurUrb + \beta_{24} * D_2$$

Where:

- $P(acctype = injury \mid A)$: the probability of an injury accident given an accident A
- $P(acctype = fatal \mid A)$: the probability of a fatal accident given an accident A
- $lMaxTdSpd$: the natural log of the maximum (rail) timetable speed at the crossing
- $lTrains$: the natural log of the total number of daily trains at the crossing

- $RurUrb$: 1 if the crossing is in a rural (non-urban) environment, 0 if in Urban
- D_2: has value 1 if warning device type is lights, 0 otherwise

The calculation for the probability of a PDO relative to a fatal accident is shown below:

Equation 28 Accident Severity Model—PDO Relative to Fatal

$$ln\left(\frac{P(acctype=PDO \mid A)}{P(acctype=fatal \mid A)}\right) = \beta_{30} + \beta_{31} * lMaxTdSpd + \beta_{32} * lTrains + \beta_{33} * RurUrb + \beta_{34} * D_2$$

Where:

- $P(acctype = PDO \mid A)$: the probability of a PDO accident given an accident A
- $P(acctype = fatal \mid A)$: the probability of a fatal accident given an accident A
- $lMaxTdSpd$: the natural log of the maximum (rail) timetable speed at the crossing
- $lTrains$: the natural log of the total number of daily trains at the crossing
- $RurUrb$: 1 if the crossing is in a rural (non-urban) environment, 0 if in Urban
- D_2: has value 1 if warning device type is lights, 0 otherwise

Taking Equation 27 and Equation 28 the individual probabilities for fatality, injury, and PDO given a collision can be calculated. The accident severity formulas used in the model are the following:

Equation 29 Accident Severity Forecast Formulas—Fatal

$$Pr(Y_i = fatal \mid A) = \frac{1}{1 + \sum_{k=2}^{3} e^{\beta_k * X_i}}$$

Equation 30 Accident Severity Forecast Formulas—Injury

$$Pr(Y_i = injury \mid A) = \frac{e^{\beta_2 * X_i}}{1 + \sum_{k=2}^{3} e^{\beta_k * X_i}}$$

Equation 31 Accident Severity Forecast Formulas—PDO

$$Pr(Y_i = PDO \mid A) = \frac{e^{\beta_3 * X_i}}{1 + \sum_{k=2}^{3} e^{\beta_k * X_i}}$$

Where:

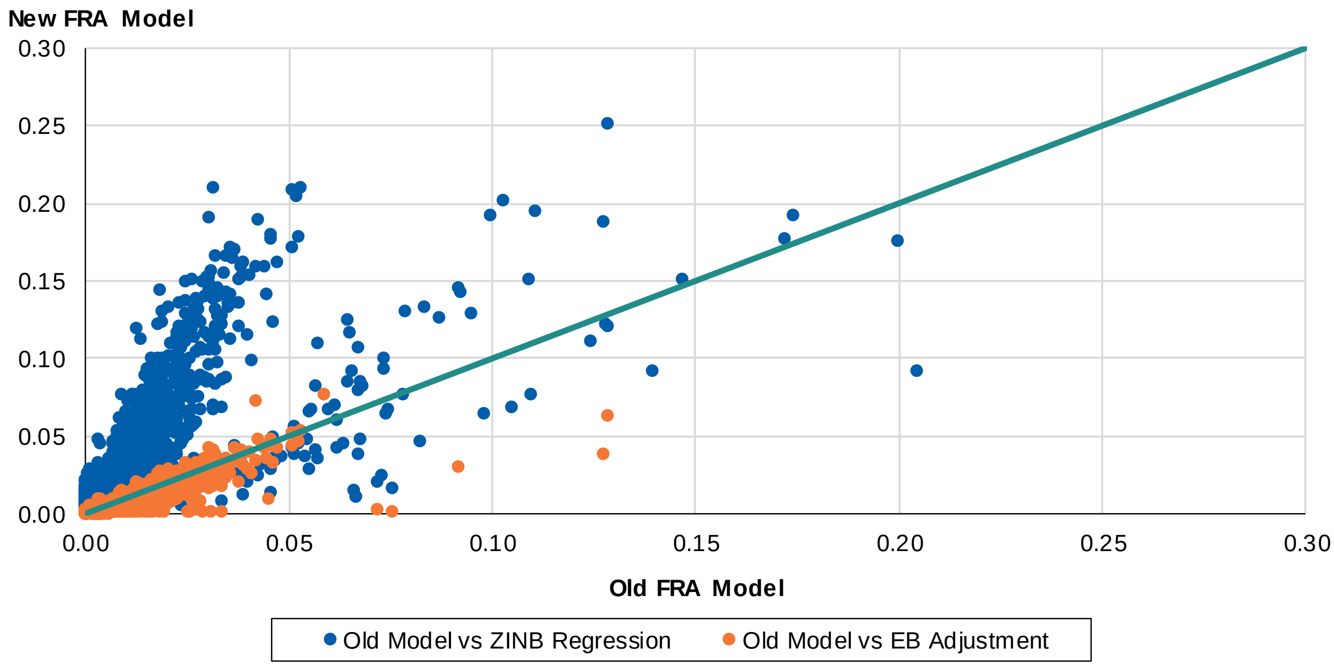
- Subscript k: indicates accident type: fatal = 1, injury = 2, PDO = 3
- Subscript i: indicates a grade crossing
- Subscript j: indicates the explanatory variable to which the β element corresponds (0 to 4)
- X_i: vector of crossing traits that explain accident severity
- Y_i: variable indicating accident type (fatal, injury or PDO)

- $\beta's$: vectors of coefficient estimates
- β_{2j}: coefficient estimate vector for the probability of injury accident relative to fatal
- β_{3j}: coefficient estimate vector for the probability of PDO accident relative to fatal

A.2 COMPARISON OF FRA MODELS

The updated 2020 FRA accident prediction model and severity model were both investigated to determine how the new probability calculations relate to the old FRA model. As previously mentioned in this report, the new FRA model is composed of the ZINB regression and EB adjustment. Plotting these two models against the old FRA model allows for a comparison to be drawn between the calculations for the probability and costs associated with collisions at crossings. Figure 26 shows the relationship between the old FRA model and the updated 2020 FRA accident prediction model. The dark blue represents the ZINB regression component of the new FRA model against the old FRA model. Similarly, the orange dots show the EB adjustment of the 2020 accident prediction model against the old FRA model. This report uses the EB adjustment of the 2020 accident prediction model to calculate the predicted number of collisions at crossings. Based on the results, the new FRA model has a lower collision probability outcome than the old FRA accident prediction model.

Figure 26 Old v New Accident Prediction Model



Although the probability calculations from the updated 2020 FRA accident prediction model are lower than the old FRA model, the outcome of these collisions are more severe in the new model. The new FRA model shows a higher fatality and injury probability calculation than the old FRA model. This observation is represented in Figure 27 and Figure 28.

Figure 27 Old vs New FRA Model Fatality Probability

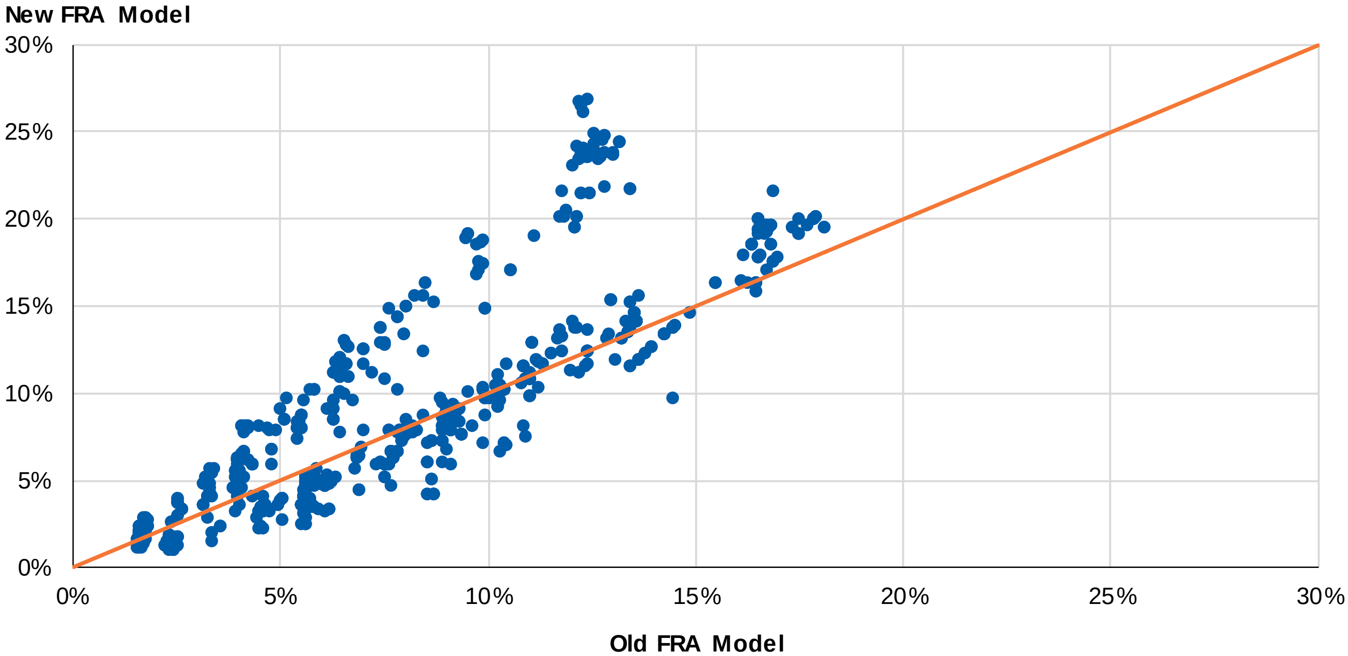
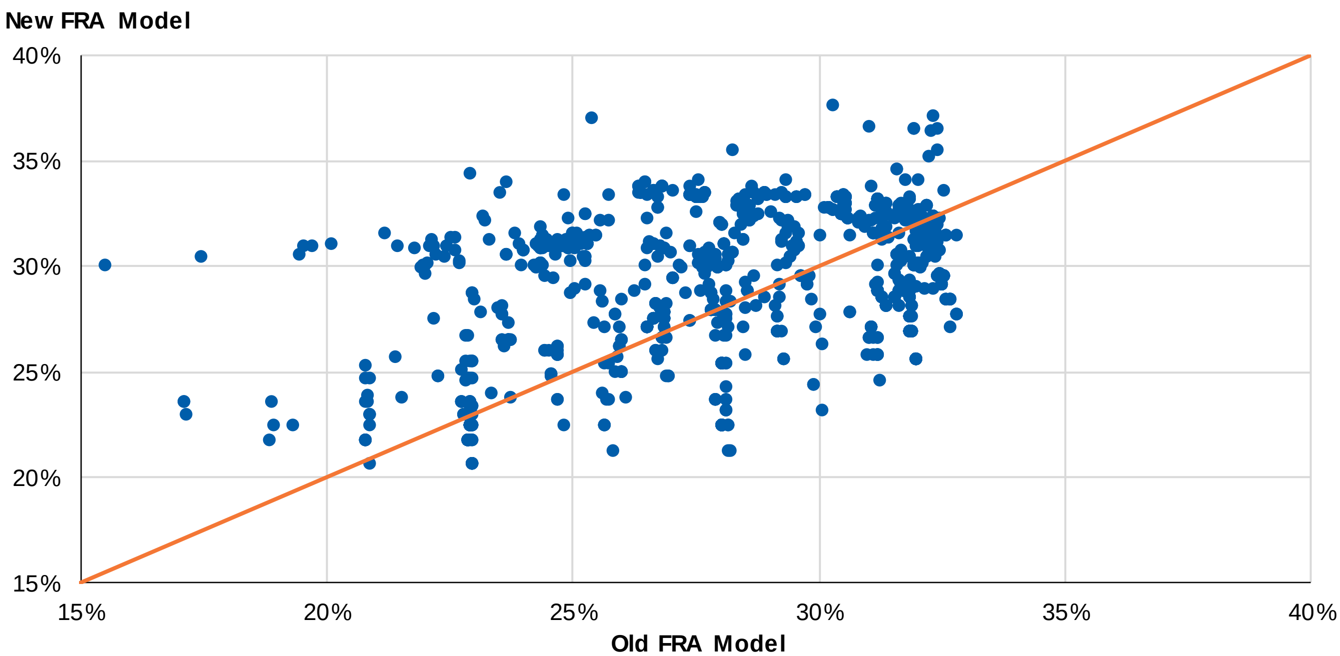


Figure 28 Old vs New FRA Model Injury Probability



A.3 SUPPLY CHAIN COSTS

Insert queries used to determine the value per ton for trucks and dollar per ton of rail, multiple modes, and mail.

Truck Supply Chain Costs

- Value per ton (truck, adjusted for inflation) = $619
- Tons per Truck = 23
- Average Truck Value = [tons] * [value per ton] = 23 * 619 = $14,454
- Average Supply Chain Cost per Truck per Hour = 11,107 * 0.4% = $58

Rail Supply Chain Costs

- Carloads: 28,656,263
- Tons: 1,968,597,676
- Tons/Carload = 69
- Dollar per ton of rail, and multiple mode and mail (2017—adjusted for inflation) = $572
- Average Railcar Value = [tons] * [value per ton] = 69 * $572 = $39,262
- Average Rail Supply Chain Cost per Rail Car per Hour = 39,262 * 0.4% = $157
- Average Rail Supply Chain Cost per Train per Hour = 157 * 43 = $6,828