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REDUCING CATASTROPHIC CRASHES ON I-81 IN VIRGINIA

Applied Policy Project

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I-81 CORRIDOR COALITION

UVA | FRANK BATTEN SCHOOL of LEADERSHIP and PUBLIC POLICY

Client Overview

This research was compiled and prepared for the I-81 Corridor Coalition. Their mission is to improve the safety and efficiency of freight and passenger movement. This will allow lives to be saved, costs to be reduced, and economic development opportunities to be expanded.

Disclaimer

The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy, University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author, and are not necessarily endorsed by the Batten School, by the University of Virginia, or by any other agency.

Honor Statement

On my honor as a student, I have neither given nor received unauthorized aid on this assignment.

Acknowledgements

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Executive Summary

Over the past few years, I-81 in Virginia has averaged around 45 catastrophic crashes per year.[1] Catastrophic crashes are incidents that result in four or more hours of non-recurring congestion.[2] These crashes, often caused by semi-trucks, have the potential to completely shutter a major interstate highway for hours on end, or at least reduce its capacity and draw traffic to a slower pace.[3] Significant investments of time and money have been allocated to I-81 by state and federal officials, yet there is no singular plan that seeks to directly address the causes and repercussions of catastrophic crashes.[4]

In addition to the direct costs imposed on those who are involved in such crashes there are also costs borne by a larger segment of the population. Commuters and truckers may be backed up in traffic for hours on end, leading to losses to Virginia's economy and lack of payment for truck drivers. Idling or slow-moving vehicles stuck in traffic lead to increased carbon emissions along I-81. The Commonwealth of Virginia is tasked with maintenance and upkeep on the road and must also respond and refund tow-truck drivers when such crashes occur. Additionally, highway improvements aimed at I-81 have cost hundreds of millions of dollars.[5]

Differing strategies have been used to address recurring congestion and lack of capacity on highways, but no single study or plan was readily available that attempted to address the prevention of catastrophic crashes, or how to respond to the subsequent nonrecurring congestion as a result. This analysis will attempt to do just that by proposing the following alternatives:

1. Instituting peak load pricing to raise revenues for improvement
2. Implementing toll/high-occupancy vehicle lanes in strategic places to expand capacity and allow for an extra lane for passage
3. Formulation of autonomous partnerships between Virginia, vehicle manufacturers, and trucking companies
4. Continuation of the I-81 Corridor Improvement Program

Additionally, each alternative will be weighed against the following criteria:

[1] VDOT, "I-81 Corridor Improvement Plan."
[2] FHWA, "Reducing Non-Recurring Congestion."
[3] Ibid.
[4] OIPI, "I-81 Corridor Improvement Plan Executive Summary
[5] Adams, "Where's All That Interstate 81 Money Going."

1. Cost-effectiveness
2. Equity
3. Political Feasibility
4. Ability to Implement

This analysis suggests that a continuation of the I-81 Corridor Improvement Program implemented in 2019 scores the highest when weighed against all four criteria. This alternative, upon which this analysis relies on the Virginia Department of Transportation's own projections, is the most likely to reduce the number of catastrophic crashes in a feasible way. I am also recommending that the state explore the alternative of autonomous partnerships further, as this analysis shows that it holds the most potential to reduce crashes caused by things like distracted driving and drowsy driving.

Problem Statement

There are too many catastrophic crashes on I-81 in Virginia. Catastrophic crashes will be defined as crashes that take four or more hours to completely clear and impact traffic and cause congestion for that same period. In the period leading up to 2018, there were an average of 45 of these crashes each year on I-81 in Virginia.[6] These types of crashes often block both lanes of traffic in both directions, snarling traffic and leading to hours-long delays which can leave drivers and truckers stuck along the highway.[7] These delays are classified as non-recurring, and account for over 50% of total delays on I-81.[8] This is compared to all other interstates in Virginia, where major incidents only account for about 16% of all delays.[9] Many of these crashes often involve tractor trailers, imposing dangerous conditions for the passenger vehicles also involved in the crashes and creating economic losses due to delays or loss of product.[10] These catastrophic crashes also lead to environmental costs imposed by stalled traffic, additional wear and tear on the vehicles that are stuck in the resulting congestion, infrastructure costs on the impacted roadway, and require resources to respond to and clear the crash site.

Programs and policies are underway to address larger issues related to I-81 in Virginia, including the I-81 Improvement Program.[11] Yet there has not been a strategic plan put forward to directly address catastrophic crashes and the resulting costs. Preventative steps to reduce catastrophic crashes, as well as policies and engineering solutions aimed at reducing delay times when crashes occur, may have benefits to the state of Virginia, residents of the state, and Virginia businesses that utilize he highway for shipping and transportation needs.

Profile of I-81 in Virginia

The preponderance of catastrophic crashes on I-81in Virginia is a major public policy problem. While there are natural barriers that require significant engineering of I-81 in Virginia, significant investments have been made to attempt to minimize these dangers.[12] I-81 serves as a north-south backbone of the nation's freight economy, shipping goods from manufacturing centers in the south, southern ports, and Mexico to urban centers in the northeast like Boston,

[6] Ibid.
[7] Guerry, "Crashed Cleared on I-81 in Roanoke County."
[8] Ibid.
[9] Ibid.
[10] FMCSA, "Large Truck and Bus Crash Facts 2018."
[11] I-81 Improvement Program
[12] Ibid.

New York, and Washington DC.[13] Areas along I-81 have also seen an expansion of distribution centers and warehouses over the past few years, as seen in figure 1 below.[14] Finally, the Virginia Inland Port serves as an important shipping center for Virginia along I-81. It operates by having trucks bring their loads to its location by the intersection of I-81 and I-66 in northwest Virginia, putting the loads on trains and hauled to terminals in the Hampton Roads area. It operates as a multimodal transfer facility for inbound freight as well, as it is offloaded at its location and trucks picks up the loads and bring them elsewhere along the I-81 corridor.[15]

The Virginia Department of Transportation (VDOT) has taken steps to expand capacity and increase safety, with more than 60 program improvements either recently completed, ongoing, or planned in the next ten years.[16] However, it has not yet addressed catastrophic crashes from a policy perspective and has not instituted a plan to alleviate the burdens of catastrophic crashes on commuters and truck drivers.

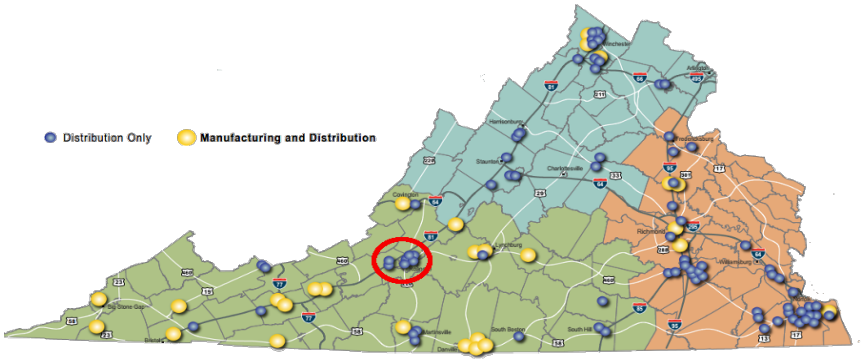

Figure 1: Map of manufacturing and distribution centers in Virginia as of 2021. I-81 runs through the southwest part of the state to Roanoke (circled in Red) and up to the Virginia Inland Port in the north (Virginia Economic Development Partnership.)

Costs to Society

There are too many catastrophic crashes on I-81 in Virginia. This simple problem leads to several direct costs on people who use the highway, externalities that affect people in the Commonwealth and beyond, and opportunity costs which are born by society. A key direct cost to consider are crashes because of too many cars. Highways with increased congestion see a higher occurrence of crashes.[17] There are over 2,000 reported crashes a year on I-81 in

[13] Beyer, What Virginia's I-81 Says About the Future of U.S. Freight
[14] Ribbon Cut on New Amazon Distribution Facility in Bristol, Va.
[15] Hampton Roads TPO. "Traffic Impact of an Inland port in Hampton Roads.
[16] VDOT, "Corridor Overview."
[17] Retallack and Ostendorf, "Current Understanding of the Effects of Congestion on Traffic Accidents."

Virginia.[18] Additionally, the average collision claim in 2018 was $3,574.[19] This means the direct costs per year for damage to vehicles alone is about $7 million. In addition to damage to vehicles, injury and death must also be priced. A 2010 study showed that an average of 25 people were killed and 1,100 were injured in crashes on I-81 in Virginia per year.[20] Considering that the National Safety Council (NSC) reports that the average economic cost of a death is $1.7 million, the total economic costs from deaths on I-81 per year are over $42 million.[21] In the same report they find that the average economic cost to an evident injury is $28,500. With 1,100 injuries per year, the economic cost from this would be over $31 million annually.

While catastrophic crashes occur only forty-five times a year and severely harm a limited number of truckers and drivers, their effects impact thousands who may be backed up miles on the highway for hours on end. Lost time for long-haul drivers and commuters alike lead to significant inefficiencies, with the Virginia economy losing up to $1,200 for every minute that drivers are stuck in traffic.[22] Combining this number with the four hours that traffic is typically impacted from a catastrophic crash, and the roughly 45 catastrophic crashes that happen each year, Virginia's economy misses out on almost $13 million per year. Another direct cost that all drivers will take on from this added congestion is increased wear & tear. The UK Department for Transport has found that wear & tear increases in congestion due to increased braking and acceleration that happens in slower moving traffic.[23]

Another cost is maintenance and cleanup. Repaving damaged roadways, fixing broken barriers, cleaning up spilled loads is not cheap, and with I-81 being about 325 miles long and serving as the longest highway in the state, it requires a serious financial undertaking to keep it up to speed. In 2000, it cost about $2.1 million per lane mile to repave a rural concrete highway and about $2.7 million per lane mile to repave a concrete urban highway.[24] These numbers may work their way to upwards of $20 million per lane mile in 2022 dollars along portions of the highway in more rural, mountainous terrain. Increased traffic and busier roads also lead to quicker decline of the condition of the highway and a more frequent schedule of repaving, which will lead to a steeper price tag over time.[25]

[18] Slack, "Vdot's I-81 Operational Improvements Receive National Recognition for Operations Excellence."
[19] Insurance Injury Institute, "Facts + Statistics: Auto Insurance."
[20] Sturgeon, "I-81: How Real Is the Fear?"
[21] National Safety Council, "Guide to Calculating Costs - Data Details."
[22] Thomas, "VDOT Launches Program to Speed up Clearance of Crashes on I-81."
[23] UK Department of Transport, "An introduction to the Department for Transport's congestion statistics."
[24] VDOT, "State of Virginia Department of Transportation Report of Roadway Values."
[25] Herbert, Rowland, and Grubic Inc., "Can You Stop the Effects of Real-Time Traffic Navigation Apps on Local Roadways?"

In addition to direct costs, externalities exist because of too many cars being on I-81 in Virginia. Key among these are CO2 emissions. Looking at trucks specifically, there were about 1.239 billion truck vehicle miles traveled in 2018.[26] Couple this with the Environmental Defense Fund's estimate that the average freight truck in the US emits 161.8 grams of CO2 per ton mile, then in the average year, there are 214,025 tons of CO2 emitted on I-81 alone .[27] With the Biden Administration pricing CO2 at $51 a ton, for a final total cost of CO2 emission on I-81 per year, by trucks alone, at about $10.9 million. Adding passenger vehicle carbon emissions to this, especially on such a congested highway, will likely send the number significantly higher. While this is not directly correlated with catastrophic crashes, preventing crashes, and allowing for traffic to pass quicker when they do occur will keep cars and trucks moving and reduce time spent idling or taking an alternate route.

Another direct cost is maintenance and cleanup. Repaving damaged roadways, fixing broken barriers, cleaning up spilled loads is not cheap, and with I-81 being about 325 miles long and serving as the longest highway in the state, it requires a serious financial undertaking to keep it up to speed. In 2000, it cost about $2.1 million per lane mile to repave a rural concrete highway and about $2.7 million per lane mile to repave a concrete urban highway.[28] Increased traffic and busier roads also lead to quicker decline of the condition of the highway and a more frequent schedule of repaving, which will lead to a steeper price tag over time.[29]

Finally, there are opportunity costs to drivers suffering from congestion because of too many catastrophic crashes happening on I-81. An obvious opportunity cost in this situation is lost production. Time stuck in traffic is time that is not spent in the office or at the worksite. Additionally, time behind the wheel is time not spent on a laptop or working out a business problem. It is estimated that Virginia's economy takes a hit of up to $1,200 for every minute that drivers are stuck in traffic.[30] Knowing that there has been an average of 45 such crashes in the past few years, and that each of these constitute four or more hours of delay, Virginia's economy stands to lose $13 million annually as a result of the congestion from crashes. This also does not consider on lost wages for truck drivers who are left idling in cases of a complete shutdown of the highway and a resulting standstill. Each of these have intangible costs for society and for their own well-being and the well-being of those around them.

[26] Donohue, "81 Corridor Update."
[27] Mathers, "Green Freight Math: How to Calculate Emissions for a Truck Move."
[28] VDOT, "State of Virginia Department of Transportation Report of Roadway Values."
[29] Herbert, Rowland, and Grubic Inc., "Can You Stop the Effects of Real-Time Traffic Navigation Apps on Local Roadways?"
[30] Slack, "VDOT Launches Towing and Recovery Incentive Program on Interstate 81 Corridor

Governance and Funding

As with any interstate highway, it is crucial to analyze the governance and funding sources to see what may be done. I-81 is governed similarly to other state highways in Virginia, but the funding resources vary.

Governance

The Federal Aid Highway Act became law in 1956 to establish the interstate highway system.[31] Growing public pressure for better transportation, increased needs for housing, and President Eisenhower's impression of the German highway system led to widespread support for this act which has become the largest engineering project in US history.[32] This act also set up the Highway Trust Fund, a source of funding for the state governments to maintain and enhance their interstates.[33] This trust fund pays out 90 percent of its amount each year to states based on funding formulas.[34] I-81 became one of the first highways to be opened on the east coast. Like all other interstate highways in the US, it is today owned and operated by the state department of transportation.

As my focus is specifically on Virginia, the state agency with jurisdiction is VDOT. Specific to I-81, many of the recent efforts to improve capacity and raise funds are a result of the 2019 Acts of Assembly 846.[35] This act amended § 58.1-2299.20 and 58.1-2701, which deal with the collection of special taxes and how those taxes are distributed, respectively.[3637] It also is made possible by the Virginia Fuels Tax Act of 2000.[38] This act by the Virginia General Assembly and signed by the Governor established the Interstate 81 Corridor Improvement Program and the Interstate 81 Corridor Improvement Fund. This fund is made possible by additional tax levies in the planning districts in which I-81 runs through. It is overseen by the Commonwealth Transportation Board, with advice and recommendations from an I-81 Advisory Committee made up of delegates, senators, and planning district commission representatives.[39] The improvement program is administered through VDOT by a program delivery director who oversees strategies, projects, and initiatives. [40] The US Department of Transportation (DOT)

[31] USDOT, "Federal-Aid Highway Act of 1956: Creating The Interstate System."
[32] Lacy, "Dwight D. Eisenhower and the Birth of the Interstate Highway System."
[33] USDOT, "The Highway Trust Fund - Policy | Federal Highway Administration."
[34] Kile, "Testimony on Addressing the Long-Term Solvency of the Highway Trust Fund | Congressional Budget Office."
[35] Ibid.
[36] VLI, "§ 58.1-2299.20."
[37] VLI, "§ 58.1-2701."
[38] Ibid.
[39] Ibid.
[40] LeGrand, "VDOT Announces New Interstate 81 Program Delivery Director."

and the Secretary of Transportation also have powers which can have an impact on the future of I-81. In addition to the highway trust fund, DOT also awards and administers several federal grants which I-81 improvements may qualify for.[41] In Maryland, local groups have been applying to increase I-81 to three lanes under the Infrastructure for Rebuilding America Grant Program.[42] These grants receive final approval from the Secretary of Transportation.

Funding

Source	Gasoline	Diesel
Federal	$0.1840	$0.2440[43]
Virginia	$0.2620	$0.2700[44]
I-81	$0.0687	$0.0789[45]

Figure 2: Gas tax per gallon of fuel. I-81 numbers calculated based on average price of gas and diesel in Staunton, VA on 02/08/2022.

While I-81 was built by the federal government through the Federal Aid Highway Act of 1956, it today is maintained, operated, and largely funded by the Virginia Department of Transportation.[46] VDOT also raises additional funds like the regional fuel tax and fees on trucks. This helps supplement the funding for the Interstate Operations and Enhancement Program for I-81.[47] Before the Infrastructure Investment and Jobs Act of 2021 was signed into law, which included reauthorization of the Fixing America's Surface Transportation (FAST) Act, FAST was last reauthorized in 2015.[48] Under this, Virginia received about $5.4 billion dollars in federal funds for its highways from the Federal Highway Administration.[49] In addition, the Infrastructure Investment and Jobs Act is expected to increase the proportion of highway funds while also creating new dollars for special projects to improve portions of I-81.[50]

The regional fuel tax, although new, has already started to bring in revenue to fund improvements already in progress on I-81. In FY 2020, even as the last third of the fiscal year was impacted by COVID-19 and it' associated stay-at-home orders, the tax brought in $69.8 million, which was about $15 million over the projected revenue for the tax at the beginning of

[41] USDOT, "Grants | US Department of Transportation."
[42] Lewis, "Another Swing, Another Miss for a Grant to Widen I-81. What Happens Next?"
[43] Ibid.
[44] Ibid.
[45] Ibid.
[46] VDOT, "I-81 History."
[47] Mannell, "PERFORMANCE DRIVEN: Virginia Takes Innovative Approach to Transportation Problem-Solving
[48] USDOT, "The Fixing America's Surface transportation Act or 'FAST' Act'"
[49] USDOT, "FAST Act | Funding | Federal Highway Administration."
[50] Weir, "Warner: Infrastructure Act Mean I-81 Funds, Broadband Expansion."

the year.[51] This is brought on by a 2.1% increase on each gallon of fuel relative to the statewide average distributor price as a result of the 2019 Acts of Assembly 846. The rate from February 2022 can be seen in figure 2 above. The recent increase in oil prices, and subsequently fuel prices, as well as price increases as a lingering effect of the Colonial Pipeline cyber-attack in May 2021 will also lead to a larger windfall for the I-81 improvement program in the next fiscal year.[52] This presumes no implementation of a gas tax holiday, which has been floated in the spring months of 2022 in response to record-level fuel prices per gallon.[53]

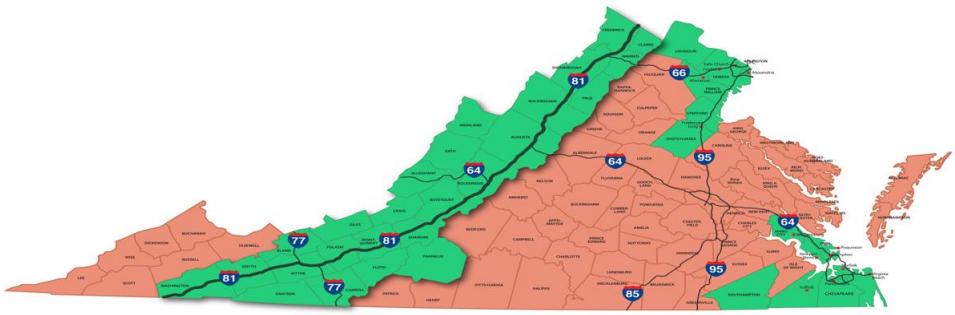

Figure 3: Map depicting counties with regional gas taxes in Virginia. The I-81 gas tax is displayed in green along the Western part of the state (Bristol Herald Courier.)

Attempting to compare I-81 in Virginia to other examples is difficult in that no two stretches of highway have similar characteristics and complexities. Simultaneously, it also offers an advantage that other policy problems do not possess, because I-81 is a national network of physically connected roadways that share the common trait for being the north-south backbone of the nation's trucking economy. Other states have not been immune to the spate of crashes involving semis that Virginia has fallen victim to, nor the ensuing backups and delays as a result.[54] In August 2021, a crash in Martinsburg, WV shut down all northbound lanes and parts of southbound lanes for seven hours, while in July of 2020 there were five crashes involving semis that shut down I-81 in a single ten-mile stretch in one day.[55] [56]

[51] Munro, "Changes Made to I-81 Gas Tax."
[52] Thomas, "AAA: Relief Coming for Virginia Drivers with Restart of Colonial Pipeline; Gas Prices Up."
[53] Burns, "Virginia Lawmakers Return Special Session, Youngkin Pushes Gas Tax Holiday Plan."
[54] Hollis, "As many as 27 trucks in bizarre string of I-81 accidents."
[55] Rhodes, "Two Drivers Hurt in Fiery Crash That Shut down I-81 North in Berkeley County."
[56] Ibid.

Variables that May Affect Analysis

Change in Contributing Factors

The I-81 Corridor Improvement Plan Executive Summary identifies four main contributing causes to the delays in clearance times: rolling terrain, lack of capacity, inadequacy of detour routes, and constrained configuration.[57] VDOT has invested money through the I-81 improvement program to add additional climbing lanes, increase capacity in key areas of the highway, and shore up existing detour routes.[58] There are additional factors which have not yet been analyzed on I-81 in Virginia that have impacted highways in other places which could contribute to crashes and delays in greater numbers in the future. One of these is climate change. A study published in 2021 details how climate variables can significantly affect the frequency of fatal traffic crashes.[59] Another is a shortage of tow truck drivers and emergency response and clearance units. VDOT launched the Towing and Recovery Incentive Program in 2021 to attempt to speed up clearance time, but an ending of the program or shortage of personnel can erase any gains made.[60]

Electric Vehicles

There are rapidly advancing technologies which may play a drastic role in affecting my analysis. A key one in transportation is the emergence of electric and vehicles. About 2.5% of all new vehicle registrations in the first half of 2021 were fully electric vehicles.[61] This still pales in comparison to gasoline-powered vehicles, but electric has been claiming a larger market share, with the number of electric vehicle registrations in the first half of 2021 more than doubling the registrations during the same period in 2020, and more than quadrupling the number from the first and second quarter of 2017. This is important because an important source of income for the I-81 improvement program is the regional fuels tax on gasoline collected in planning districts in which the highway runs through. This may pose a larger problem when electric semis begin becoming available on the market. Both Tesla and Freightliner are planning to begin rollout of their electric semis in 2022.[62]

[57] Ibid.
[58] Ibid.
[59] Zou, "Exploring the Impact of Climate and Extreme Weather on Fatal Traffic Accidents."
[60] Boyer, "New Towing and Recovery Incentive Program Offered along Interstate 81 Corridor to Clear Commercial Crashes More Quickly."
[61] Miller, "While EV Registrations Grow Through the First Half Of 2021, Non-Electric Remains Dominant."
[62] Vaughn, "Yes, Electric Big Rigs Are Coming—and We Drive Four of Them"

Autonomous Vehicles

Another technological change which could change the course of transportation infrastructure is self-driving, or autonomous, vehicles. These allow for the passenger to let technology take full control and eliminates user-error. Autonomous vehicles like those made by Tesla are already in a wide Beta test on city streets around the world, and many other manufacturers are racing to catch up.[63] Engineers do not predict that many people will still be able to afford autonomous vehicles within the next ten years, but they do foresee businesses, rideshares, and commercial sectors being able to buy into the market.[64] Regardless, infrastructure projects take years to plan and build, and what happens ten years or 20 years must be considered today.

The shift to autonomous vehicles must be considered for the impacts it will have on human capital, the value of time, and safety on the roadway. This development could reduce or eliminate driver-caused semi crashes, which account for eight of the top ten factors in large truck crashes.[65] Autonomous vehicles may also lead to redirected resources by the trucking industry who will no longer have to pay drivers, significantly reduce drivers needed, or in times of extreme demand, expand their operations and grow their revenue. Finally, autonomous vehicles may one day have the capacities to simply pick up and drop off passengers or goods, eliminating the need for some people to get onto I-81. This may increase congestion by people willing to send their car out more often for trips they previously would not want to take themselves. Since they are not the ones stuck in traffic, they plan ahead and send the car out early, and avoiding paying for a toll or express lane. The same may be true for autonomous trucks, leaving middle and lower-income drivers with more autonomous vehicles in the main lanes, with only a paid express lane as a potential option to avoid congestion.

Advanced Technology

The final change that may come along and make my analysis obsolete is a sudden advancement in technology that impacts transportation, traffic movement, and tracking of vehicles. Police in Florida have started using drones to assess traffic crashes as well as to manage large events.[66] They have stressed, however, that drones will not be used to monitor active traffic and issue citations. This is largely true in other states, but has not held true in Canada, where police have started using drones to issue citations and identify vehicles to be

[63] Templeton, "Tesla's 'Full Self-Driving' Is 99.9% There, Just 1,000 Times Further To Go."
[64] Cusack, "How Driverless Cars Will Change Our World"
[65] USDOT, "The Large Truck Crash Causation Study - Analysis Brief."
[66] Sachs, "Florida Police, Fire Can Use Drones to Watch Crowds, but Not to Issue Traffic Tickets."

impounded.[67] Another emerging technology which would alter traffic on I-81 and this analysis is intelligent speed assistance, or ISA. With ISA, sensors and cameras in vehicles identify street signs and uses various methods to slow speeding drivers, such as vibrations, audible warnings, a reduction in engine power, and a less reactive accelerator pedal.[68] This technology will be mandatory on new models of cars sold in the EU from 2022 onwards.[69] Finally, an increase in public-private partnerships to privately finance enhancements to I-81 will lead to logistical challenges and questions about already existing programs.[70] Impacted programs could include the Interstate 81 Corridor Improvement Fund, the Towing and Incentive Recovery Program, and the regional gas tax. Finally, satellite tracking has started to emerge as a feasible resource for states to monitor and enforce traffic patterns. Evolving technologies have allowed the tracking of a vehicles' trajectory and velocity can be tracked relative to traffic patterns.[71] Some states have even started inserting GPS devices in state owned vehicles so their performance can be tracked by satellites, but this has received pushback from state employee unions.[72]

[67] CTV News Vancouver, "Police Use Drone to Crack down on Speed Racing, Catch Driver Doing Nearly Twice the Limit."
[68] Streeter, "Europe Is A Year Away From Mandating Speed-Limiting Car Features."
[69] ETSC, "Intelligent Speed Assistance (ISA)."
[70] Mallett, "Public-Private Partnerships (P3s) in Transportation."
[71] Ahmadi et. al "Moving Vehicle Detection, Tracking and Traffic Parameter Estimation from a Satellite Video: A Perspective on a Smarter City."
[72] Besthoff, "Safety, Savings & Surveillance? State Labor Unions Concerned About Vehicle Tracking."

Existing Evidence & Alternatives

There is a dearth of comprehensive analyses of catastrophic crashes, the root causes that lead them to be catastrophic crashes, or the effects they have on commerce, the environment, or safety. However, my proposed alternatives have been implemented, proposed, studied, or had variations implemented or proposed elsewhere. My four proposed alternatives are peak load pricing mechanisms to help fund expansions and additional projects on areas of I-81 with high rates of catastrophic crashes, instituting express lanes/toll lanes on areas of I-81 with high rates of catastrophic crashes, a state-carrier partnership to invest in autonomous vehicles, a continuation of the ongoing I-81 Corridor Improvement Plan. I will weigh these against each other and against maintaining the status quo of current projects, taxes, and programs overseen by VDOT.

Peak Load Pricing

Peak load pricing involves charging an increased rate on vehicles traveling a given roadway based on the time of day and the size of the vehicle. Vehicles attempting to use a roadway during peak hours would be charged more than those that traverse it during night or slower hours during the day. Likewise, large vehicles like semi-trucks would be charged more for usage than personal vehicles. The benefits to this may be twofold. First, it provides a revenue stream for roadway enhancements, improvements, or expansions aimed at minimizing the number of catastrophic crashes. Additionally, it may motivate trucking companies to change their routes to the nighttime to save money by avoiding peak hours. This allows freer roadways for truck drivers to navigate during the night, while allowing for a smoother commute with fewer delays for commuters during the day. These changes in routes may be especially beneficial to I-81, where there is currently the highest percentage of crashes involving heavy trucks.[73]

A version of this already exists in Northern Virginia with HOT Lanes.[74] These charge drivers in single-occupancy vehicles during peak traffic hours. Many of these types of projects have been built through public-private partnerships. One segment of these lanes on I-95 and I-395 raised about $58 million in revenue in the second half of 2019.[75] These profits often go back to the private companies that helped finance, design, and build such roadways, but revenue returning to VDOT can be used to expand roadways and enhance I-81 to make it less prone to

[73] Ibid.
[74] Goffman, "What Is Congestion Pricing?"
[75] Poole, "Opinion | Maryland Chose the Right Model for Its Express Lanes Project."

catastrophic crashes. Because this has already been implemented elsewhere in the Commonwealth, this alternative is proven and could be implemented without significant delays. It also is an option which can be placed along the segments of I-81 with the highest catastrophic crash rates and can be turned off or altered. While heavily utilized in transportation, similar concepts are used at ski resorts, restaurant happy hours, and entertainment complexes.[76] Again, this could serve as a funding mechanism for an extra lane on I-81 to allow for better flow in times of non-recurring delay because of catastrophic crashes.

Toll and Express Lanes

Toll lanes and express lanes have become a common way to expand highways without increasing the cost to taxpayers or the state. The cost is passed on to users who are willing to pay the fee and access an additional lane. I-495 in Northern Virginia utilizes a public-private partnership in which private equity finances an express lane, reaps the revenue from it, and also bears the cost if few people use it.[77] Typically these are built to alleviate congestion and provide a smoother commute in fast growing areas with heavy highway usage like suburbs.[7879] They have also been built already with this in mind on small sections of I-81 in southwestern Virginia, and paid for in bonds, in order for trucks to more easily climb and descend the steep grades and allow traffic to pass in the other two lanes.[80]

This alternative, however, would seek to add a third lane in each direction in areas that have experienced a high catastrophic crash rate to allow for easier passage of trucks and vehicles past the crash site during cleanup, and as a result, a reduction in congestion and wait times behind the crash. Even when one lane is blocked on I-81, there is a 65% reduction in capacity.[81] Similar to peak load pricing options, this alternative already exists elsewhere in Virginia, utilizes public-private partnerships, reaps revenues that can be reinvested into the roadway, and can be scaled up or scaled down with existing technology. Additionally, an additional third lane paid for by tolls may be opened to all users of the highway in cases where the other two lanes may be fully or partially blocked due to a catastrophic crash.

Autonomous Partnerships

[76] ibid.
[77] Ibid.
[78] Lazo, "I-66 Express Lanes Are Two Years Away. Northern Virginia Commuters Are Seeing the Changes."
[79] Palmer, "Overland Park Approves Adding Toll Lanes to FlaU.S. Highway 69. What Happens Next?"
[80] Ibid.
[81] Ibid.

Another alternative I plan on introducing is a state-carrier partnership for autonomous semis in Virginia. As mentioned earlier, autonomous vehicles are still in their early stages, and it could be years before there is wide adoption among the trucking industry.[82] Even when the industry begins converting, there will likely be significant concerns surrounding the elimination of middle-class jobs and new technologies being proven in real-world environments. Virginia must tackle these issues while also ensuring that it does not invest heavily in a partnership that will impose significant upfront costs while only reaping benefits equal to those of surrounding states that did not form partnerships. One solution to this would be the establishment of one of the nation's first autonomous transfer hubs. Autonomous transfer hubs are dedicated areas where trucks are driven to by humans from origin point to have their loads switched over to an autonomous semi and carried to another transfer hub.[83] A study has shown that this type of network would save carriers up to 40% in operational costs, while eliminating the driver errors that account for eight out of the ten leading causes of semi crashes.[8485]

Transfer hub partnerships have already been agreed to and construction has started on such facilities in places like California and Texas, respectively.[8687] The opportunity exists for Virginia to capitalize on these initial gains while proactively seeking to reduce catastrophic crashes on I-81. Such a network may be built from Bristol in the Southwest of Virginia to the Virginia Inland Port in the north. These facilities and corridors may present numerous benefits to drivers, industry, the state, and consumers. For Virginia based truckers, elimination of jobs may be at a minimum because loads would still need to be transported around the state to the facilities in the north and the south. The industry would benefit by having trucks that could operate almost continuously, 24/7, maximizing uptime and minimizing operational costs per mile.[88] The state may benefit from investment by such companies into the facilities, bringing additional jobs to Bristol and to the Virginia Inland Port. It also would eliminate the user-error which leads to catastrophic crashes that require state resources to clear and cost residents of Virginia hours in congestion and lost productivity. Finally, consumers may benefit from lower operational costs and the efficiency of continuously operating loads, which could lead to savings being passed on to them.

Continuation of Current Policies

[82] Ibid.
[83] Ibid.
[84] Ryder, "Ryder Teams Up with Georgia Tech for Industry's First Data-Driven Study on Impact of Autonomous Trucking."
[85] Ibid.
[86] Forde, "Embark to Open Freight Transfer Hubs in Los Angeles, Phoenix."
[87] Goodwin, "Waymo Via Building Autonomous Trucking Hub in Dallas-Fort Worth."
[88] Ibid.

My final alternative is a simple continuation of the I-81 Corridor Improvement Plan. While there is no evidence that the existing regional fuels tax and vehicle fees has reduced traffic, it will provide about $2 billion over the next ten years to fund programs to expand capacity in critical areas to mitigate nonrecurring delays. An continuation of the current program may be used to fund an additional lane in each direction on I-81 in areas that experience a high occurrence of catastrophic crashes. The current tax under the 2019 Virginia Acts of Assembly 846 are 2.03 percent of the statewide average wholesale price of a gallon of diesel fuel for diesel vehicles such as semis, and 2.1 percent of the statewide average distributor price of a gallon of unleaded regular gasoline for vehicles like a standard passenger vehicle.[89] The additional vehicle registration fees apply to vehicles not designed or used for transportation of passengers, and are applied per 1,000 pounds, at an increasing scale depending on the weight of the vehicle. This ranges from $6 per thousand pounds for vehicles weighing up to 15,000 pounds to $23.25 per thousand pounds for vehicles over 40,000 pounds.[90] These taxing mechanisms are estimated to bring in about $2 billion in revenue over the next ten years.[91]

Increases of regional fuel taxes and vehicle registration fees elsewhere going forward may be compared against the initial implementation on the I-81 corridor in Virginia in 2019. Efforts to double the vehicle registration fee have also recently been undertaken in Pennsylvania, which I-81 runs through on its way to its terminus in upstate New York.[92] This proposal received immediate pushback from carriers who are threatening to register their vehicles in other states as a result. The proposal varies in that it is coupled with other revenue-generating proposals such as electric car fees and an increased sales tax on car sales. It also is proposed as a replacement of a statewide gas tax that the Governor of Pennsylvania intends to cut. This is in line with Virginia's Governor-elect who has promised to cut the gas tax.[93] One risk of this is the International Fuels Tax Agreement. Under this, carriers register and pay fuel taxes in each state through the single state the carrier is based in.[94] If Virginia's prices on gas and registration begin sharply increasing, carriers based in the state may look to move elsewhere, leading to a possible net loss in revenue and a loss in innovation inside the Commonwealth.

[89] Ibid.
[90] Ibid.
[91] Ibid.
[92] Murphy, "Pennsylvania Truckers Object to Proposed Doubling of Registration Fee."
[93] Ibid.
[94] Virginia DMV, "International Fuels Tax Agreement."

Criteria

Cost-Effectiveness

Cost effectiveness is the net present value of future costs over the number of projected catastrophic crashes. This analysis projects a 3 percent discount rate. The cost effectiveness of each alternative will be weighed against one another. I plan on utilizing a heavy weight of 30% for this criterion, as infrastructure projects can get very expensive and there are measurable benefits to the reduction of congestion, CO2, property damage and loss of life that would accompany the reduction of catastrophic crashes on I-81. While there is significant research that has been devoted to this alternative in this paper, this section also has the largest number of assumptions. Not all statistics on emissions, government costs, and other costs are up-to-date, and varying studies show different projections on costs and crash statistics that directly impact costs.

Equity

Infrastructure projects in the US have a long history of both intentionally and unintentionally imparting inequities on historically marginalized groups.[95] This certainly must be considered for any changes to I-81, particularly for changes with the aim of saving money, time, and lives. This criterion will only be weighed at 5% but still requires significant time and attention. One measure will be how additional HOT lanes or toll lanes will disproportionately impact working class people who utilize the roadway to get to work or go about their business. It will also attempt to measure the impact of these lanes on the non-toll lanes, as people may not be able to regularly afford the tolls or to drive them at peak times, and how increased or decreased congestion on them impacts people. I will also analyze how the current gas tax for I-81 has impacted people and how moving to an autonomous partnership may affect working people. There also exists the opportunity to analyze how carbon emissions related to changes on I-81 may disproportionately impact people more susceptible to climate change and pollution.

Political Feasibility

There are several decision makers involved with any significant changes to I-81. This includes the Governor, the Secretary of Transportation, the Virginia General Assembly. It also includes the Commonwealth Transportation Board and the I-81 Advisory Committee. Private sector interests also play a significant role, and as such, carriers and trucking associations must be

[95] King, Noel. "A Brief History Of How Racism Shaped Interstate Highways."

considered. Significant emphasis has been placed on I-81 in the last few years in the Virginia transportation sector. As a result, previous attempts to improve I-81 and policy positions of the current and former administration will be considered. This criterion will be critical to the initiation and completion of the chosen alternative. This will receive a significant weight of 30% to it because of the sheer number of stakeholders who have an interest in seeing my alternatives implemented or blocked. This will include government officials, advocacy organizations, local and interstate business interests, interests of residents along the I-81 corridor, and more. This measure will be more qualitative and less quantitative than the last two, however, it will be pertinent to compile statistics of how similar projects have been approved or defeated by stakeholder groups in Virginia, elsewhere in the US, and any other countries with similar relevant projects. There is already significant evidence of how this will apply to scaling up current policies, as there are numerous articles and reactions to the implementation of the current I-81 program in 2019. Different stakeholders are also likely to have increased levels of investment in certain alternatives. It is likely that carriers will be heavily interested in the autonomous partnerships but will not pay as much attention to the addition of a toll lane on a certain stretch of I-81.

Ability to Implement

This will receive the most significant weight of 35%. Infrastructure in the US are costly, time consuming, and technologically challenging, and the weight of this criteria will reflect that. Continuing the current I-81 Improvement Program will likely be easy to implement, as it would primarily require only a continuation by the general assembly and support from VDOT and the rest of the executive branch. Perhaps the most challenging part of this alternative is where increased revenue should be reinvested in the highway program. Congestion pricing and toll lanes will be somewhere in the middle, as these have been implemented elsewhere in Virginia, but mostly in urban areas with not as much geographical diversity. I will look to challenges with implementing elsewhere in Virginia as well as rural highways elsewhere in the country. Autonomous trucking partnerships will likely be the most challenging to implement, as autonomous trucks have not hit US roadways in any commercially significant way.[96] There are major opportunities on this front, but major barriers that must be accounted for. I will attempt to measure the costs of implementing the infrastructure necessary for autonomous trucking options, as well as regulations and other hurdles that must be settled for this alternative to be viable.

[96] Ibid.

Cost-Effectiveness

Infrastructure projects and maintenance in the US is notoriously expensive and hard to cost out.[97] The following is no different, due to varying datasets on vehicle miles traveled (VMT), average load size on semis, average delay for a single driver because of a crash, differing estimates of roadway construction, differing predictions and long-term trends on consumer preferences and truck traffic, and more. This section will make several assumptions and will attempt to identify and utilize values that are towards the median of estimates publicly available for the data points listed above. I am still weighing this criterion at 30% because of the unique nature of infrastructure. It requires capital investment, regular maintenance, and stable funding sources to serve the scores of people who utilize it daily. Please see the appendix for calculations of costs, VMT, NPV, and cost-effectiveness.

I am only weighing this section at 20%. It is important to recognize that many of these programs carry benefits beyond reducing catastrophic crashes, such as an additional lane that can be opened to allow traffic to flow easier in times of backup from a catastrophic crash.

Baseline Outcome Projection

1.144 billion VMT by trucks on average from 2010-2020. The number of VMT increased by about 13.754 million on average. Over the 11-year period from 2010-2020, including the base year of 2018 there was an average of 1 catastrophic crash for every 25.436 million VMT. By projecting the total number of VMT on I-81 to 2035, while still projecting 1 catastrophic crash for every 25.436VMT, this analysis estimates there to be an increase to almost 57 catastrophic crashes in that year.

Alternative Outcome Projection

Alternative 1: Peak load pricing – Peak load pricing is aimed at reacting and responding to many of the problems caused by catastrophic crashes, such as lane closures and congestion. There is limited research on the effect of peak load pricing on crashes. One study from 2009 analyzed the Stockholm congestion charging system It found a 3.6% reduction in the number of traffic crashes.[98] While this number includes all vehicles on all roadway types, I will assume this 3.6% number holds constant to our example of I-81. This would lead to 55 catastrophic crashes in 2035, a minimal reduction from the baseline.

[97] Vartabedian, "Years of Delays, Billions in Overruns: The Dismal History of Big Infrastructure."
[98] Singichetti, "Congestion Pricing Policies and Safety Implications: A Scoping Review."

Alternative 2: Toll and express lanes – Evidence from a study conducted of Texas's freeway system shows that crash frequencies increased at an average of 11 percent when highways were reconfigured to include an HOV lane.[99] While the research team did not attempt to explain the increase in crashes, and while there are significant differences between the urban highways around the Dallas area and I-81, the study is the most comprehensive I have seen in relation to impact of toll/HOV lanes on crashes. Assuming the 11 percent number holds true for I-81, this would lead to 73 crashes in 2035, substantially more than the 57 projected at baseline.

Alternative 3: Autonomous vehicles – Autonomous partnerships would take significant time to implement and have never been envisioned at the scale proposed. However, they are hypothesized in my APP to be the most preventative option to reduce the number of catastrophic crashes. Approximately 55% of truck crashes in Virginia in 2017 were caused by some type of user error.[100] Assuming full implementation of autonomous trucks over the time horizon, as well as the complete elimination of user-error as a result of full automation, there would only be 24 catastrophic crashes in 2035. This is well-below half of the projected number of catastrophic crashes projected out to 2035. However, the slow rollout and implementation of autonomous vehicles, the continuation of human rolling stock, and human error from passenger vehicles leading to mishaps and crashes involving semis renders the 55% reduction highly unlikely. Assuming that 5% of trucks on I-81 in Virginia are autonomous by 2025, 20% are autonomous by 2030, and 50% are autonomous by 2035, and assuming that replacing human drivers will eliminate half of all human-error caused crashes (27.5% of total crashes) there would be just 28 catastrophic crashes in 2035.

Alternative 4: I-81 Corridor Improvement Project – The current I-81 improvement program is expected to lead to 450 fewer crashes per year out of about 2,200 (VDOT, 2020.) This is a 20.45% reduction. Assuming that these are spread out among all vehicle types, and impacts catastrophic crashes equally, the number of catastrophic crashes, on average, will be reduced from 45 to a floor of about 43 crashes per year in 2030, when the current ten year improvement plan is completed. This is compared to 54 crashes per year if the current trends were to persist. If this 20% number continues with future trends, there would be 45 catastrophic crashes in 2035, the same as there were in the base period.

Cost of status quo in base year 2018.

[99] Cooner & Ranft, "Safety Evaluation of Buffer-Separated High-Occupancy Vehicle Lanes in Texas."
[100] Ibid.

The I-81 Corridor Improvement Project had not yet been implemented. As noted earlier in the analysis, the total cost of lost productivity is $13 million. $360,000 was spent on towing and recovery cleanup. The estimated emissions costs were $43,605. While there are likely significant additional costs that cannot be accounted for in this analysis, the preliminary baseline costs is $13,403,605.

Cost projected out to 2035

I tied the initial figure above to my projected growth in crashes in the baseline and alternative outcome projection. Detailed analysis may be found in the appendix. It is also crucial to note that the first expenditures from the I-81 Corridor Improvement program were paid out in 2020. In 2035, without any alternative policies or the I-81 Corridor Improvement Plan, costs associated with affects from catastrophic crashes and the response to them would total $17,736,915.74. This is up over 32% from base levels in 2018. This also presumes 5% inflation, which infrastructure projects often experience, and which is below current inflation levels.[101]

Cost of all alternatives over time horizon

This is another section where I am making assumptions and further data is needed, particularly from engineers. A congestion pricing network will require about $765 million of capital over the time horizon in order to build roadway (about $10 million a mile on average), establish and prove technologies, and ensure maintenance and enforcement of the system. Toll lanes come in as the cheapest over the time horizon. It will also need to be funded at about $10 million per mile, but expertise and technology has already been established elsewhere on Virginia interstates and much of that experience can be transferred to I-81. The cost ends up being just under $570 million. The autonomous partnership comes in at $1.28 billion. The reason for this being that thousands of trucks will need to be purchased to fulfill the goal of having about half the rolling stock being autonomous by 2035. Additionally, major infrastructure and technological hurdles exist that will require R+D and tech innovations. Finally, VDOT projects the I-81 Corridor project to accumulate $2.6 billion in costs between 2021 and 2035.[102] It is worth noting that this is paid for through the gas tax, vehicle fees, bonds, and other revenue streams for the state. The autonomous partnership would likely be a public-private partnership with industry and carriers taking on significant upfront costs. The toll and congestion plans would both have drivers paying fees to pay for the system, like HOV lanes in Northern Virginia

[101] Day, "Infrastructure Prices Rises to Exceed Inflation, Peaking in 2022."
[102] Ibid.

that bring in tens of millions of dollars a quarter.[103] Adding the status quo would add $17,736,915.74 to each estimate

Cost effectiveness measure

While these alternatives have large sticker prices, it is again worth emphasizing that three of them are projected to pay for themselves, and that they each benefit people in ways beyond preventing catastrophic crashes. Costs associated with catastrophic crashes are also likely underestimated. Despite this, calculating cost effectiveness will help paint a clearer picture of what investment is having the most impact on catastrophic crashes. This will be done by dividing the total discounted horizon cost by the total difference between projected crashes under the status quo in in each year until 2035 and projected crashes each year under the alternative under the alternative.

Alternative 1: Congestion pricing – $555,621,112.33 / 28.58 = $19,440,906.66

Alternative 2: Toll lanes – $415,370,397.89 / -87.33 = $ (4,756,303.06)

Alternative 3: Autonomous vehicles – $729,612,512.22 / 80.75 = $9,035,597.83

Alternative 4: I-81 Corridor Improvement Project – $1,841,167,442.53 / 115.81 = $15,898,858.37

In this method, the most to least cost-effective alternatives, regarding catastrophic crashes, is autonomous vehicles, then the I-81 plan, then congestion pricing, and then toll lanes.

[103] Ibid.

Equity

As this report mentions previously, infrastructure projects in the US have a long history of both intentionally and unintentionally imparting inequities on historically marginalized groups. [104] Even though this criterion is only being weighed at 5%, it is critical that any proposed alternative must be implemented with the interests of all stakeholders in mind, and that past indiscretions in designing the nation's highway system be accounted for when designing and implementing an alternative.

Peak Load Pricing

The evidence on this front is mixed. On one hand, congestion pricing can be used to compensate any poor drivers being harmed.[105] Revenues can be redistributed towards new programs, whereas roadways without pricing generate no revenue to redistribute. However, such programs are outside the scope of this project. Rather, it is important to look at drivers who regularly commute through I-81 to reach work. Such fees may impose a burden on people attempting to reach their job at a manufacturing facility or distribution center. Additionally, in places where peak load pricing is only used for an optional lane, roughly half of people using it are not regular commuters, but people who use the roadway once a week or less.[106] This argues that if people have the choice, they will not take it.

Toll and Express Lanes

Toll and express lanes are somewhat like peak load pricing in that it charges users to drive a certain stretch of highway. It differs in two key reasons. First, this analysis is projecting toll lanes to only occupy a new, single lane of the highway, as opposed to charging all drivers for using the roadway. Additionally, this analysis projects it as a set fare, as opposed to peak load pricing which may fluctuate based on time, load size, and amount of congestion. This alternative does give drivers a free option, but it may continue to have disproportionate impacts on people who are not willing or able to pay for the toll lane. Traffic may still be slowed or cluttered by commuters and truckers unwilling or unable to pay to use the toll lane. Analysis from SR-91 and I-15 in California show mixed results in income-levels' willingness to use tollways.[107] What is

[104] Ibid.
[105] Manville & Goldman, "Would Congestion Pricing Harm the Poor? Do Free Roads Help the Poor?"
[106] FHWA, "Income-Based Equity Impacts of Congestion Pricing—A Primer."
[107] FHWA, "Low-Income Equity Concerns of U.S. Road Pricing Initiatives."

undeniable is that, on roadways without mass transit, lower-income people will spend a bigger portion of their take-home income on accessing a toll lane.[108]

Autonomous Partnerships

This analysis projects this alternative to have the least detrimental impact on lower-income Virginians who use I-81. Through this proposal, the State of Virginia would enter partnerships with truck manufacturers and shipping companies to advance the rollout of autonomous vehicles along I-81. There would be no direct cost burden on the regular I-81 commuter, nor any immediate costs on truck drivers using the roadway. Furthermore, there may be opportunities for lower-income Virginians to benefit from a growing economy that may result from the projected reduction in catastrophic crashes, and an increase in commerce with driver shortage being filled by autonomous vehicles.[109]

Continuation of Current Policies

The I-81 Corridor Improvement Program was passed by the general assembly in 2019 and has a number of funding mechanisms to pay for an estimated $2 billion worth of improvements for a decade timespan. Two key ones mentioned earlier are vehicle registration fee increases borne by trucking companies for their vehicles using I-81 and an additional regional gas tax in the counties that sit in planning districts that I-81 runs through.[110] The gas tax is most relevant to this criteria, and much evidence points to the conclusion that a gas tax acts similarly to a sales tax in that it is regressive and disproportionately impacts lower-income people.[111] Furthermore, higher income households are increasingly likely to own electric vehicles that escape these additional taxes, as the electric vehicle market is still fairly unregulated with respect to special taxes.[112] [113] Despite this, there is so far no evidence that the gas tax along I-81 has limited traffic or priced anyone off the road. Additionally, it still allows for all lanes to be free of charge to drivers, unlike peak load pricing and the toll lane option.

[108] Plotnick, et. Al. "The Impacts of Tolling on Low Income Persons in the Puget Sound Region."
[109] Brereton, "Are Autonomous Trucks a Long-Term Solution to Driver Shortages?"
[110] Ibid.
[111] Sawhill, "How Higher Gas Prices Hurt Less Affluent Consumers and the Economy."
[112] Baxandall, "The Pros and Cons of Higher Gas Taxes, and How They Could be Offset for Lower-Income Families."
[113] Morris, "Electric Vehicles Will Need New Taxation or Governments Will Lose Billions."

Political Feasibility

Proposed alternative programs and policies are of little value if there is no political will or likelihood of initiating the project. This is particularly true of public works projects; the legislative and executive branch of Virginia government would have to support proposals for them to come to fruition. That is why I am weighing this alternative at 35%. Even the best plans with broad support may see disagreement over contracts, timing, and priorities, and key power players in Virginia in government, industry, and advocacy may be capable of blocking a proposal at any turn, making it vital that the chose alternative is politically viable and popular.

Peak Load Pricing

In this section peak load pricing and toll lanes will heavily overlap in their similarity of charging drivers to use the roadway and using revenues to fund improvements and expand the highway to three lanes in key areas to allow for reduced congestion during the cleanup of catastrophic crashes. In 2019, a universal toll was proposed to be levied against class 6 vehicles and larger using I-81.[114] This proposal drew the ire of the powerful American trucking Association. Eventually, this proposal was stripped as a funding mechanism for the already authorized I-81 Corridor Improvement Plan, and the regional gas tax was passed by the general assembly. Attempting to institute this alternative again, on top of the regional gas tax, would likely lead to fierce opposition from trucking associations again, as well as small trucking companies based in Virginia, as was the case when the idea of tolls was first proposed in 2018.[115]

Toll and Express Lanes

Like congestion pricing, toll lanes would charge drivers for active highway usage. The proposals to fund the authorized I-81 Corridor Improvement Program also included a plan to build a toll lane in many areas requiring annual passes that only commuters in class 5 vehicles and smaller could purchase.[116] Again, trucking associations revolted, arguing that this would have little benefit to the truck traffic that constitutes a significant part of the traffic on I-81.[117] Like peak load pricing, it is unlikely that powerful stakeholders would support this plan.

Autonomous Partnership

[114] Lamb, "Virginia Lawmakers Strike Tolling Plan From I-81 Bills."
[115] Casey, "Small Trucking Companies Worry about the Possibility of I-81 Tolls."
[116] Ibid.
[117] Ibid.

Due to a lack of knowledge on autonomous vehicle pilot programs and the risk, but also potential benefits, associated with being the first to test something on a wide-scale, autonomous partnerships are hard to predict political feasibility on. As mentioned earlier, benefits to such a program could be transfer hubs, hi-tech manufacturing and repair centers, jobs, increased safety, and more efficient transportation of goods.[118] However, the trucking industry may be skeptical of further development.[119] Furthermore, area residents and regular commuters may pause at the idea of the highway they regularly use being some kind of proving ground for an emerging technology. This is another area where conflicts may arise between stakeholders attempting to steer contracts and benefits to their chosen vendor and could lead to tension or even a failure to act between the general assembly and the executive branch of Virginia.

Continuation of Current Policies

A continuation of the I-81 Corridor Improvement Plan would likely be the most politically feasible option. The program has been in place for over two years and has already resulted in over $100 million in revenue raised for projects and shovels hitting dirt.[120] This policy was a compromise after lawmakers in Richmond could not come to agreement over toll lanes or vehicle pricing mechanisms on trucks. One potential blockade to the continuation of this program, or at least a blockade preventing it from reaching its revenue and spending targets, are pauses and reductions of the gas tax.[121] Otherwise, this is a policy with broad support from Democrats and Republicans, and a trucking industry that accepted it as a compromise in the place of other options that are proposed in this report.[122]

[118] Ibid.
[119] Can a Self-Driving 40-Ton Truck Be Safe? Developers Say Yes but Others Are Skeptical."
[120] VDOT, "I-81 Project Update, Series 2021 Authorization."
[121] Beals, "Youngkin Pushes for Temporary Pause on State Gas Tax."
[122] Ibid.

Ability to Implement

Ability to implement will carry the heaviest weight in this analysis at 40%. This is due to the complex, arduous, and time-consuming process that infrastructure projects often go through from the first shovel hitting the dirt to the ribbon cutting. Even then, funds must be established for maintenance and management. The following alternatives will be judged on whether or not similar programs already exist, and if so, if their knowledge and tech can easily be transferred to I-81.

Peak Load Pricing

Peak load pricing has been implemented in other countries, and elsewhere in the US in individual lanes, but never has it been adopted across all lanes on an interstate highway.[123] In addition to the likely disagreement with this plan from commuters and truckers alike, the Virginia Department of Transportation would have to make significant investments in the technology to charge tens of thousands of vehicles a day a fee to use I-81. It would need increased enforcement mechanisms as well, and it would likely be years before enough funds were raised so that shovel meets dirt. The state may enter into agreements with private partners or consulting firms to provide expertise, but that runs into disagreements and competition that this analysis has looked at earlier. Additionally, any failure in this high-tech system would lead to automatic revenue loss, as the state cannot shut down a highway to all traffic until a component is fixed.

Toll and Express Lanes

These lanes are much more common than congestion lanes, and multiple examples already exist within Virginia. I-95, I-395, and I-495 in Northern Virginia have high occupancy vehicle (HOV) lanes while sections I-66 in Northern Virginia have express lanes that charge tolls on users wishing to use them during rush hour.[124] These were largely built using public-private partnerships, with the private entities receiving the revenues to renovate and fund their additional lanes.[125] Virginia has experience with this alternative, but exclusively in a single urban center. VDOT would need to work with private partners to translate the technology to a more rural setting.

[123] Plitt, "NYC Poised to Implement the Country's First Congestion Pricing Program."
[124] VDOT, "High Occupancy Vehicle Systems."
[125] Ibid.

Autonomous Partnership

Autonomous trucks are still not fully viable. They have been introduced in test phases and trails, but self-driving big-rigs have not yet hit the interstate highway system en masse.[126] Even if the technology were to be developed at a more rapid pace, there is still a dearth of regulations and standards for self-driving cars, let alone self-driving 30-ton trucks.[127] By establishing a pilot program, Virginia will be forced the lead the country in rolling out autonomous vehicles and developing first-of-its-kind regulatory frameworks. The challenge would be daunting, but the opportunities for commerce and economic development are enormous.

Continuation of Current Policies

The continuation of the I-81 Corridor Improvement Program would require no additional steps for implementation, as much of the funding has already reached state coffers and projects are either underway or planned for the near future.[128] As the timeframe for the improvement plan stretches to 2038, it goes well beyond the 2035 goal that this analysis is looking at. However, a renewed focus must be put on preventing and responding to catastrophic crashes.

[126] Rosevear, "Aurora and Werner Enterprises Are Testing Self-Driving Tractor-Trailers on a Lonely Texas Highway."
[127] Furchgott, "Public Streets Are the Lab for Self-Driving Experiments."
[128] VCTB, "Interstate 81 Corridor Improvement Plan."

Outcomes Matrix

For my outcomes matrix, cost effectiveness will be weighed at 20%, equity will be weighed at 5%, political feasibility will account for 35% of the overall score, and ability to be implemented will be the most significant at 40%. I will assign a score of 1 for an alternative with low outcomes, two for medium, and three for a positive projected outcome.

	Cost Effectiveness (20%)	Equity (5%)	Political Feasibility (35%)	Ability to Implement (40%)	Cumulative Score
Peak Load Pricing	Medium ($19.441 million)	Low	Low	Low	1.2
Toll/Express Lanes	Low (-$4.756 million)	Low	Low	Medium	1.4
Autonomous Partnership	High ($9.036 million)	High	Medium	Low	1.85
Continuation of I-81 Corridor Improvement Plan	Medium ($15.899 million)	Medium	High	High	2.75

Figure 4: Decision Matrix

Out of a possible score of 3, the following alternatives are listed in order from highest to lowest total score:

1. Continuation of I-81 Corridor Improvement Plan
2. Autonomous Partnership
3. Toll/Express Lanes
4. Peak Load Pricing

Recommendation

My recommendation to the client is to continue advocating for and ensuring a strong I-81 Corridor Improvement Program. This option performed the best in the ability to implement and the political feasibility criteria, while still being somewhat cost-effective and a solution that promotes equity more than other alternative policies that have been proposed in the past to pay for I-81 improvements. With it already being law because of the 2019 Acts of Assembly 846, members of the I-81 Corridor Coalition, and particularly those in Virginia, may work with VDOT and those in charge of delivering the program to ensure that it is implemented fairly across the state with benefits being wide ranging. Most importantly, this analysis shows that it can play a crucial role in reducing catastrophic crashes along I-81 and the associated costs on society that are tied to catastrophic crashes.

In addition to working to strengthen the current policy in place, I also recommend furthering relationship with stakeholders on the issues of autonomous vehicles. While the ability to implement is low and the technology is not viable yet, it has the potential to dramatically reduce catastrophic crashes by eliminating or greatly reducing crashes caused by distraction or other forms of human error. It has the potential to be attractive to government officials, trucking associations, and industry, and, through the analysis of this report, appears to have the least harmful impact on lower-income drivers using I-81. Finally, the opportunities for commerce and economic development are tremendous. Concerns about I-81 being treated as a proving ground are valid, but western Virginia has the potential to be a hub of business and industry if it were to partner with carriers and truck manufacturers to mutually benefit one another.

Implementation

The recommendations of this analysis are to continue working with stakeholders in Virginia to ensure a successful and impactful I-81 Corridor Improvement Program. There are no legislative maneuvers necessary to promote passage or change of legislation since the I-81 Corridor program was authorized and appropriated in 2019. However, it is overseen by the Commonwealth Transportation Board (CTB), who is responsible for several transportation projects and initiatives in Virginia. Other people in the Virginia transportation sphere oversee implementation such as I-81 Program Delivery Director Dave Covington. Additionally, the I-81 Advisory Committee, comprised of area leaders, makes recommendations to the CTB on how to further develop the I-81 corridor. Since the program is already implemented, those groups have the greatest say over how and where money is spent.

The autonomous trucking pilot program is a near opposite from the I-81 Corridor Improvement Program in that it has not been proposed, introduced, debated, or funded at any level in Virginia government, nor at any other statewide level. Stakeholders from all corners of Virginia will have to come together to collaborate to paint a clearer vision of how each of their needs may push this venture forward. VDOT may do this by applying for competitive grant funding with CTB. The US Department of Transportation (USDOT) has a competitive grant program that was funded at $60 million in 2019 aimed at projects exploring automated driving systems.[129] This is a good start, but the size of the projected partnership is much larger. Trucking organizations like the American Trucking Association, trucking companies like UPS and Schneider, as well as industry leaders such as Amazon.

VDOT already employs a connected and automated vehicles program to guide the department in the deployment and sustainment of automated technologies and initiatives, but investments in the program must be increased to meet the size and scope of the proposed pilot program. It must also strengthen its relationship with research partners like the Virginia Tech Transportation Institute to expand programs like the Virginia Connected Corridors program.[130] Their ongoing work may be used to supplement to major increases investment shared by public and private partners.

[129] USDOT, "U.S. Secretary of Transportation Announces Automated Driving System Demonstration Grant Winners."
[130] VTTI, "VCC Purpose | Virginia Connected Corridors."

Conclusion

There are too many catastrophic crashes on I-81 in Virginia. Current trends project the catastrophic crash rate to increase from 45 per year to upwards of 60 per years by 2035 without intervention. These catastrophic crashes also lead to environmental and economic losses, as well as costs to Virginia government.

The I-81 Corridor Coalition is in a strong position to work with its' members and other stakeholders to improve the safety and efficiency of freight and passenger movement. By doing this, it may save lives, reduce costs, and allow for greater economic opportunity. The current I-81 Corridor Improvement Plan has proven in its' early years that the funding it is bringing in to initiate new projects has the potential for serious gains. By driving this project forward, as well as working with partners to unlock the major potential that exists in autonomous vehicles, I-81 can become a significantly safer roadway for commuters and truckers and can strengthen its position as a major backbone for economic development along the eastern seaboard.

Appendix

	Current Trajectory		Current I-81 Program	Peak Load Pricing	Tolls/HOV Lanes	Autonomus	Real Assumptions-Autonomus
2021	49.14		48.14	47.37	54.55	22.11	49.14
2022	49.68		47.65	47.89	55.15	22.36	49.68
2023	50.22		47.14	48.42	55.75	22.60	50.22
2024	50.76		46.61	48.94	56.35	22.84	50.21
2025	51.31		46.06	49.46	56.95	23.09	49.89
2026	51.85		45.48	49.98	57.55	23.33	49.56
2027	52.39		44.89	50.50	58.15	23.57	49.22
2028	52.93		44.27	51.02	58.75	23.82	48.85
2029	53.47		43.63	51.54	59.35	24.06	48.47
2030	54.01		42.96	52.06	59.95	24.30	48.07
2031	54.55		43.39	52.59	60.55	24.55	46.75
2032	55.09		43.82	53.11	61.15	24.79	45.39
2033	55.63		44.25	53.63	61.75	25.03	44.00
2034	56.17		44.68	54.15	62.35	25.28	42.58
2035	**56.71**		**45.11**	**54.67**	**62.95**	**25.52**	**41.12**

Catastrophic crashes per year projections, aligned with VMT growth projections, and considering projections of how the alternative will impact crash rates.

Cost of Lost Productivity

$13 million per year at 45 catastrophic crashes

Year		Current Trends	Current I-81 Program	Peak Load Pricing	Toll/HOV Lanes	Autonomus	Real Assumptions-Autonomus
2021		$ 14,906,574.15	$ 14,601,734.71	$ 14,369,937.48	$ 16,546,297.31	$ 6,707,958.37	$ 14,906,574.15
2022		$ 15,070,592.25	$ 14,454,205.02	$ 14,528,050.93	$ 16,728,357.39	$ 6,781,766.51	$ 15,070,592.25
2023		$ 15,234,610.34	$ 14,299,967.00	$ 14,686,164.37	$ 16,910,417.48	$ 6,855,574.65	$ 15,234,610.34
2024		$ 15,398,628.44	$ 14,139,020.63	$ 14,844,277.82	$ 17,092,477.57	$ 6,929,382.80	$ 15,229,243.53
2025		$ 15,562,646.54	$ 13,971,365.93	$ 15,002,391.26	$ 17,274,537.65	$ 7,003,190.94	$ 15,134,673.76
2026		$ 15,726,664.63	$ 13,797,002.88	$ 15,160,504.70	$ 17,456,597.74	$ 7,076,999.08	$ 15,034,691.39
2027		$ 15,890,682.73	$ 13,615,931.50	$ 15,318,618.15	$ 17,638,657.83	$ 7,150,807.23	$ 14,929,296.42
2028		$ 16,054,700.82	$ 13,428,151.77	$ 15,476,731.59	$ 17,820,717.91	$ 7,224,615.37	$ 14,818,488.86
2029		$ 16,218,718.92	$ 13,233,663.70	$ 15,634,845.04	$ 18,002,778.00	$ 7,298,423.51	$ 14,702,268.70
2030		$ 16,382,737.02	$ 13,032,467.30	$ 15,792,958.48	$ 18,184,838.09	$ 7,372,231.66	$ 14,580,635.95
2031		$ 16,546,755.11	$ 13,162,943.69	$ 15,951,071.93	$ 18,366,898.18	$ 7,446,039.80	$ 14,180,569.13
2032		$ 16,710,773.21	$ 13,293,420.09	$ 16,109,185.37	$ 18,548,958.26	$ 7,519,847.94	$ 13,769,677.12
2033		$ 16,874,791.31	$ 13,423,896.48	$ 16,267,298.82	$ 18,731,018.35	$ 7,593,656.09	$ 13,347,959.92
2034		$ 17,038,809.40	$ 13,554,372.88	$ 16,425,412.26	$ 18,913,078.44	$ 7,667,464.23	$ 12,915,417.53
2035		$ 17,202,827.50	$ 13,684,849.28	$ 16,583,525.71	$ 19,095,138.52	$ 7,741,272.37	$ 12,472,049.94
Savings from Current Trend (2035)		**$ -**	**$ 3,517,978.22**	**$ 619,301.79**	**$ (1,892,311.02)**	**$ 9,461,555.12**	**$ 4,730,777.56**
Lost Productuvity in 2018	$ 13,000,000.00						
Catastrophic crashes in 2018	45						
Inflation Assumption	5%						

Difference in lost productivity, tied to projected reduction in catastrophic crashes above, projected to 2035 (Black denotes saving, red denotes increased loss.)

vehicles per accident	5000			
accidents per year	45			
% trucks	30%		truck lbs of co2 idle	16
% cars	70%		car lbs of co2 idle	4
truck co2 lbs total	1080000			
car co2 lbs total	630000			
total co2 lbs base year	1710000		cost per co2 ton (Biden)	51
total tons base year	855			
total cost base year	**$ 43,605.00**			

Cost of CO2 emissions using Biden Administration carbon price of $51 per ton

90 minute cleanup valuation	$3,000
valuation of 4 hour cleanup	$8,000
number of accidents per year	45
total maintenace per year	**$360,000**

Cost of crash cleanup via $2,500 - $3,500 as part of VDOT towing and recovery incentive program

Year	Current Trends	Current I-81 Program	Peak Load Pricing	Toll/HOV Lanes	Autonomus	Real Assumptions-Autonomus
2021	$ 15,369,371.68	$ 15,055,068.03	$ 14,816,074.30	$ 17,060,002.56	$ 6,916,217.25	$ 15,369,371.68
2022	$ 15,538,481.97	$ 14,902,958.06	$ 14,979,096.62	$ 17,247,714.98	$ 6,992,316.89	$ 15,538,481.97
2023	$ 15,707,592.26	$ 14,743,931.47	$ 15,142,118.94	$ 17,435,427.41	$ 7,068,416.52	$ 15,707,592.26
2024	$ 15,876,702.55	$ 14,577,988.28	$ 15,305,141.26	$ 17,623,139.83	$ 7,144,516.15	$ 15,702,058.82
2025	$ 16,045,812.84	$ 14,405,128.48	$ 15,468,163.58	$ 17,810,852.25	$ 7,220,615.78	$ 15,604,552.99
2026	$ 16,214,923.13	$ 14,225,352.06	$ 15,631,185.90	$ 17,998,564.67	$ 7,296,715.41	$ 15,501,466.51
2027	$ 16,384,033.42	$ 14,038,659.04	$ 15,794,208.22	$ 18,186,277.10	$ 7,372,815.04	$ 15,392,799.40
2028	$ 16,553,143.71	$ 13,845,049.40	$ 15,957,230.54	$ 18,373,989.52	$ 7,448,914.67	$ 15,278,551.65
2029	$ 16,722,254.00	$ 13,644,523.15	$ 16,120,252.86	$ 18,561,701.94	$ 7,525,014.30	$ 15,158,723.25
2030	$ 16,891,364.29	$ 13,437,080.29	$ 16,283,275.18	$ 18,749,414.36	$ 7,601,113.93	$ 15,033,314.22
2031	$ 17,060,474.58	$ 13,571,607.53	$ 16,446,297.50	$ 18,937,126.79	$ 7,677,213.56	$ 14,620,826.72
2032	$ 17,229,584.87	$ 13,706,134.77	$ 16,609,319.82	$ 19,124,839.21	$ 7,753,313.19	$ 14,197,177.94
2033	$ 17,398,695.16	$ 13,840,662.00	$ 16,772,342.14	$ 19,312,551.63	$ 7,829,412.82	$ 13,762,367.87
2034	$ 17,567,805.45	$ 13,975,189.24	$ 16,935,364.46	$ 19,500,264.05	$ 7,905,512.45	$ 13,316,396.53
2035	$ 17,736,915.74	$ 14,109,716.47	$ 17,098,386.78	$ 19,687,976.48	$ 7,981,612.08	$ 12,859,263.91

Growth in non-I-81 Corridor Improvement Plan costs to 2035

in millions	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	Total
Operational Improvements	$11	$16	$12	$45	$43	$38	$39	$39	$39	$14	$14	$15	$15	$15	$16	$16	$17	$17	$18	$441
Capital Improvements																				
Rural Projects	$1	$2	$29	$26	$36	$87	$64	$114	$114	$45	$21									$540
Regular Projects	$2	$1	$58	$58	$58	$168	$244	$180	$218	$154	$154	$84	$84	$121	$77	$77	$77	$37	$37	$1,889
sub-total	$3	$3	$87	$85	$95	$255	$308	$294	$333	$199	$175	$84	$84	$121	$77	$77	$77	$37	$37	$2,429
Total	$14	$19	$100	$130	$138	$293	$347	$333	$372	$213	$189	$98	$99	$136	$93	$93	$94	$55	$55	$2,870

* Preliminary and subject to change

Projected Outlays on I-81 Corridor Improvement Plan

	Costs of Alternatives			
	Congestion Pricing	Toll Lanes	Autonomous Partnership	I-81 Corridor
2021	$0	$0	$0	$ 19,000,000.00
2022	$0	$0	$0	$ 100,000,000.00
2023	$50,000,000	$20,000,000	$5,000,000	$ 130,000,000.00
2024	$100,000,000	$50,000,000	$10,000,000	$ 138,000,000.00
2025	$100,000,000	$100,000,000	$15,000,000	$ 293,000,000.00
2026	$150,000,000	$150,000,000	$25,000,000	$ 347,000,000.00
2027	$100,000,000	$100,000,000	$50,000,000	$ 333,000,000.00
2028	$100,000,000	$75,000,000	$75,000,000	$ 372,000,000.00
2029	$75,000,000	$40,000,000	$100,000,000	$ 213,000,000.00
2030	$50,000,000	$15,000,000	$100,000,000	$ 189,000,000.00
2031	$10,000,000	$3,500,000	$150,000,000	$ 98,000,000.00
2032	$7,500,000	$3,605,000.00	$150,000,000	$ 99,000,000.00
2033	$7,725,000.00	$3,713,150.00	$200,000,000	$ 136,000,000.00
2034	$7,956,750.00	$3,824,544.50	$200,000,000	$ 93,000,000.00
2035	$8,195,452.50	$3,939,280.84	$200,000,000	$ 93,000,000.00
	$766,377,203	$568,581,975	$1,280,000,000	$ 2,653,000,000.00

Projected long-term costs of alternatives

	Current I-81 Program	Peak Load Pricing	Tolls/HOV Lanes	Real Assumptions-Autonomus
2021	1.00	1.77	(5.41)	-
2022	2.03	1.79	(5.47)	-
2023	3.08	1.81	(5.52)	-
2024	4.15	1.83	(5.58)	0.56
2025	5.25	1.85	(5.64)	1.41
2026	6.36	1.87	(5.70)	2.28
2027	7.50	1.89	(5.76)	3.17
2028	8.66	1.91	(5.82)	4.08
2029	9.84	1.92	(5.88)	5.00
2030	11.04	1.94	(5.94)	5.94
2031	11.16	1.96	(6.00)	7.80
2032	11.27	1.98	(6.06)	9.70
2033	11.38	2.00	(6.12)	11.63
2034	11.49	2.02	(6.18)	13.59
2035	11.60	2.04	(6.24)	15.60
	115.81	28.58	(87.33)	80.75

Difference between crashes projected in status quo and crashes projected for each alternative for each year, with the total at the bottom

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