DEAD END

POLICY INTERVENTIONS TO CURB PEDESTRIAN DEATH IN VIRGINIA

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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.

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Executive Summary

After decades of gradual decline, pedestrian fatality rates have spiked dramatically in the last 15 years, a trend that is uniquely American in nature. Things are no different in Virginia, where dozens of pedestrians suffer entirely preventable death and serious injury every year. Although the causes of pedestrian death are complex, this report identifies a few key drivers of the problem. Systemic causes include a shift in consumer preferences for taller and heavier vehicles, distracted driving, and lack of sufficient pedestrian infrastructure. However, no two factors are more predictive of pedestrian safety than visibility, which is determined by weather and time of day, and vehicle speed, where the chance of pedestrian death increases exponentially as speed increases.

This report considers a variety of policy options designed to increase pedestrian safety, from technical solutions such as automated emergency braking to more sweeping changes, such as lowering speed limits at night. After considering a wide variety of policy alternatives, I select three to analyze in more depth:

- **Speed cameras**, which will fine vehicles in gross violation of the speed limit. By incentivizing vehicles to slow down, pedestrian crashes will be less likely and less severe.
- **Improved street lighting**, which will increase visibility at night, which is when the vast majority of pedestrian deaths occur. With more well-lit streets, vehicles will be more likely to see pedestrians before it's too late.
- **Leading pedestrian intervals**, which give pedestrians a few-second head start when using a crosswalk before parallel traffic is allowed to turn, reducing the chance of a vehicle colliding with a pedestrian.

After ranking each alternative across the criteria of effectiveness, scope of effectiveness, cost, and feasibility, I ultimately recommend that the Virginia state government implement the speed camera alternative due to its broad scope of effectiveness, clear path toward implementation, and the strong evidence base to support estimates of the policy's effectiveness.

Introduction

As many as 40% of Americans report a fear of flying (De Visé, 2023). Indeed, the precarity of a machine that weighs thousands of pounds flying at high speeds leads one to think about a fiery death, but in reality, driving and walking are far more dangerous – and far more common. Walking is a particularly unique form of transportation in that it's the only transportation mode to experience such a shocking increase in fatality rates over the last 15 years. The built environment of the United States has never been conducive to safe, convenient pedestrian use (McKibben, 2022), but that doesn't mean that pedestrian deaths aren't a solvable problem, or at least a problem that can be significantly mitigated with the right policy tools.

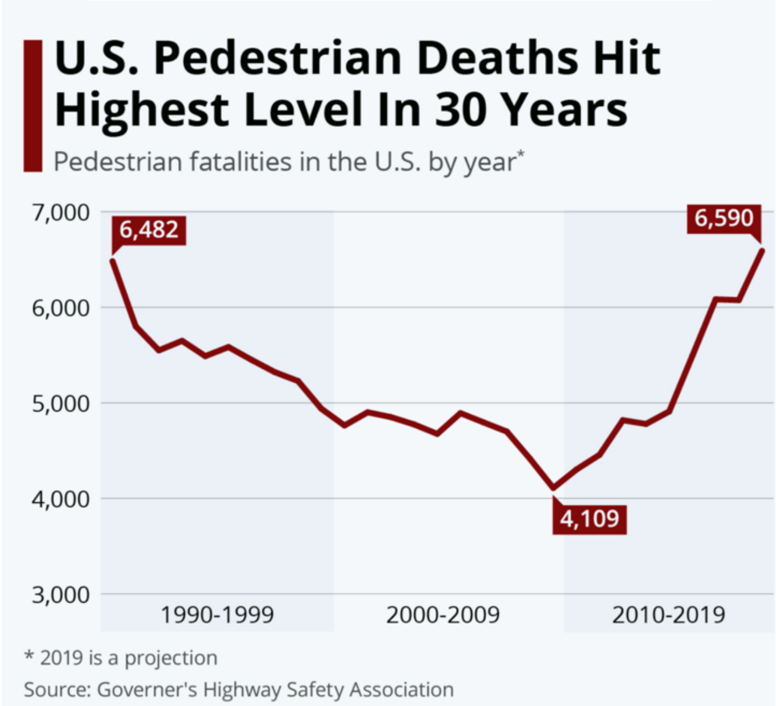
The scope of this investigation into the problem of pedestrian deaths will be confined to Virginia. This choice is made because although pedestrian fatalities have spiked across the country since the late 2000s, pedestrian death rates still vary wildly by state. In addition, because traffic law is generally a state-level affair, many valuable policy alternatives would go unconsidered if this analysis focused on federal government capabilities. This paper will examine the context in which pedestrian deaths have spiked and discuss the literature surrounding potential policy fixes. Next, I will select a few policies to analyze in more depth, ultimately recommending the policy best suited for addressing this public safety issue.

Problem Definition and Orientation

Too many pedestrians are being killed by vehicles in Virginia. Pedestrian fatality rates have been sharply rising in Virginia, jumping 69% from 2012 to 2022 (National Highway Traffic Safety Administration, n.d.). Making Virginia's roads safer for pedestrians will save lives and facilitate more walkable communities.

In concrete terms, 1.99 pedestrians died for every 100,000 people in Virginia as of 2022 (ibid.). The recent increase in pedestrian fatalities is a nationwide phenomenon, with pedestrian deaths rising by 77% from 2010 to 2021 nationwide (Cogan, 2023). In that same period, most OECD countries saw decreases in death rates. In fact, in 1975, the US pedestrian death rate was below that of France, but today, the US pedestrian death rate is more than double that of France’s rate (Freemark, 2022). Clearly, such a sharp increase in pedestrian fatalities is a new and uniquely American problem.

FIGURE 1



Perhaps this problem wouldn’t be so alarming if the rest of the developed world had dramatically reduced their pedestrian fatality rates while US rates remained stagnant, but this isn’t the case. Indeed, for decades, American roads gradually became safer over time. In 1980, 3.6 pedestrians were killed per 100,000 people, but as roads became safer and awareness of the dangers of drunk driving became more widespread, this rate dropped nationwide, reaching a national average of 1.3 deaths per 100,000 people in 2009 (Insurance Institute for Highway Safety, 2022). Since then, however, the rate has increased dramatically, standing at 2.3 deaths per 100,000 people in 2022 (ibid). This trend matches the change in the raw number of pedestrian deaths over time, as illustrated in Figure 1.

The value at issue here is preventing death. Beyond the inherently valuable goal of saving lives, a safer outdoors in Virginia will foster walkable communities, which have a range of environmental and economic benefits (Steuteville, 2021). These concerns are relevant to my client, the Virginia Transit Association (VTA). The VTA is a trade association representing public transit companies in Virginia, advocating on their behalf in Richmond on issues such as safety in public transportation. This report was made for their benefit.

Primary Drivers of Pedestrian Fatalities

Any specific pedestrian crash is caused by a variety of factors, and it's no different with pedestrian fatalities in the aggregate. However, we can identify certain factors that play a larger role in causing fatalities than others. Perhaps the causes that most come to mind when thinking about pedestrian crashes are drunk driving and distracted driving. Interestingly, although drunk drivers certainly still kill pedestrians throughout the nation, drunk driving can be definitively ruled out as a driver of the recent *increase* in pedestrian deaths, as rates of drunk driving fatalities have decreased. Specifically, drunk driving fatalities declined by 35% between 1991 and 2022, and without including the surge in drunk driving fatalities caused by the COVID-19 pandemic, this decrease would be even steeper (Responsibility.org, 2022).

This decrease in drunk driving lies in stark contrast to the increase in distracted driving. Notably, robust data is much more difficult to collect surrounding distracted driving compared to drunk driving because distracted drivers involved in a crash can simply lie to the police, saying they weren't on their phone when they were. Still, existing data indicate a sharp increase in distracted driving around the time that pedestrian fatalities began to increase in frequency. For example, the manipulation of hand-held devices while driving increasing in frequency by 82% from 2013 to 2022 (Injury Facts, n.d.), and just from 2020 to 2022, experts estimate that screen interaction increased by 20% (Marin Cogan, 2024). While it's hard to say definitively due to measurement difficulties, we can conclude that distracted driving is likely a major driver of pedestrian death.

Another cause is the lack of pedestrian infrastructure in Virginia. By pedestrian infrastructure, I'm referring to features such as streetlights, crosswalks, sidewalks, raised medians, and more. A lack of pedestrian infrastructure is a serious problem in Virginia; for example, a lack of sidewalks routinely tops the list of Richmond's biggest transportation complaints (Oliver, 2023). Roads without sidewalks are 67% more likely to experience pedestrian crashes than roads with sidewalks, making it a serious safety concern (Abou-Senna et al., 2022). Similarly, evidence shows that improving crosswalks, such as by making crosswalks more visible or adding technological sophistication, prompt safer behavior from both drivers and pedestrians (Pulugurtha et al., 2012; Sanguino et al., 2024). Despite these facts, many of Virginia's cities still lack crosswalks (Roberts Jr, 2020; Partnership for Smarter Growth, 2024).

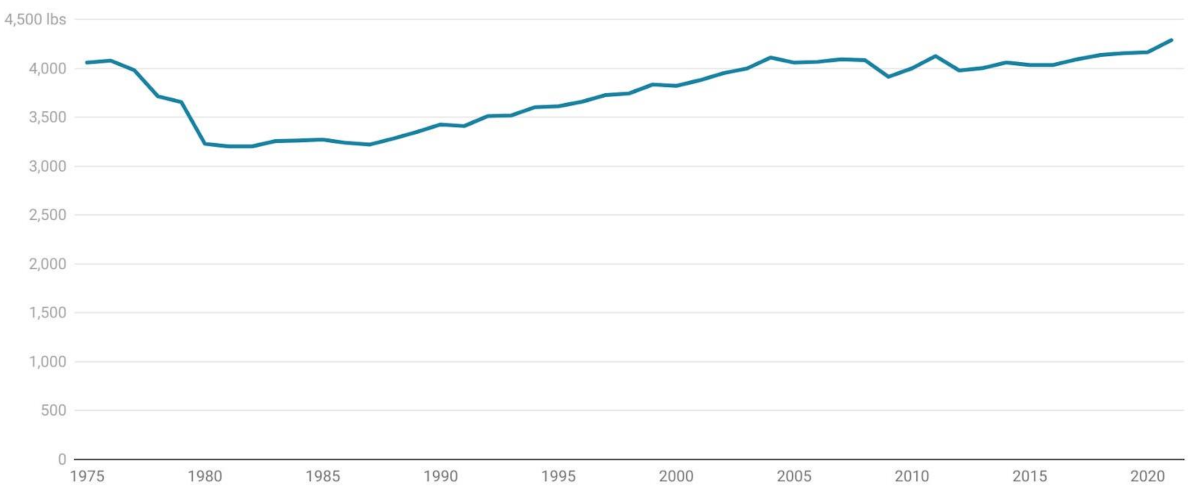
Another cause to consider is the growing consumer preference for larger vehicles. Over the last few decades, American consumers have demonstrated a strong and growing interest in SUVs and light trucks, with interest in sedans declining. Indeed, in 1977, SUVs and light trucks represented just 23% of new car sales in the United States, but by 2021, these larger vehicles made up over 80% of such sales (Zipper, 2023). This trend has caused the average weight of vehicles on US roads to increase by about 1,000 pounds since 1980, as can be seen in Figure 2. Multiple studies have shown a clear link between taller, heavier vehicles and a gre ater risk of a traumatic brain injury or death in the event of an accident (Tyndall, 2024), with some studies going so far as to claim that between 2000 and 2019, more than 8,000 pedestrian deaths would have been averted had all light trucks been replaced with cars in that time period (Tyndall, 2021). The rationale is simple: heavier vehicles impact pedestrians with greater force, and taller vehicle hoods mean that if a pedestrian collision occurs, the vehicle will strike the pedestrian's head and torso rather than their legs.

Distracted driving, poor pedestrian infrastructure, and larger vehicles likely play major roles in causing pedestrian fatalities, but no two factors are more determinative of pedestrian safety than visibility and vehicle speed. In fact,

FIGURE 2

Average weight of passenger vehicles in the United States

Includes cars, SUVs, pick-up trucks and minivans. Measured in pounds (lbs).



Source: US Environment Protection Agency (EPA) • Created with Datawrapper almost all of the recent increase in pedestrian deaths can be pinned on increased deaths specifically at night; in comparison, pedestrian deaths during the day have remained relatively constant since 2010, rising only slightly since then (Badger et al., 2023). As of 2023, 76% of pedestrian deaths occur in the dark, with the decreased visibility of night reducing the reaction time of pedestrians and drivers alike (ibid).

On the subject of vehicle speed, it's vital to understand that the chance of a pedestrian crash resulting in the pedestrian dying increases exponentially as vehicle speed rises. A pedestrian struck by a vehicle going 32 MPH only has a 25% chance of dying, while the same pedestrian would have a 90% chance of dying if struck by a vehicle going 58 MPH (Tefft, 2011). Clearly, the risk of pedestrian death increases non-linearly, meaning small increases in speed can have dramatic impacts on the likelihood of pedestrian deaths. It is for this reason that placing pedestrians in close proximity to high-speed vehicles is so dangerous.

Unfortunately, this exact urban design is not uncommon in Virginia. Richmond's Hull Street is a great example of just such a road. Running through Richmond's southern edge, this four-lane road has a posted speed limit of 35 MPH, with cars regularly exceeding this speed (Partnership for Smarter Growth, 2024). Shops and residences line the road, with much of the road lacking sidewalks (ibid). It's no surprise that arterial roads like Hull Street are the setting for most pedestrian deaths in Richmond (Vanasse Hangen Brustlin, 2023).

Potential Solutions

Policy wonks have proposed dozens of measures to improve pedestrian safety in past decades, but many of these potential solutions can be categorized based on similar themes. This report will consider solutions across the themes of behavior modification, vehicle modification, limiting vehicle speed, and better pedestrian infrastructure.

Behavior Modification

Behavior modification refers to solutions aimed at changing driver behavior. For example, one extremely low-cost method of improving pedestrian safety is implementing leading pedestrian intervals (LPIs), where pedestrians are allowed to cross at crosswalks a few seconds before adjacent vehicles receive a green light, decreasing the possibility of a car turning right just as a pedestrian enters the crosswalk and thereby preventing a collision. Similarly, some pedestrian advocates have proposed that local governments ban right turns on red lights (RTOR). The logic behind this policy is that many drivers are so focused on looking left when turning right at a red light that they often miss pedestrians who have just entered the adjacent crosswalk, resulting in a pedestrian crash.

These behavior modification policies are some the of most well-studied alternatives. For instance, the evidence for LPIs is solid. One study comparing pedestrian crashes at intersections before and after LPIs were implemented found a 58.7% reduction in pedestrian-involved crashes after LPIs were set (Fayish & Gross, 2010). As for RTOR, although most comprehensive studies on this policy are decades old, the most comprehensive studies find moderate increases in pedestrian crashes as a result of the implementation of RTOR (Preusser et al., 1982; Zador et al., 1982). Other research finds no statistically significant increase in pedestrian deaths as a result of RTOR policies, but much of this research lacks the larger sample sizes of the studies which find that RTOR endangers pedestrians (Hauer, 2004). As a result, there’s strong reason to believe that removing RTOR and implementing LPIs at crosswalks, particularly in urban areas, would increase pedestrian safety.

However, it’s important to note that most pedestrian fatalities in Virginia occur away from intersections (Vanasse Hangen Brustlin, 2023). This fact mirrors the national trend, where only 24% of pedestrian fatalities occur at road intersections (National Safety Council, n.d.). Most deaths happen because a pedestrian attempts to cross the road away from an intersection (i.e. jaywalking) or because a vehicle deviates from the roadway illegally (National Highway Traffic Safety Administration, 2023). This information is valuable because it suggests that policy changes that aim to boost pedestrian safety at intersections, such as banning RTOR and implementing LPIs, may only address a relatively small portion of total pedestrian fatalities in Virginia.

Another recent development in behavior modification surrounding transportation policy has been Virginia’s new hands-free law, which makes it illegal to hold a cellular device while driving, with a few exceptions. Because Virginia has already implemented this measure, this analysis won’t consider it for analysis. However, it's worth noting that the evidence surrounding these laws is mixed. Research finds that these laws typically reduce cell phone usage, but are correlated with only minor reductions in traffic accidents (Kolko, 2007).

Better Pedestrian Infrastructure

Interviews I conducted with VDOT officials indicate that the state government is focused on crosswalks as a cost-effective method to address pedestrian danger on state-owned roadways. As a result, it makes sense to investigate the impact of increased investment in pedestrian crosswalks. One study found that in some circumstances, more clearly demarcated crosswalks could actually decrease pedestrian safety, as pedestrians may feel that the crosswalk gives them 'permission' to not pay attention when crossing the road (Herms, n.d.). However, that study only compared marked and unmarked crossings.

Other studies investigating the safety effects of adding advanced signaling technology to crosswalks have found that investing in crosswalks can greatly increase safety. Specifically, modifications such as speed bumps running parallel to the crosswalk, as well as flashing lights which trigger automatically as pedestrians enter the crosswalk, have been shown to work particularly well, with one study finding that these safety improvements reduced driver speed by more than 70% at night (Sanguino et al., 2024).

Like before, the fact that most pedestrian deaths occur away from intersections mean that upgrading existing crosswalks might have a limited effect on reducing pedestrian fatalities. It's for this reason that adding more crosswalks is just as (if not more) important as upgrading existing crosswalks. We might hypothesize that deaths frequently occur away from intersections because people are unwilling to walk long distances to the nearest crosswalk, leading to them jaywalking, which surprises motorists and results in deadly collisions. In this case, more crosswalks could tangibly reduce the frequency of pedestrian death.

VDOT is typically less likely to consider sidewalks for infrastructure investment as they're far more expensive and time-consuming to build, requiring right-of-way permissions that may be difficult to obtain if utilities run their services under the sides of the road. For example, some estimates place the cost of installing a new sidewalk at as much as $1,000 per foot (Todd Litman, 2023).

VDOT officials I spoke with expressed hesitance to recommend substantial investments in sidewalks for this reason.

Another potential infrastructure upgrade is better street lighting, with the idea being that more light would help drivers see pedestrians at night, potentially reducing fatalities as a result. For a look into the data, one observational study found that pedestrians were 2.4 times more likely to be killed by a vehicle when they weren't in the presence of a street light (Ferenchak et al., 2022). The reduction in crashes caused by more street lighting holds across a variety of traffic conditions, regardless of traffic volume, road conditions, or other factors (Jackett & Frith, 2013). Although street lighting isn't cheap either, if lighting improvements are applied specifically to roads that yield disproportionately large pedestrian fatalities, this policy may be cost-effective. Better street lighting is also the only pedestrian infrastructure improvement that would directly improve visibility, the lack of which is a core cause of pedestrian fatalities. Better lighting would likely increase driver reaction times, greatly reducing the chance of a crash that results in a pedestrian death.

Vehicle Modifications

Of all the potential remedies to pedestrian death in the United States, the solutions that receive the most attention are typically technological measures designed to upgrade vehicles' ability to reduce pedestrian crash frequency and severity without any human input. Such systems are typically called automated emergency braking systems (AEBs). These technological upgrades and others like them are convenient for policy-makers because they don't require any major shift in roadway design or access, and also because their efficacy is well-studied and supported by a large body of evidence (Haus et al., 2019).

For these reasons, NHTSA issued a new safety standard in April 2024 requiring all cars and light trucks to include AEB systems by 2029, which will surely help reduce pedestrian fatalities. Similarly, in early 2024, NHTSA initiated the regulatory process to develop standards mandating that new vehicles must have anti-drunk driving technology installed by a certain date (National Highway Traffic Safety Administration, 2024). Such technology, to include breathalyzers, may be present in all cars in the future, virtually eliminating the problem of drunk driving.

Another new technology that may improve pedestrian safety is autonomous vehicles. The 360˚ nature of autonomous vehicle sensors means that such vehicles may, in theory, be more capable of tracking pedestrian movements than human-operated vehicles. One study investigated this issue, examining accidents between 2015 and 2017 in California. The authors found that autonomous vehicles were associated with a statistically significant reduction in the number of crashes involving pedestrians compared to human-operated vehicles (Petrović et al., 2020). That being said, the sample size for this study was relatively low, examining just 300 accidents. Furthermore, autonomous driving technology isn't sufficiently well-developed for it to be implemented on a massive scale, making this a policy alternative for the future.

Despite state and federal interest in technology such as AEB systems and widespread breathalyzer use, government officials have expressed much less interest in new standards limiting vehicles' weight and height. The Virginia state government currently sets limits on size and weight for freight-hauling vehicles such as semi-trucks, and the federal government levies a heavy vehicle use tax (HVUT) on vehicles weighing 55,000 pounds or more (Federal Highway Administration, 2020). However, these policies could be extended to cover light trucks and SUVs. For example, one might imagine the state government taxing vehicle purchasers $100 for every 100 pounds of vehicle weight beyond an initial threshold weight of 4,000 pounds. Such a policy would increase the price of heavy light trucks and SUVs relative to sedans, and would increase government revenues as well. This policy would be of dubious popularity, but may dramatically reduce the severity of pedestrian crashes over the long-term by shifting customers towards more pedestrian-friendly vehicles.

Limiting Vehicle Speed

If placing pedestrians near high-speed vehicles greatly increase the risk of a pedestrian fatality, then why not simply lower speed limits in residential areas? To fully consider the implications of such a policy, it's important to understand how speed limits are set. Historically, the common practice among traffic engineers was to set a road's speed limit within 3 MPH of the 85th percentile of driver speed. For example, if exactly 85% of drivers choose to drive at or below 50 MPH, then the speed limit would typically be set at 50 MPH. This idea can be traced back to a study conducted in 1964 (Fitzpatrick et al., 2021). The rationale for this rule is that in the aggregate, drivers intuitively understand the speed at which it is safe to travel, meaning that speed limits should be set according to how fast people choose to drive.

However, this practice has been the subject of significant criticism since its introduction. There's no reason to assume that drivers have a strong understanding of how safe a section of road is. The 85th percentile benchmark mandates that if drivers suddenly started driving 5 MPH faster than the day before, the speed limit should be raised despite road conditions remaining unchanged, a concept which many people have critiqued as nonsensical and disconnected from safety considerations (National Association of City Transportation Officials, 2020).

Recent research by the National Cooperative Highway Research Program found that crashes in urban areas had the lowest frequency when average speed was within 5 MPH of the posted speed limit, leading them to recommend a 50th percentile benchmark rather than an 85th percentile benchmark (Fitzpatrick et al., 2021). Thankfully, VDOT has already begun incorporating this research into their process for the setting of speed limits (Virginia Department of Transportation, 2023), resolving to account for actual road conditions rather than relying solely on vehicle speed to set speed limits. In addition, the General Assembly passed a new law this year allowing local governments to reduce the speed limit on state-owned roads to as low as 15 MPH in business and residential areas (Torres, 2024). Clearly, the state government is taking steps to address the artificially high speed limits set according to the 85th percentile benchmark.

While the new law marks a step in the right direction, many localities may decline to exercise this new power, while others may exercise it too infrequently to deliver any meaningful improvement in pedestrian safety. If the state government were to take further action to reduce speed limits, what might that look like? One interesting but tragically understudied policy option is to reduce speed limits at night. The basis for this idea is the fact that when darkness and high speed (both of which are major drivers of pedestrian death by themselves) combine, the two factors interact to create particularly unsafe conditions for pedestrians.

The rationale behind this sinister interaction is founded on how the two factors combine to limit driver reaction times. Various studies have estimated the upper bound of driver reaction time (specifically, the time between an object unexpectedly appearing in the roadway and the driver braking) to be approximately 1.5 seconds (Johansson & Rumar, 1968). If standard headlights give a driver visibility up to about 50 meters in front of the vehicle, and driver reaction time is 1.5 seconds, then at 36 MPH and above, the stopping distance of most vehicles exceeds the vehicle’s forward seeing distance (Sullivan & Flannagan, 2001). This means that if a pedestrian were to suddenly appear in front of a vehicle traveling at or above 36 MPH, many cars may not be able to come to a complete stop in time, potentially resulting in a collision with the pedestrian.

This paper has already discussed the policy option of increasing public investment in street lighting, which would help to alleviate this deadly interaction by increasing visibility. However, it’s also possible to reduce the intensity of this interaction by reducing vehicle speeds at night. One might imagine a policy wherein speed limits are automatically reduced by 10 MPH in urban and residential areas between sunset and sunrise. Unfortunately, there is scant research investigating the validity of such a policy, and the external validity of the available research is suspect. Specifically, research has been conducted on the effect of varying speed limits by time of day on animal collision rates in rural areas. One such study found that lower nighttime speed limits did not reduce wildlife collisions to any significant degree (Riginos et al., 2019). That being said, this study occurred in rural Wyoming and involved a relatively small sample size. In addition, replacing deer with pedestrians may return very different results. Overall, although the logic of this policy is sound, more evidence is needed before a convincing case can be made to the public for the necessity of such a policy.

Another obvious policy option to boost pedestrian safety by reducing vehicle speed is to increase enforcement of speed limits. Speed limit enforcement by police, which might entail a marked police car simply sitting on the side of a road as well as ticketing people for speeding, creates what researchers call a ‘time halo effect’, wherein average vehicle speed is reduced in the area where enforcement took place even after police have left the area. One study, which used a stationary marked police car as its measure of enforcement, found that the time halo effect vanishes after about three days given a single day of traffic enforcement on a particular road (Hauer et al., 1982). That same study also found that given five straight days of traffic enforcement on a single road, the time halo effect increased in intensity, lasting for at least six days after traffic enforcement stopped. Given this, it seems clear that more police visibly monitoring vehicle speed would help to keep vehicles below the speed limit, thereby protecting pedestrians.

Unfortunately, there are too few traffic cops available to enforce the speed limit on every dangerous road in the state of Virginia, making such a solution infeasible to scale. Newer studies have investigated if speed cameras might provide the same enforcement effects without requiring a regular police presence. Evidence for this conjecture is broadly positive; there is general agreement in the literature that speed cameras reduce average vehicle speed, while some studies go further, illustrating a correlation between speed cameras and reduced deaths (Allsop, 2010; Chin, 1999). Despite such strong evidence, Virginia law enforcement is only legally permitted by state law to place speed cameras in school zones, highway work zones, and construction areas (Payne, 2024).

Opponents of speed cameras have attacked speed cameras as privacy violations, tools for local governments to gouge their citizenry, and as tools which disproportionately affect poorer, more non-white communities. These disparities arise in part because people in these communities are more likely to incur late fees than people in wealthier, whiter communities, and because roads in poor areas often lack the kind of infrastructure which typically limits vehicle speed, such as sidewalks and frequent crosswalks (Hopkins & Sanchez, 2022). This concern points to a broader hesitancy, particularly among Democrats, to support increased traffic enforcement out of fear that increased interaction between police and citizens may lead to needless violence, and particularly violence of a racially charged nature.

For example, jaywalking was decriminalized in New York City in 2024 after decades of criticism that the NYPD used the law to target racial minorities (Wise, 2024). Indeed, a 2019 study found that 92% of 2023 jaywalking stops in New York City involved Black and Hispanic people, even though such people made up only 55% of the city’s population at that time (Duenez, 2022). Although the disproportionate impact of speed cameras on poorer, more non-white communities is clear, the idea that investing in traffic enforcement contributes to structural racism should not be allowed to obscure the very real safety benefits that traffic enforcement, and speed cameras in particular, can provide.

Clearly, there are a variety of solutions worth considering, each with its own unique blend of costs, benefits, and risks. However, for the purposes of the following analysis, I will focus on three: speed cameras, improved street lighting, and leading pedestrian intervals. I've chosen to analyze these alternatives further due to the strong evidence base proving their effectiveness, their political feasibility, and their low cost compared to other alternatives.

Key Criteria

Alternatives will be ranked across a range of criteria. First, I will evaluate the scientific literature to estimate effectiveness, which will be measured as the percent reduction in fatal and severely injurious crashes generated by each alternative. To be clear, the ability of these alternatives to reduce less injurious crashes, to include crashes resulting in minor injuries or fender-benders, won't be measured, as our chief goal is to reduce death and serious harm.

Second, alternatives will also be judged according to their scope of effectiveness, meaning the extent to which each alternative generates safety benefits regardless of crash type or crash conditions. For example, a policy may greatly reduce the frequency of collisions for pedestrians specifically but generate no safety benefit for other road users, reducing the policy's scope of effectiveness. Although the goal of this analysis is to investigate policy options to reduce pedestrian death, speed cameras and improved street lighting are also projected to reduce non-pedestrian collisions. Given that the majority of road users are *not* pedestrians, ignoring the costs and benefits that accrue to other road users as a result of these policies would be irresponsible. As a result, scope of effectiveness is a necessary criterion and will be given an outsized weighting in the following analysis.

Third, alternatives will be judged according to their cost, which will be estimated according to how expensive it would be to implement each alternative across a square kilometer of an urban area. I specify "urban area" because there is strong reason to believe that the cost of these alternatives may differ considerably across rural and urban areas; for example, there are fewer roads in a square kilometer of rural area, so the cost of outfitting this square kilometer in street lighting will be much lower than for an urban area. In addition, because more pedestrians exist in urban areas, I feel that it's rational to constrain our focus to these places for the cost criterion. I will cost each alternative according to a 25-year time horizon, with costs to be presented on an annualized basis.

The final criterion is feasibility. Feasibility includes a policy's likelihood of receiving enough political support to be passed into law (political feasibility), as well as the likelihood of each policy receiving buy-in from key stakeholders (stakeholder feasibility). Logistical feasibility, or the ease with which a policy can be implemented, will also be considered here. All three of the considerations will be considered a single criterion due to their inter-related nature.

Findings

Speed Cameras

When installed alongside roads, speed cameras will monitor passing traffic, taking photos of the license plates of passing cars which are found to be speeding. Violators will then be fined. As a result, traffic is greatly encouraged to obey the speed limit. Lower vehicle speeds will result in fewer fatal crashes. Under Virginia's current legal framework for speed camera use by law enforcement, motorists driving in excess of 10 miles per hour beyond the speed limit will receive a fine in the mail of up to $100. These mail-in penalties are less severe than regular speeding tickets issued in-person by police officers in that they don't affect a driver's permanent record or increase their insurance premiums. Motorists would be alerted to the cameras' presence through nearby signage.

Effectiveness

Although almost all investigations of the effectiveness of speed cameras find a reduction in traffic collisions, the magnitude of these estimates of efficacy vary widely. However, for the purpose of this analysis, I will de-prioritize estimates derived from simple before-and-after comparisons, where causality may be tainted by confounding factors. Thankfully, estimates derived from more causal methodologies are less varied. For example, a quasi-experimental study on speed cameras in England found a 15% reduction in crashes as a result of speed cameras (Graham et al., 2019), while a separate difference-in-difference study found that accidents were reduced by at least 17% (Tang, 2017). Many other, less robust studies found significantly higher effects, with some estimates reaching as high as a 71% reduction in road deaths (Pilkington & Kinra, 2005). To account for these studies, we will assume that the causal effect of speed cameras is an annual 20% reduction in the number of crashes.

Cost

The effectiveness of speed cameras on slowing nearby vehicles has been shown to dissipate beyond 500 meters from the speed camera's location (Tang, 2017), meaning that cars will obey the speed limit more consistently even on roads adjacent to roads equipped with speed cameras. With a range of effectiveness of 500 meters, one speed camera can effectively enforce the speed limit across a circular area of .78 square kilometers, with the speed camera located at the center of this circle. To make this analysis easier, I round up and assume that one speed camera can enforce the speed limit across one square kilometer. A speed camera pilot program in Fairfax County, Virginia, estimated the cost per speed camera to be $3,000 per month, which includes equipment and signage costs as well as the cost of the labor hours required to administer the program (Fairfax County, 2024). This number assumes that police departments would lease speed cameras from private providers, as is typical. Extrapolating this monthly cost to an annual basis, the cost of implementing this alternative across a square kilometer of an urban area is $36,000 per year.

The other main cost to consider is the time cost of making people drive slower. One study found that speed camera implementation reduced average speed by about 5 miles per hour in urban and rural areas alike. Most vehicles travel at or near the speed limit; these vehicles won't be greatly affected by a speed camera. The effectiveness of the cameras stems from greatly reducing the speed of a select few vehicles who choose to drive recklessly. As a result, the *average* driver bears a negligible time cost from a speed camera. Indeed, many analyses have found no significant change in average travel time associated with small, policy-driven reductions in average speed (Archer et al., 2008). As a result, this analysis considers the time cost associated with speed cameras to be zero.

Because speed cameras are typically leased from a private company, I assume that the current annual cost of $36,000 will remain unchanged over the 25-year time horizon used for this analysis. That being said, readers should keep in mind that innovation in speed camera technology could drive the annual cost of this policy much lower as we near the time horizon. There is no way to reliably estimate the extent to which the annual cost may or may not fall, so this analysis will use the unadjusted estimate described above.

Scope of Effectiveness

The scope of effectiveness for speed cameras is broad. By incentivizing vehicles to strictly obey the speed limit, they reduce the frequency and severity of pedestrian death *in addition* to non-pedestrian death, providing similar safety benefits to motorists as those provided to pedestrians. Also, speed cameras produce these beneficial outcomes regardless of the time of day or weather. As a result, the scope of effectiveness is rated as high.

Feasibility

Speed cameras are a hotly debated issue in the state of Virginia, with a variety of stakeholder perspectives. Critics of the program argue that the justice system should not serve as a source of revenue for local governments, pointing to the $33 million in fines collected by Virginia law enforcement in the first four years of the cameras being legalized, which occurred in 2020 (Cline, 2025). These revenues have not been included in the costing section above because they technically count as transfers from the public to the government, and thus aren't actually social costs incurred as a result of policy implementation. However, they must be considered when evaluating this policy's feasibility, as the revenues greatly increase bureaucratic buy-in (contributing to high stakeholder feasibility) while simultaneously stoking public ire.

A national poll found that 49% of Americans support speed cameras generally, while 60% support their use specifically on roads with a proven history of speeding-related crashes (Erie Insurance Group, 2022). A survey of residents in Alexandria, Virginia, found something similar, with more Virginians supporting cameras than not, but with many people still holding serious reservations about the policy (Miles, 2022). This month, a bill to expand the use of camera technology at crosswalks in school zones passed the General Assembly, passing the House of Delegates by a vote of 54-40 and the Senate by similar margins (Cline, 2025). The bill included a variety of provisions designed to address commons concerns surrounding speed cameras.

For instance, photographs taken by Virginian speed cameras are to be stored in a secure database, to be deleted no later than 60 days after the associated fines are collected, thereby assuaging critics' concerns about privacy (Amendment in the Nature of a Substitute, 2025). While they reside in the government's care, photographs taken by the speed cameras may be used as evidence in separate legal proceedings only after a court order is issued. In addition, proceeds from these speed cameras can only be spent on traffic safety projects, and not as general revenue for localities (ibid.). Provided that these provisions are included in future speed camera bills, the policy is likely politically feasible.

Beyond political feasibility, we must also consider logistical feasibility. There is already a process by which the state government helps fund local police departments, contributing what are known as "599 funds" (Virginia Department of Criminal Justice Services, 2025). The General Assembly would likely appropriate additional funds to local police departments to help them fund the leasing of new speed cameras. Police departments would be authorized to determine the placement of these cameras after consulting with VDOT, with the goal of making data-driven decisions regarding where placement would have the greatest effect at reducing crashes. The company leasing the cameras to the government would then be responsible for maintenance. From a bureaucratic perspective, the program could pay for itself through its generation of fines.

Clearly, interest exists among many legislators to continue to expand the use of speed cameras within an already-existing legislative framework, and the likelihood of bureaucratic buy-in is high. At the same time, we must consider the fact of divided public opinion on the policy. As a result of these factors, the feasibility of speed cameras is rated as medium.

Improved Street Lighting

Along with excessive vehicle speed, poor visibility is a primary driver of pedestrian death. As a result, it's unsurprising that the vast majority of pedestrian deaths occur at night (Badger et al., 2023). By adding street lighting to roads which are currently unlit, visibility will increase, and vehicles will be less likely to strike and kill pedestrians.

Effectiveness

Estimates of the effect of road lighting on accident frequency and severity aren't as numerous as with speed cameras, but there are still a variety of estimates to choose from. Many of these estimates are comparable; for example, the New Zealand Transit Agency estimates that street lighting decreases accident frequency by 35% during darkness (Jackett & Frith, 2013), while a meta-study, which examined the effects estimated by a variety of quasi-experimental studies, finds an average reduction of 30% (Wanvik, 2009). The latter meta-study also found that street lighting decreased the frequency of *fatal* crashes at night by 60%. Because we're most concerned with limiting severe crashes rather than fender-benders, I'll use the estimate predicting an annual 60% reduction in fatal and severely injurious crashes for this analysis.

Cost

Industry experts report that the spacing of light poles should be approximately three times their height (DeWald, n.d.). If we assume that the average light pole is 15 feet tall, then a light pole must be placed every 45 feet to adequately light a roadway. As a result, 73 streetlights would be needed to adequately light a one-kilometer stretch of road. We might assume that one could fit, at most, 20km of roadway in one square kilometer of an urban area; that is, 10 horizontal and 10 vertical roads arrayed in a grid pattern to create blocks, with each road being 1 kilometer long and there being slightly less than 10 meters in between neighboring parallel roads. Under these assumptions, 1,460 streetlights would be needed to adequately light one square kilometer of an urban area. However, this is likely an overestimate, as even New York City's Manhattan only features 16km of roadway per square kilometer. As a result, I will assume that the average urban area in Virginia can bear 10km of roadway per square kilometer, meaning 730 streetlights would be needed to light the area. The average cost of purchasing and installing a new street light is approximately $2,500 per light plus another $500 for its installation (Eco-Smart, 2024), for a total cost of $3,000 per light. This gives us a total cost of $2.19 million for purchase and installation. LED streetlights last up to 25 years (Green Frog Systems, n.d.), allowing us to annualize this cost to $87,600.

We must also consider the cost of electricity. An LED streetlight costs about $4.32 to operate per month (Eco-Smart, 2024), meaning that outfitting a square kilometer of urban area in new lighting would cost approximately $37,850 per year. Adding purchase, installation, and electricity costs together gives us a total cost of $125,500.

Scope of Effectiveness

Like speed cameras, improved street lighting will reduce both pedestrian and non-pedestrian road deaths. Unfortunately, during the daytime, street lighting is switched off and does nothing to make anybody safer. Granted, approximately 75% of pedestrian deaths occur at night (Badger et al., 2023), but the ideal policy alternative would provide a strong increase in road safety *all the time*, not just between sunset and sunrise. More importantly, only about half of all nighttime crashes occur on unlit roads, while only 16.7% of nighttime crashes specifically involving a pedestrian occur on unlit roads (Shan Di, 2025). As a result, this policy could only ever address a small slice of the problem. However, like with speed cameras, improved street lighting improves safety for motorists in addition to pedestrians. Due to these considerations, the policy is rated as medium on the scope of effectiveness criterion.

Feasibility

Unlike with speed cameras, nobody is vehemently opposed to improving street lighting. However, the policy may still be politically infeasible due to its high cost. As we've seen above, even proposals to add marginal amounts of new street lighting will quickly become expensive, increasing the difficulty of convincing the General Assembly to pursue this alternative. In addition, the path toward policy implementation is less than clear. Successful implementation would require the General Assembly to appropriate a large amount of funds to VDOT, and this measure would require approval by the Governor as well. The policy may encounter more difficulty when these funds reach VDOT, as renewed investment in street lighting would mark a change in VDOT policy. Currently, the department's default policy is no street lighting for roads, and that when lighting is required for safety reasons, to install lighting at "nodes, not roads", meaning that intersections and crosswalks may receive lighting, but roads may not (Khoury, 2019).

Unfortunately, only 24% of pedestrian crashes occur at intersections at a national level, meaning VDOT's current policy does little to protect pedestrians (National Safety Council, n.d.). VDOT may resist a change to their policy if one were mandated by the General Assembly, suggesting low stakeholder feasibility. In addition, the lack of concrete data on the extent to which any given road is lit makes it difficult to identify which roads would actually receive any appropriated funds for new lighting. The process for picking locations for lighting improvement would be labor-intensive for VDOT, who would likely have to field requests from Virginians to decide where to implement street lighting improvements. This indicates low logistical feasibility. For these reasons, street lighting is rated as low on the feasibility criterion.

Leading Pedestrian Intervals (LPIs)

Leading pedestrian intervals refers to the practice of re-timing crosswalk signaling technology to give pedestrians a few-second head start before right-turning cars are given a green light, thereby decreasing the probability that a car will turn right just as a pedestrian enters the crosswalk and preventing collisions in the process.

Effectiveness

Leading pedestrian intervals are the least studied alternative considered in this analysis, but there are a few estimates we can use to inform our discussion of the policy's benefits. The Federal Highway Administration asserts that the intervention decreases pedestrian-vehicle crashes by 13%, a number sourced from a 2021 paper using a quasi-experimental before-after study design (Goughnour et al., 2021). Meanwhile, a separate paper found a 59% reduction in these crashes using an identical methodology across a smaller sample size (Fayish & Gross, 2010). I will weigh the former paper more highly given its recency and larger sample size, so I will assume that LPIs reduce pedestrian-vehicle crashes by 30% for this analysis.

Cost

Let us assume that on any square kilometer in an urban area in Virginia, there are between 15 and 30 signalized crosswalks where LPIs could theoretically be implemented. The Federal Highway Administration states that implementing an LPI at one intersection costs around $200 if no analysis of the location is needed, and around $1200 if a pedestrian-vehicle study must be conducted prior to changing the timing of any traffic control systems (Federal Highway Administration, n.d.). If we assume that most intersections won't require any study to re-time and assert that implementing LPIs will cost, on average, $500 per intersection, then outfitting a square kilometer of urban area with LPIs would cost between $7,500 and $15,000. This cost would be entirely upfront, as once the signals have been re-timed, no additional maintenance will ever be needed.

Scope of Effectiveness

Although LPIs keep pedestrians safe regardless of the time of day, they are unique among the alternatives considered in this analysis in that they only safeguard pedestrians and have no effect on the safety of motorists. Theoretically, it may be true that delaying a green light for a few extra seconds after perpendicular traffic is stopped could reduce the chance of a broadside collision (colloquially known as a "T-bone" collision), where a vehicle tries and fails to make a yellow light before the signal turns red and strikes a car moving perpendicularly. However, the scientific literature is silent on this issue, so with no way to confidently estimate the value of this potential safety benefit, I have no choice but to ignore it in favor of concluding that LPIs only benefit pedestrians. In addition, LPIs can only be implemented at crosswalks where crosswalk signaling technology exists, which is not the case for many crosswalks in Virginia, particularly in less wealthy neighborhoods. As a result of these factors, LPIs are rated as low on the scope of effectiveness criterion.

Feasibility

LPIs are a less invasive way of protecting pedestrians compared to speed cameras, and their implementation is far cheaper than improved street lighting. LPIs represent an exceedingly technical solution, meaning that there is no opinion polling data on this policy. However, this technicality likely decreases the chance of public pushback while increasing bureaucratic interest in the policy. In addition, we should consider that some Virginia localities, such as Arlington County, have already begun to implement LPIs at many intersections (Arlington County, 2025). Indeed, it's difficult to imagine what an anti-LPI interest group might look like given the policy's inoffensive nature.

Implementation would likely take the form of the General Assembly appropriating funds to VDOT, approval by the Governor, and VDOT buy-in, which will entail VDOT working with localities to identify intersections with a significant risk for vehicle-pedestrian conflict, which can easily be determined using historical data. From here, it's simply a matter of traffic engineers re-timing identified intersections. As a result of the straightforwardness of these factors, LPIs are rated as high on the feasibility and ease of implementation criterion.

Outcomes Matrix

Criteria	Speed Cameras	Improved Street Lighting	LPIs
Scope of Effectiveness	High	Medium	Low
% Change in Severe Crashes	-20%	-60%	-30%
Cost per Square KM	$36,000	$125,500	$7,500 - $15,000
Feasibility	Medium	Low	High

Recommendation

I recommend that the Virginia state government implement the speed camera alternative due to its relatively low cost, clear route toward implementation, and effectiveness proven by a wide variety of scientific literature. While the other two alternatives are promising, aspects of both make them less attractive than the speed camera alternative. Leading pedestrian intervals only reduce the frequency of collisions between vehicles and pedestrians specifically, while the other two will also reduce other types of collisions. Only 15.5% of fatal crashes in Virginia from 2016 to 2024 involved pedestrians (Shan Di, 2025), so although this analysis is geared toward analyzing ways to reduce pedestrian deaths, alternatives which solely focus on this subset of deaths won't fare well in an analysis when compared to policies which would also reduce non-pedestrian road deaths. In other words, despite the low cost, high feasibility, and decent effectiveness of LPIs, I cannot in good conscience recommend the policy over speed cameras due to the vast difference in scope of effectiveness. However, it should be noted that speed cameras and LPIs are entirely compatible policies, so if the General Assembly is serious about protecting pedestrian safety, both policies should be considered.

Speed cameras won out over improved street lighting due to cost concerns. Lack of adequate street lighting, particularly in less developed, more urban areas, remains a serious problem, and data indicates that properly lighting these areas would reduce deadly or severely injurious crashes by far more than either of the other two alternatives. However, the cost of illuminating a square mile of an urban area was found to be about four times greater than the cost to cover that same square kilometer with a speed camera.

In addition, the path toward implementation for improved street lighting is much less clear, further elevating the speed camera alternative. Also, we must consider that speed cameras would reduce crash frequency regardless of the time of day, while improved street lighting would only affect nighttime crashes. LPIs and improved street lighting have a role to play in safeguarding pedestrians in specific circumstances suited to their characteristics, but in general, the go-to policy to address road danger (and particularly danger to pedestrians) is speed cameras.

Appendix A

The following discussion analyzes what would have happened had each of the three considered alternatives been implemented in the past. This exercise is intended to make the differing costs and benefits of these alternatives more concrete by estimating the impact they might have had if they had been fully implemented within the city of Richmond from 2016 to 2024.

Speed Cameras

What would have changed if Richmond had been saturated with speed cameras from 2016 to 2024? According to data collected from the Virginia Department of Transportation, during this time period, there were 191 crash fatalities within the city limits of Virginia's capital. The city currently operates a number of speed cameras in school zones, but these cameras only operate during the school year and at set times during the day (Sriraman, 2024), so to make the analysis simpler, we'll assume that the city currently has zero speed cameras within its boundaries.

Had Richmond's streets been inundated with speed cameras during this time, we might expect 20% fewer deaths, or 38 lives saved over this nine-year period. In addition, we must also consider the impact of speed cameras on the number of serious injuries, defined as pedestrian crashes which resulted in a pedestrian receiving an "A" rating from police on the KABCO scale. For context, the KABCO scale is the method police use to track accident severity. In Virginia, an "A" rating indicates that someone involved in the crash suffered paralysis, significant burns, crush injuries, or other serious injuries. If we assume that speed cameras would reduce the frequency of crashes by 20%, then speed cameras in Richmond would have prevented approximately 415 serious injuries over the examined nine-year period.

From here, it's not difficult to monetize these casualty reductions using federal Department of Transportation (DOT) benefit-cost analysis guidance. As of 2024, the DOT recommends valuing deaths at $13.2 million, while they recommend valuing an "A" classification on the KABCO scale at approximately $1.25 million (U.S. Department of Transportation, 2024). As a result, had the city of Richmond been inundated with speed cameras from 2016 to 2024, they would have prevented about $1.02 billion in losses, or $113.5 million per year.

What about the annual cost of saturating the city with speed cameras over this period? We calculated above that the annual cost of equipping one square kilometer with a speed camera was $36,000, and Richmond's city limits encompass an area of approximately 162 square kilometers. Simple multiplication tells us that achieving the full annual benefit of inundating the city with speed cameras would have cost approximately $5.83 million per year, or $52.5 million in the nine-year period from 2016 to 2024. Thus, the net present value (NPV) of this policy is approximately $967.5 million.

This number doesn't account for the benefits derived from preventing minor injuries or property damage resulting from accidents, and incorporating these benefits would only increase the NPV further. In addition, even if we believed that speed cameras would be less effective in urban areas, perhaps because the speed limit isn't always the limiting factor of vehicle speed in big cities, the NPV would still be overwhelmingly positive even if we assumed that speed cameras would prevent only 5% of deadly and severely injurious crashes rather than the 20% assumed in this analysis.

Better Street Lighting

In the nine-year period covered by our dataset, 11 people died in crashes within the Richmond city limits in areas that police deemed not well-lit, while the same unlit areas of Richmond saw 157 people involved in sufficiently severe crashes to warrant them receiving an “A” on the KABCO scale. Had the locations of all these crashes been well-lit, 7 lives would have been saved, and 94 severe injuries would have been prevented. This is equivalent to a benefit of about $209 million in savings across our period of analysis.

Estimating the cost of fully implementing this alternative within Richmond’s city limits is exceedingly difficult given that most Richmond roads are already equipped with street lighting, and there is no detailed data on the extent to which any particular stretch of Richmond roadway is well-lit. The city government reports that approximately 3,000 lane-kilometers of roadway exist within the city limits (Richmond Connects, 2011). If we generously assume that all but 200 lane-kilometers of Richmond roadway is already well-lit and that the average number of lanes on a Richmond roadway is 2, then accessing the benefits of fully implemented street lighting would require equipping 100 kilometers of roadway with new lighting. Thus, the initial investment will cost about $21.9 million, while the cost of electricity to light 100 kilometers of roadway for nine years is about $3.4 million, meaning the total cost of fully outfitting Richmond’s roads with street lighting is $25.3 million. Thus, we arrive at an NPV of approximately $184 million. Notably, this value doesn’t account for the crime reduction that better street lighting has been shown to cause (Welsh & Farrington, 2008). If included, this benefit could greatly increase the NPV.

Leading Pedestrian Intervals

Applying the 30% crash reduction value to all pedestrian-vehicle crashes within Richmond intersections with either a traffic signal or a pedestrian crosswalk from 2016 to 2024, LPIs would have prevented 4 deaths and 19 severe injuries had the policy been fully implemented throughout the city during that time. The value of preventing this loss is equivalent to a monetary benefit of $76.5 million.

As with the other alternatives, we can also calculate the cost to implement LPIs at all Richmond intersections, where possible. VDOT is responsible for maintaining 441,000 roadway intersections in the state of Virginia. From this number, we might assume that the city limits of Richmond encompass perhaps 5% of this number, which is about 22,000 intersections. If we further assume that one-third of these intersections have crosswalk signaling technology which can be re-timed, then LPIs could be implemented at 7,300 intersections. At $500 per intersection, implementing LPIs at all Richmond intersections where crosswalk signaling exists would cost $3.65 million, which would be a one-time cost. Thus, the NPV of this alternative would be about $73 million.

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