DRIVING CHANGE

ROAD PRICING AS A PUBLIC HEALTH STRATEGY

FOR THE DISTRICT OF COLUMBIA

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INTRODUCTION

Climate change is a public health crisis, already causing adverse effects including increased respiratory and cardiovascular disease and premature deaths related to weather and heat. In the District of Columbia, climate change most threatens residents, particularly those living East of the Anacostia River, who already face health inequities due to poor air qualilty from congested vehicle corridors, as well as poor access to healthy food, green space, safe streets, and public transportation.

While climate mitigation itself will have critical health benefits, climate mitigation strategies often have immediate co-benefits for health. For example, climate mitigation policies proposed to reduce the transportation sector's greenhouse gas emissions often confer benefits beyond just emissions reduction. Immediate and local public health, equity, and environmental "co-benefits" stemming from climate mitigation policies include cleaner air, improved physical activity, and reduced noise, among other improvements (Johnson et al., 2021; Karlsson et al., 2020; Scovronick et al., 2019).

Although these co-benefits are extremely significant, oftentimes economically outweighing the cost of implementation, they have been largely overlooked in policy and decision making processes (Karlsson et al., 2020; Markandaya et al., 2018).

Road pricing, also known as congestion pricing, is the practice of charging motorists for driving on a particular roadway, or for driving or parking in a particular area. Often increased during peak periods, road pricing is a proven policy tool for reducing the concentration of vehicles entering and driving within a defined urban area, thereby relieving congestion, and is also an effective policy tool to achieve multiple health co-benefits. This white paper highlights the potential public health, equity, environmental, and other co-benefits the District of Columbia and its residents could enjoy if it implemented a road pricing program, which would reduce vehicle emissions by decreasing the number of vehicles driving in the downtown core. Furthermore, it provides decision makers and stakeholders with public health-specific information to guide equitable and evidence-based policies.

TRAFFIC: A THREAT TO PUBLIC HEALTH

Traffic adversely affects public health due to its links to air pollution, noise pollution, traffic violence, and harmful effects on community health and the environment. Increased tailpipe emissions resulting from traffic congestion contribute significantly to worsening air quality, particularly in urban areas where vehicles are a dominant emissions source (Currie & Walker, 2011; Jakubiak-Lasocka et al., 2014). In addition to the air pollution-attributed health impacts from motor vehicles, traffic contributes to additional public health impacts such as injury, climate change, and environmental degradation.

As we will discuss in later sections, heavy traffic congestion has been linked to high concentrations of contaminate compounds in waterways and heavy metal deposits in soil (Athanasopoulou & Kollaros, 2016; Awonaike et al., 2022). Moreover, tens of thousands of deaths in the United States are the result of traffic-related crashes; in 2021, 40 fatal crashes occurred in the District alone (National Highway Traffic Safety Administration, 2022; Metropolitan Police Department, 2022). There is no shortage of studies, reports, and resources that exemplify how traffic contributes to negative public health outcomes.

TRAFFIC CONGESTION

Traffic congestion arises when a roadway system approaches vehicle capacity, leading to wasted fuel and increased tailpipe emissions (Levy et al., 2010). A continual issue globally, traffic congestion in the United States has been on the rise over the past decade as Vehicle-Miles Traveled (VMT) continue to increase in urban areas in particular (Bureau of Transportation Statistics, 2023; Schrank et al., 2011). Increases in VMT signals a rise in the level of driving, ultimately contributing to traffic congestion because the number of cars exceeds the capacity of the infrastructure to support roadway demand. Aside from contributing to delays, unreliable travel time, and wasted productivity, traffic congestion is a threat to public health.

AIR POLLUTION

Traffic is a significant driver of outdoor air pollution, one of the leading risk factors for disease and illness globally, accounting for more than 1 in 9 deaths worldwide. Globally, air pollution contributes to 6.7 million premature deaths annually. In the United States, roughly 100,000 deaths were attributed to air pollution exposure in 2019 alone (Health Effects Institute, 2022).

Whenever a fuel source is burned, notably during the incomplete combustion process in vehicles with internal combustion engines (nearly 300 million vehicles in the U.S. alone), particles and gasses are released into the air (Alternative Fuels Data Center, n.d.; Transportation Energy Institute, 2022). These particles and gasses are frequently characterized as hazardous air pollutants and duly impact air quality and human health. Motor vehicles most frequently emit nitrogen oxides (NOx), volatile organic compounds (VOCs), carbon monoxide, hydrocarbons, and particulate matter (PM10 and PM2.5) (Department of Transport and Main Roads, 2017; United States Environmental Protection Agency, 2023). In addition to the primary pollutants mentioned, NOx and VOCs are precursors to the formation of ozone, a secondary air pollutant that is known to contribute to reduced lung function, exacerbate existing asthma conditions, and increase susceptibility to respiratory illness (Lippmann, 1991; United States Department of Transportation, 2015). In the United States, the transportation sector is responsible for 55% of NOx emissions and almost 10% of particulate matter emissions (PM2.5 and PM10) (United States Environmental Protection Agency, 2023; World Health Organization, 2022). The District Department of Energy and the Environment's (DOEE) 2020 Ambient Air Quality Trends Report acknowledges that air quality issues within the District largely stem from vehicle emissions, and that the District does not meet the National Ambient Air Quality Standards (NAAQS) for ozone (DOEE, 2020). This is an admission by the District government that transportation has a significant impact on its overall emissions profile.

Air pollutants released from vehicular emissions, such as NOx and PM2.5, as well as a mix of other harmful constituents, have the ability to penetrate deep into our lungs and enter our bloodstream, leading to systemic effects on cardiovascular and respiratory function (C40 Knowledge Hub, 2019). In a UN Health Agency Report released last year, data shows that almost the entire global population (99%) breathes air

containing high levels of pollutants (World Health Organization, 2022). Given the concentration of population in urban centers, cities especially have large numbers of people exposed to traffic-related air pollution. Both short- and long-term exposure to air pollution lead to impacts on health, yet long-term exposures have an increasing contribution to the public health burden of chronic diseases, such as lung cancer, type 2 diabetes mellitus, ischemic heart disease, and chronic obstructive pulmonary disease (COPD) (Health Effects Institute, 2022). Air pollution also contributes to respiratory illness susceptibility, including COVID-19. A study conducted in Italy by Frontera et al. (2020) shows that the regions with the highest levels of air pollution also had the highest number of COVID-19 cases, with patients presenting more severe symptoms that required ICU admittance. Furthermore, mortality was also higher in these regions, a two-fold increase when compared to regions with lower levels of air pollution (Frontera et al., 2020).

Specifically, air pollution from traffic-related congestion contributes to thousands of premature deaths a year nationwide (Levy et al., 2010). A 2021 study found that on-road vehicle emissions are the largest contributor to air pollution-related health burdens in the District of Columbia, accounting for over 50% of NO2-attributable asthma cases and 23% of air pollution-attributable premature deaths (Nawaz, 2021). A 2011 health risk assessment study conducted by researchers at the Harvard T.H. Chan School of Public Health found that exposure to traffic-related air pollution costs the US healthcare system an upward of $18 billion annually, and that's only for the 83 largest urban areas (in which DC was included) (Levy et al., 2010). That study projected that following a period of decline in vehicle emissions (potentially due to policy measures such as catalytic converters, which controls exhaust emissions on the vehicle itself but does nothing to limit the number of people driving) the District may expect to see a rise in monetized PM2.5-related mortality risks due to increased vehicle miles traveled (VMT) (Levy et al., 2010).

Health-related impacts from air pollution are seen at the population level, though particular subgroups have heightened vulnerability. Children, the elderly, communities of color, and low-income populations are at an increased risk of exposure, susceptibility, and impact to air pollution-attributable health effects. Children are highly susceptible to traffic-related air pollution exposures, manifesting in health complications such as asthma, atopy, and wheeze (Krämer et al., 2000). Elderly populations are also at risk for air pollution-attributable complications. A study conducted in Northern California by Alexeef et al. (2022) sought to evaluate health costs associated with traffic-related air pollution exposure in an elderly cohort. The authors found that incremental increases in exposure to nitrogen dioxide (NO2) was associated with increased annual total care costs, emergency room (ER) costs, and outpatient care costs.

In the District of Columbia, air pollution and its subsequent health effects are unevenly and inequitably distributed. This is largely due to historical and contemporary race-based practices and policies, including exclusionary zoning and industrial facility siting, that have segregated residents with lower income and residents of color into parts of urban areas that are in closer proximity to roadways and other high-emitting sources of air pollution (Mohai and Saha, 2015). A study conducted by Castillo et al. (2021) found that when compared to least impacted areas, such as Wards 2 and 3, PM2.5-attributable morbidity and mortality were five times higher in the most impacted areas, such as Ward 7 and 8.

Rates of asthma, a condition closely linked to poor air quality, are 50% higher in the District of Columbia than the national average. The highest rates are in Ward 5, Ward 7, and Ward 8, wards with a higher proportion of Black residents, lower rates of education and employment, and higher levels of poverty.

In the District of Columbia:

On-road vehicle emissions account for over 23% of air pollution-attributable premature deaths.

NOISE POLLUTION

While the literature on health effects attributable to traffic-related air pollution are comprehensive, the dearth of noise exposure data globally has limited observational studies of associated health effects. However, the effects on health due to traffic-related noise pollution are gradually garnering more attention. Based almost exclusively on findings in Western Europe, the World Health Organization has named noise pollution as one of the largest environmental contributors to adverse health effects (second only to air pollution) in its European environmental noise guidelines (European Environment Agency, 2021). Associated health effects include but are not limited to high blood pressure, hearing loss, sleep disruption, and stress-related illnesses (United States Environmental Protection Agency, 2023). In the European Union (EU), the European Environment Agency (EEA) estimated that environmental noise, primarily from road traffic, contributes to 48,000 new cases of ischemic heart disease and 12,000 premature deaths yearly (European Environment Agency, 2020; European Environment Agency, 2021). In 2011, the WHO estimated that in Western Europe only, one million healthy life years were lost due to traffic-related noise (World Health Organization, n.d.).

In the United States, the top sources of environmental noise are road and rail traffic, aviation, and occupational and industrial activities (National Academy of Engineering, 2010). An analysis conducted by Hammer et al. (2013) estimated that tens of millions of Americans experience adverse health outcomes associated with noise exposure. The authors estimated that in 2013 alone, 104 million Americans (nearly one in three) experienced annual noise levels greater than 70 decibels (dBA), putting them at risk of noise-induced hearing loss. Racial and socieconomic disparities in noise exposure pervade across the United States, likely increasing risk of adverse educational and health outcomes associated with noise exposure for communities of color (Casey et al., 2017; Chakraborty, 2023).

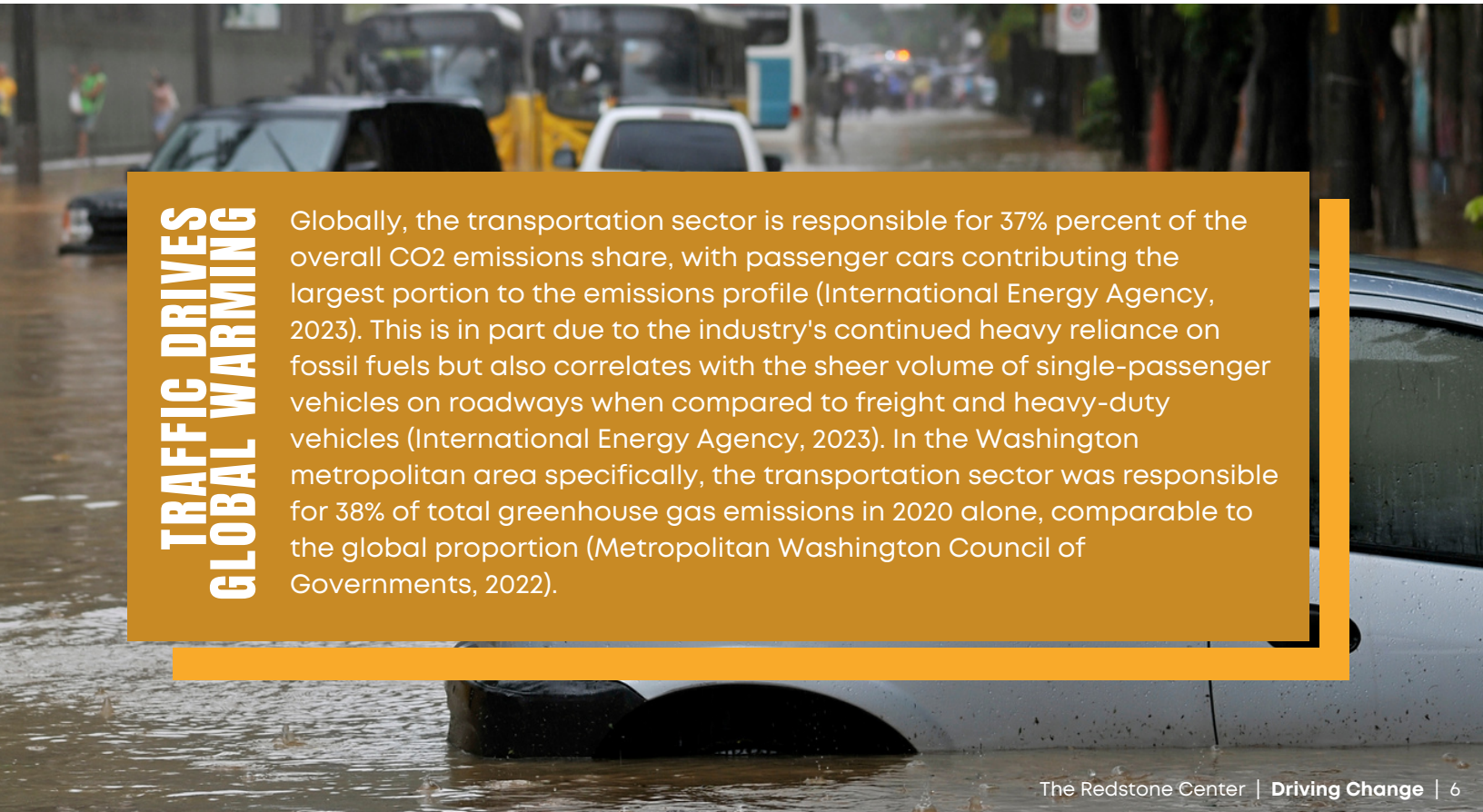
Similar to air pollution, consistent or long-term exposure to even low levels of noise pollution can lead to chronic disease outcomes (Hammer et al., 2013). Noise disruptions during sleep have particularly profound impacts on health. Roadways, a constant source of sonic disturbance, can activate a person's "fight or flight" response, disrupting their sleep and

elevating their heart rate and blood pressure (Haralabidis et al., 2008). Furthermore, decreases in quality or quantity of sleep can increase cardiovascular strain, disrupting circadian rhythms (Sforza et al., 2004). Outside of sleep disruption, environmental noise can increase annoyance and stress, lending to a host of health complications, including heart disease (Sandrock et al., 2008). A cohort study based in Vancouver, BC found that exposure to traffic-related air pollutants and communuty noise were both associated with coronary heart disease mortality (Gan et al., 2012). A study by Huang et al. (2013) found that higher decibels of noise pollution even amplified the effect of higher concentrations of air pollutants (PM2.5, black carbon, and CO) on heart-rate variability in young adults.

Several studies also link increased environmental noise to children's health, citing poor school performance, decreased learning and concentration, and lower reading levels as associated outcomes (Lercher et al., 2002; Stansfeld et al., 2005). Educational challenges like lower reading levels can contribute to school absenteeism, which leads to drop out – which is linked to long-term health challenges (Balfanz and Byrnes, 2012).

Excessive noise, particularly from pollutant-emitting vehicles, is yet another environmental injustice with inequitable public health consequences. One case study of Texas public schools found that children attending schools with the top 25% highest exposure to both road noise and NO2 were significantly more likely to be Black, Hispanic, and eligible for free/reduced lunches (Chakraborty, 2023).

Racial and socioeconomic disparities in noise exposure likely increase the risk of adverse educational and health outcomes associated with noise exposure for communities of color.



TRAFFIC DRIVES GLOBAL WARMING

Globally, the transportation sector is responsible for 37% percent of the overall CO2 emissions share, with passenger cars contributing the largest portion to the emissions profile (International Energy Agency, 2023). This is in part due to the industry's continued heavy reliance on fossil fuels but also correlates with the sheer volume of single-passenger vehicles on roadways when compared to freight and heavy-duty vehicles (International Energy Agency, 2023). In the Washington metropolitan area specifically, the transportation sector was responsible for 38% of total greenhouse gas emissions in 2020 alone, comparable to the global proportion (Metropolitan Washington Council of Governments, 2022).

TRAFFIC VIOLENCE

Road traffic also affects public health due to traffic violence, one of the leading causes of injury and death in the United States. In 2021, the 42,915 people killed on US roadways represented a 16-year high in national traffic fatalities (National Highway Traffic Safety Administration, 2022). Traffic violence also causes injury, life-long health challenges, and trauma, which can ripple across entire communities. Road traffic injuries are the leading cause of unintentional injury worldwide, and the World Health Organization predicts road traffic injuries will be one of the leading causes of disability-adjusted life expectancy by 2030 (Papic et al., 2022; Zimmerman et al., 2012). Disabling physical and mental health impacts of traffic injuries reduce quality of life and cause long-term missed work, forced job change or early retirement (Alemany et al., 2013; Alghnam et al., 2015; Papadakaki et al., 2017). Long-term decreases in wages and employment opportunities, combined with increased healthcare expenses, create a significant economic burden for families, commonly leading to or entrenching poverty. (Alemany et al., 2013; Zakeri et al., 2021).

The extent of these burdens vary depending on personal and societal factors. A two-year cohort study found that female sex, low education, low income, physically demanding occupations, pre-injury comorbidities and high-injury severity were all negatively associated with returning to work post-injury (Papic et al., 2022). However, studies show road traffic injuries of all severity levels are associated with reduced Health-Related Quality of Life (HRQOL) (Rissanen. et al., 2020). A tri-national cohort study found that a “great proportion” of patients maintained high levels of psychological distress one year after the injury (Papadakaki et al., 2017). These results were in accordance with other studies, and is even more striking considering that post-traumatic psychological distress following traffic violence is likely underreported, particularly in men.

Our currently inequitable transportation system prioritizes car usage over pedestrian and cyclist safety, increasing the risk of traffic violence for people using active transportation modes. The above-mentioned tri-national cohort study found that pedestrians and cyclists were the most at risk of poor health outcomes one year after a road traffic injury when compared to other road users (Papadakaki et al., 2017).

Pedestrians and cyclists in the US face higher risk of traffic violence than in other developed nations. Between 2010 and 2018, per capita fatality rates for pedestrians rose by 19% and 11% for cyclists, whereas rates in the United Kingdom, Germany, Denmark and the Netherlands fell or remained stable (Buehler and Pucher, 2020). An analysis from Virginia Tech and Rutgers University suggests this could be due to poorer walking and cycling infrastructure, higher urban speed limits, more vehicle miles traveled, larger and more powerful motor vehicles, and worse training, testing, and enforcement of traffic regulations (Buehler and Pucher, 2020).

Minority populations, children, and the elderly disproportionately experience the public-health threats of traffic violence. While the intersection of traffic violence with disability and ableism is understudied, a scoping review found that physically disabled people consistently have a significantly higher risk of collisions, injuries, and fatalities related to road traffic (Schwartz et al., 2022). When the built environment is designed to only support movement of "able–bodies" these environments may produce disabling and "risky" experiences (Schwartz et al., 2022).

Traffic violence also has disparate impacts on Black residents, who are more likely to die in traffic crashes when compared to other racial groups (Governors Highway Safety Administration, 2021). A pedestrian-related hospitalizations study found that the hospital admissions rates, costs per capita, and proportion of stays exceeding one week in length were higher for Black and Multiracial/Other than white individuals (Hamann et al., 2020). The implicit racial biases of motorists when making quick decisions could play a role in the racial disparities in pedestrian injuries. A study comparing the number of drivers yielding to a Black vs. a white pedestrian in a high-income neighborhood in Las Vegas, Nevada, found that significantly more cars failed to yield in a crosswalk while the Black pedestrian was in the same half of the roadway compared to when the white pedestrian was in same half of the roadway. (Coughenour et al., 2017). A study in Houston, Texas, found that the proportion of Black pedestrians involved in crashes in majority non-Black census block groups is substantially elevated, relative to majority-Black census block groups (Haddad et al., 2023). An analysis of crash-location coordinates for the more than 22,000 pedestrians killed between 2008–2012 found that lower-income neighborhoods bear higher overall rates of pedestrian fatalities than higher-income neighborhoods within the same city (Maciag, 2014). When Black pedestrians are struck, incidents are disproportionately less likely to be reported to the police, so the true burden is likely underestimated (Edwards & Gutierrez, 2021).

Implicit racial biases of motorists when making quick decisions could play a role in the racial disparities in pedestrian injuries.

People with low incomes and people of color disproportionately reside near commuter highways, and pay a price for others' road use in the form of injury, illness, and death (Cohen & Hoffman, 2019; Frumkin, 2005). Disinvestment in local-facing public transit as well as the racial residential segregation legacy of urban renewal highway projects share blame for this crisis (Patterson, 2020). In the District, these disproportionate burdens of traffic violence are most evident in Wards 7 and 8. Wards 7 and 8 have the highest percentages of disabled residents, residents under 18 years old, and Black residents, and where they live is consistently the site of the highest volume of traffic fatalities in the District (Department of Parks and Recreation, 2022; DC Health, 2018; Lazo et al., 2022). An analysis of District census tracts found that tracts with higher proportions of Black residents have over two times the number of fatal/serious crashes than those with lower proportions of Black residents (Calder, 2023). In 2021, there were 40 traffic fatalities in the District and half of the victims were in Wards 7 or 8 (Pascale, 2022). Pedestrians also made up half of the victims (Pascale, 2022). Though the District launched its Vision Zero in 2014, as of December 2023 the District is not on track to meet its goal of zero traffic fatalities or serious injuries by 2024. In fact, the District just reached a 15-year high in deaths from traffic crashes, with 45 deaths so far in 2023, the highest since 2007 (Anderson, 2023).

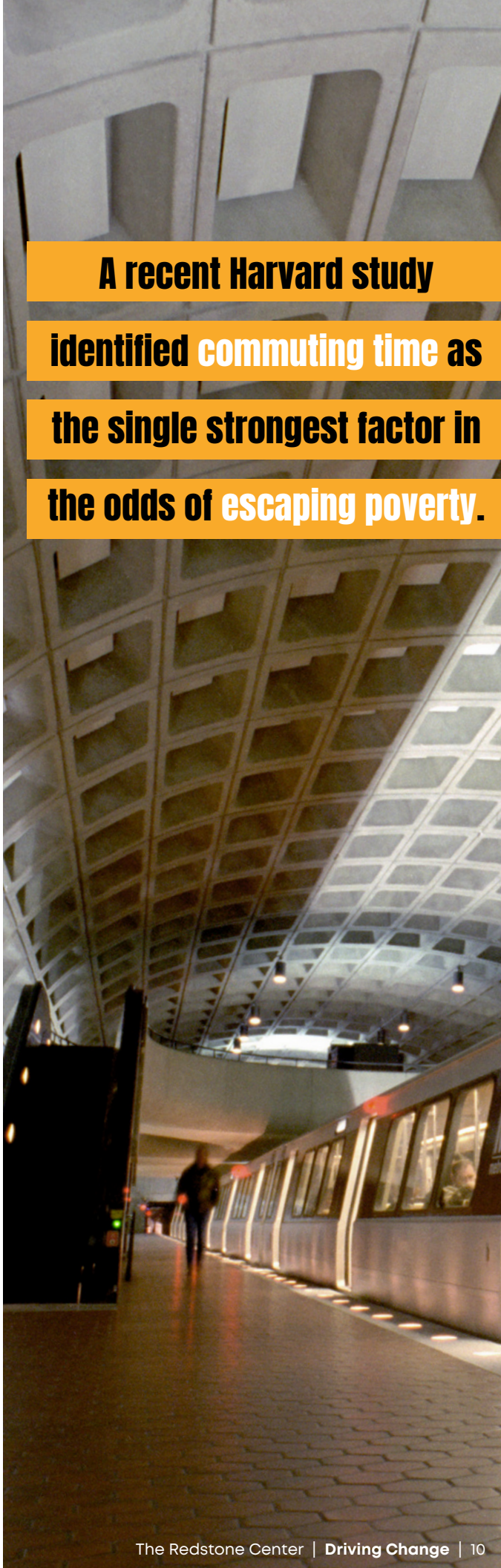
COMMUNITY HEALTH

In addition to traffic-caused injury and death, traffic and traffic violence have a secondary health effect: they limit safe access to public spaces and infrastructure, with adverse effects for community health (Hamann et al., 2020; Rigolon et al., 2017). In the Health Equity Report for the District of Columbia 2018, the District Department of Health (DC Health) recognized that 80% of community health outcomes are driven by social determinants of health, not the healthcare system (DC Health, 2018). These determinants, and therefore our health, are largely shaped by the places we live, work and play. Beyond just schools and workplaces, this includes parks, recreational facilities, grocery stores and markets, local businesses, and cultural touchstones. The transportation systems that surround and connect our built environments determine our access to these spaces as well as our relative safety within them.

Due to a history of prioritizing commuters in transportation planning, our highways, interstates, and urban roadways prioritize the quick passage of individuals driving at these peak times over any other mode or time of transportation, which can lead to unsafe local infrastructure (Governors Highway Safety Association, 2022; Greater Greater Washington, 2021; International Transport Forum, 2020; Smart Growth America, 2022). When highways are built through neighborhoods, such as the I-295 in Southeast DC, increased motor vehicle traffic not only increases local air pollution exposure, it also limits pedestrian safety and related opportunities for active transportation and other physical activity (Meyer and Leff, 2021; Sallis et al., 2011). Based on pre-COVID-19 pandemic transit data, 65% of DC neighborhoods are walkable and about 58% of commuter trips are by bike, walking, or public transit (DC Health, 2018). However, there is an unequal spread of accessible transit across the District. WMATA, rideshare and biking options abound in Ward 1 (where over 50% of households have a vehicle but 47.8% of residents commute via transit) and Ward 2 (where over 50% of households have a vehicle but 38.6% of residents commute via active modes) (DC Health, 2018). Access to public/active transportation and employment options decrease further out from the city center and the share of low-wage workers living in these neighborhoods increases (Begley et al., 2021; DC Health, 2018).

Decreased access to active modes of transportation (walking, biking, and public transit) is specifically linked to decreased physical activity (Kaufman et al., 2015). Physical activity prevents and mitigates diabetes and other chronic diseases (Skelly et al., 2020; United States Department of Health and Human Services, 2018). But more than 1 in 4 District residents report no physical activity – a rate notably higher than the national average (DC Health, 2018). Differences in access to safe means of physical activity across neighborhoods exacerbate health inequities. Thirty-eight percent of adults in Ward 8 report physical inactivity compared to just 6 percent in Ward 3 (DC Health, 2018). Prevalence of diabetes and cardiovascular disease are also highest in Wards 7 and 8 (DC Health, 2018). The Health Equity Report for the District of Columbia 2018 suggests that investments in public transportation, pedestrian, and bicycle infrastructure create opportunities for people to incorporate active exercise into their daily routines (DC Health, 2018).

These inequities in the District's public transportation system have additional far-reaching health impacts. The DC Department of Health has identified access to transportation as a key driver of health outcomes, due to its essential links to employment and other vital services (DC Health, 2018). Indeed, a recent Harvard study identified commuting time as the single strongest factor in the odds of escaping poverty (Chetty & Hendren, 2015). In the District, neighborhoods with low-wage workers have less access to bus and rail infrastructure and face higher commuting times (Begley et al., 2022). As the Metrorail system has been historically oriented to the needs of daily commuters from the suburbs, there is a significant mismatch in Wards 3, 4, 7 and 8 between the location of Metrorail stations and residential density (DC Health, 2018). When public transit, and the ability to safely walk and bike, are less accessible, devoting scarce resources to car ownership becomes a priority in order to provide access to essential goods and services. This is particularly evident in Wards 7 and 8, where only four full-service grocery stores and one hospital serve almost 150,000 residents facing the highest rates of unemployment and chronic disease in the District (DC Health, 2018; DC Health Matters, 2023; Jones and Simpson, 2023; Vilakazi and Collins, 2023).



ADDT'L. ENVIRONMENTAL HEALTH IMPACTS

In addition to contributing to and exacerbating a host of human health outcomes, traffic congestion also contributes to environmental degradation. Exposure to ozone has been shown to reduce photosynthesis, tree growth, and disrupt other physiological processes (Felzer et al., 2007). The National Park Service has released a series of growth loss maps for various tree species across the continental US, visually representing expected biomass loss due to air pollution exposures (National Park Service, 2018). Predicting tree biomass is important for a multitude of reasons, including estimating carbon storage and balance capacity, and considering shade cover, which is particularly important in urban centers such as DC (Li et al., 2020).

Even though environmental air and noise pollution impacts are most frequently cited when talking about traffic congestion, heavily utilized roadways also contribute to water pollution and contamination. A study published by Awonaike et al. (2022) found that a group of contaminate compounds detectable in rivers and streams in proximity to roadways, including polycyclic aromatic hydrocarbons, organophosphate esters, benzotriazoles, herbicides, have a common source: road surfaces. The study found a strong concentration between heavily trafficked roadways and higher chemical concentrations. Researchers discovered over 35 different contaminants in waterways, contaminants that are most commonly used in vehicle fluids, tires, paints, and vehicle furniture (Awonaike et al., 2022). Some of these contaminants, namely organophosphate esters, are linked with adverse reproductive health and birth outcomes, asthma and allergic disease, and neurodevelopment (Doherty et al., 2019). Furthermore, benzotriazoles are recognized for their properties of ecotoxicity due to their ability to accumulate in aquatic organisms (Health Canada, 2023).

Road traffic has also been linked to heavy metal deposits in soil. A study conducted by Athanasopoulou and Kollaros (2016) found that iron, copper, zinc, lead, cadmium, chromium and other non-volatile heavy metals, are frequently found in roadside topsoil, and in roots and leafage of vegetables and trees within 50 meters of roadsides. The researchers found a notable connection between an increase in concentrations of heavy metals relative to traffic density. Lead-contaminated soil is especially hazardous to children, known to cause developmental deficits such as IQ loss, hyperactivity, and learning disability (U.S. Environmental Protection Agency, 2020).

ROAD PRICING: A PUBLIC HEALTH SOLUTION

INTRODUCTION TO ROAD PRICING

Road pricing, also known as congestion pricing, is the practice of charging motorists [1] for driving on a particular roadway, or for driving or parking in a particular area. Often increased during peak periods, road pricing is a proven policy tool for reducing the concentration of vehicles entering and driving within a defined urban area, thereby relieving congestion. Road pricing schemes can include toll-based or non-toll based elements, and are often variable (higher prices under more congested conditions and lower prices under less congested conditions). More detailed information on types of road pricing mechanisms and their system descriptions can be found in Table 1. Aside from revenue generation (and more efficient and reliable trips for people who still choose to drive), benefits of road pricing implementation include improved air quality from reduced traffic, as well as traffic safety, environmental, and climactic improvements. When cities invest generated revenue back into transportation infrastructure, road pricing mechanisms can also promote active transport that can contribute to higher levels of physical activity, including walking, cycling, and the use of public transit.

Road pricing has been successfully implemented in cities including Singapore, London, Stockholm, and Milan, with impressive results for both environmental and human health. In the United States, New York City is on its way (as soon as Spring 2024) to becoming the first American city to implement a congestion pricing scheme, intended to reduce vehicle traffic, combat pollution, and invest in the city's public transit system (Kaske & Woodhouse, 2023).

In 2019, the D.C. Council directed the District Department of Transportation to conduct a study evaluating the potential benefits of congestion pricing for the District (District of Columbia, 2015). The report was required to be made public by July 2020 but as of November 2023 has not yet been released. By moving forward with a road pricing scheme for the downtown core, Washington, DC, has the opportunity to join the small circle of cities that have prioritized the health of their constituents, and drastically reduce the health and environmental impacts from traffic congestion. The following sections describe the potential health benefits of implementing an urban road pricing scheme.

TABLE 1: ROAD PRICING TOOLS, BROADLY

Toll-Based Model	Description
Congestion/Area Pricing	Charge for circulating within a defined are or zone as well entering it
Cordon Pricing	Charge every time a vehicle enters or exits a defined area or zone
Roadway Pricing	Charge for driving on a designated roadway
Lane Pricing	Charge for driving in designated lane on a designated roadway

Non-Toll-Based Model	Description
Priced vehicle sharing	Charge for renting a vehicle
Parking pricing	Charge for parking in designated areas
Vehicle miles traveled (VMT pricing / road user charge	Charge for each mile driven

[1] Because road pricing charges motorists directly for use of roads, it affects their decision of whether to use them. It is worth noting that motorists already pay indirectly for roads through taxes; the U.S. spends over $200 billion per year on roads and highways, constituting 6% of direct general spending (Urban Institute).

TABLE 2: GLOBAL ROAD PRICING STRATEGIES AND THEIR PUBLIC HEALTH IMPACTS

Developing and implementing a road pricing scheme in the District of Columbia will require the consideration of circumstances that are unique to the capital area. Each city that has implemented a road pricing scheme has identified and prioritized public health and economic benefits that contributed to the construction of a system that fits its needs and helps achieve its climate and health goals. These cities also continue to change their systems over time to best face new challenges and travel patterns, including vehicle electrification and commuter patterns during and after the COVID-19 pandemic.

	SINGAPORE, 1998	LONDON, 2003	STOCKHOLM, 2007	MILAN, 2012
PRICING TOOL	Electronic Road Pricing (ERP) scheme: Fully automatic on vehicle size, specific routes, times of day, and directions; price adjusts with congestion in real time	Congestion Charge zone (CCZ): 21 km2 in central London	Cordon pricing for going in/out of central city through a congestion price gate [as of 2020 there were 18 total]	Cordon pricing for "Area C" Cerchia dei Bastioni, a Limited Traffic Zone (LTZ) of 8.2 km2, 4.5% of the whole territory of the Municipality of Milan [36 entry points to Area C]
PRICES & EXEMPTIONS	ERP rates and charges are reviewed quarterly. As of August 2023, prices for different roads, directions, and times of day ranged from $0.00 to $6.00 SGD Exemptions: emergency vehicles, towed vehicles	As of 2023, £15 to enter the zone (has been raised by each Mayor over 20 years to continue the deterrent effect) Exemptions: Disabled drivers, emergency vehicles; exemptions for less polluting vehicles such as hybrids are being phased out Discount for residents of CCZ	Fees vary based on time of day. As of 2019, the highest peak cost per passage is $4.14 USD Exemptions: emergency vehicles, buses, motorbikes, mopeds, and drivers with disabilities Businesses can deduct the tax as a cost by notifying the Swedish Tax Agency	A daily entrance ticket costs €5, which covers all accesses made by the same vehicle during that day. You can also buy tickets for multiple days for 30 euros or 60 euros Exemptions: Mopeds, motorcycles, electric cars, vehicles for disabled people, public utility and public transport service vehicles, taxis, hybrid, methane-powered, LPG and biofuel cars Discount for residents of Area C and for commercial vehicles
PRIORITIES FOR REVENUE INVESTMENT	Revenues from ERP have supported public transit, street safety, and transit-oriented development (expanded the bus and rail system and constructed new intermodal transit hubs; a comprehensive bicycle and pedestrian network has been created with a focus on first-and-last mile connectivity projects)	Any income left after operating costs is reinvested in London's transport infrastructure	Tapping revenues from its congestion pricing scheme to raise funds for new metro lines that will service affordable housing developments	Revenue is cycled back into the mobility infrastructures and is used for creating bicycle lanes, pedestrian zones, and special speed zones
AIR QUALITY IMPACTS	GHG reduced by 10-15% within the inner city As of 2006, reduced traffic in the charging zone led to an 176,400 pound reduction in CO2 emissions and a 22 pound reduction in particulate matter	Significant decreases in airborne particulate matter (30-65%), achieving European legal limits for the first time Reductions in CO2 and NOx	As of 2016, observed post-pricing reductions of 14% in carbon dioxide (CO2), 7% in nitrogen oxide (NOx) and 9% in particulate matter Estimates show that there will be 20-25 fewer premature deaths per year in Stockholm's inner city	Significant reduction in concentrations of Black Carbon inside Area C compared to outside areas Observed 18% reduction of total particulate matter, 42% reduction in ammonia, 18% reduction in NOx, and 35% reduction in C02
TRAFFIC SAFETY IMPACTS	Original ALS system reduced vehicle crashes by 25%	Estimated 35% per month decrease in road traffic crashes in CCZ Observed 46.3% decrease in road traffic crashes in the CCZ and also observed significant decreases in non-charged areas adjacent to the charging zone	3.6% per year reduction in vehicle crashes in zone-based charging area	24% reduction of all road casualties has been observed between 2011 and 2012, to be compared with an 11% reduction city-wide during the same period
ACTIVE TRANSPORT GAINS	Despite strong population growth, the ERP has reduced traffic in the inner city by 24% (ALS had already reduced traffic by 45%), while bus and train ridership is up by 15% Funded extensive public transit improvements	As of 2016, 300 new buses; updated bus routes; improved frequency of buses; 8,500 park-and-ride spaces; bike/pedestrian infrastructure In central London, bus wait times fell by 30% and delays due to traffic congestion fell by 60% Even though London's population had grown over 20% since 2000, by 2019 trips by private car were 14.7% below 2000 levels, while public transport use, walking and cycling were all up	As of 2019, Stockholm added 197 new buses, 16 bus routes, 2,800 park-and-ride spaces, and built new bike/pedestrian infrastructure	As of 2015, polluting vehicles are circulating less in the area: their numbers have decreased by 49% (-2,400 vehicles daily) and the share of cleaner vehicles has gone from 9.6 to 16.6% of the total traffic

AIR & NOISE POLLUTION

Road pricing has the potential to address health disparities from air and noise pollution, with particular benefits for vulnerable populations including infants and children, those in proximity to roadways, and those living in populous urban areas. Evidence from cities that have implemented road pricing demonstrate that the reduction of vehicular emissions has the ability to reduce the risk of serious illness, such as asthma, bronchitis, and heart attacks, and equitably improve public health.

Notably, one of the attainable outcomes driving the continued implementation of road pricing in Stockholm was improved public health. Since the expansion of Stockholm's road pricing scheme, the city saw the largest reductions in traffic-related emissions, between 10-15%, in the inner city–the area which is also the most densely populated (Eliasson, 2014). It was estimated that this reduction in emissions would lead to 20-25 fewer annual premature deaths in Stockholm's inner city (total population of 600,000), a health-protecting effect that is roughly three times larger than would have been seen from alternative policy measures, such as a fuel tax increase (Eliasson, 2014). Additionally, a study conducted by Simeonova et al. (2018) evaluated the congestion tax in Stockholm and effects on air pollution and children's health. The authors found that NO2 levels fell by 15-20% and PM10 fell by 10-15% compared to pre-congestion tax levels, which was followed by a significant reduction in visits for acute asthma attacks among children (aged 0-5). In addition to these immediate improvements in acute asthma visits, the study also found that congestion pricing resulted in an overall decline in asthma rates by 15.2% among children. This highlights the dual improvements that road pricing can have for children: 1) limiting acute asthma attacks for those who already have asthma, and; 2) fewer children developing asthma over time.

In addition, a study conducted by Currie and Walker (2011) evaluated the effects of the adoption of EZ-pass, a road pricing mechanism, and its effects on infant health, and found that reduced congestion from toll pricing effectively reduced the incidence of premature mortality and low birth weight for those in proximity to the toll plaza by around 8 and 10%, respectively.

Other road pricing pilots in London, Singapore, and Milan also saw similar benefits in improved air quality and public health. According to a recent study, 1,888 extra years of life have been saved among London's roughly eight million residents who are now breathing cleaner air (Provonsha, & Sifuentes, n.d.). Furthermore, London's Low Emission Zone (LEZ) [2] yielded significant decreases in airborne particulate matter, between 30% and 65%, bringing airborne particulate matter within European legal limits for the first time (C40 Cities, 2016). Since the implementation of road pricing in 1998, Singapore has experienced a 10-15% reduction in carbon dioxide and other greenhouse gasses in its inner city, meeting air quality standards set by the United States Environmental Protection Agency (EPA) (Environmental Defense, n.d.; Provonsha & Sifuentes, n.d.). And Milan's 2012 adoption of Area C, a cordon pricing scheme, has led to significant reductions in concentrations of particulate matter (18% reduction), ammonia (42% reduction), and nitrogen oxides (18% reduction) within their restricted traffic zone (C40 Cities, 2015).

While not well studied, the reductions in traffic resulting from urban road pricing schemes are expected to lead to reductions in traffic-related noise, thereby decreasing noise pollution and its adverse health effects.

CARBON EMISSIONS

In several of the cities that have implemented them, road pricing mechanisms have contributed to the decline in overall greenhouse gas (GHG) emissions, including a 10-15% reduction in CO_2 emissions in Singapore's inner city, a 16% decline in London's CO_2 emissions, and a 14% reduction in CO_2 in Stockholm (Provonsha & Sifuentes, n.d.). It is anticipated that Stockholm's expansion of road pricing will confer an additional savings of 15-20,000 metric tons of CO_2 annually (C40 Cities, 2015).

London's Low Emmission Zone yielded significant decreases in airborne particulate matter.

[2] London's Low Emission Zone (LEZ) was implemented in 2008 and was further expanded to become an Ultra-low Emission Zone in 2019 (C40 Cities, 2016).

TRAFFIC VIOLENCE

Compelling data from Singapore, London, Stockholm, and Milan illustrate how road pricing can be a valuable tool for improving traffic safety and reducing injury and death from traffic violence in urban areas.

In 1975, Singapore pioneered the Area License Scheme (ALS), the first-ever cordon scheme. In addition to relieving congestion and improving air quality, the ALS system quickly reduced vehicle crashes by 25% (Environmental Defense, n.d.). London followed suit in 2003 with a Congestion Charge Zone for its center city. A scoping review of the safety implications of congestion pricing policies found that road traffic crashes decreased by an estimated 35% per month in the zone-based charge area following congestion pricing implementation (Singichetti, 2021). An additional London study observed significant decreases in road traffic collisions in non-charged areas adjacent to the charge zone (Ding et al., 2021). Transport for London (TfL) also estimated that, in the three years following implementation of the zone-based charging scheme, the scheme was responsible for the reduction of 40-70 additional injury crashes per year beyond the crash reductions already expected to occur due to separate road safety initiatives and a general declining trend in road traffic crashes (Transport for London, 2006). In Milan, there was a 24% reduction of all road casualties in the Area C congestion zone in the year following road pricing implementation, compared with an 11% reduction city-wide during the same period (C40 Cities, 2015). Furthermore, Stockholm saw a 3.6% annual reduction in vehicle crashes in their zone-based charging area (Eliasson, 2009).

In addition to decreases from road pricing itself, cities have invested revenue from road pricing schemes into traffic safety improvements. For example, Milan has directed revenue from the Area C congestion zone into mobility infrastructure to create bicycle lanes and pedestrian zones (Area C Milano, n.d.). Historically, many cities have relied on congestion itself as a stopgap to reduce fatal and injurious crashes on urban arterial roadways. However, given the harmful health effects of traffic congestion, traffic safety improvements are a far more health promoting solution. Traffic safety measures such as speed bumps and traffic circles,

building protected bike lanes and expanding sidewalks, and adding bollards, curb extensions, and chicanes are all strategies that can contribute to slower vehicle speeds and safer streets for all modes of transportation. Revenue from road pricing could be directed toward these safety improvements to further reduce traffic violence in the District.

A scoping review of the safety implications of congestion pricing policies also noted studies reporting increases in the number of cyclist injuries following road pricing implementation across different cities, due to mode shifts and increases in bicycle use (Singichetti, 2021). A Health Impact Assessment of a future road pricing scenario in San Francisco, CA, simulated driver-bicyclist and driver-pedestrian injury collision data up to ten years post-implementation. The study concluded that vehicle-bicyclist injury collisions would increase less than they would increase if the road pricing policy were not implemented, and that driver-pedestrian injury collisions would remain the same with road pricing (even with increased pedestrian traffic) but would increase 10% without it (Wier et al., 2011).

If the District expects a rapid increase in cyclists on our roadways, its traffic infrastructure should be prepared to promote safety for these users as well as the pedestrians and motorists around them. The District's road spaces could be better designed to promote safe sharing by different modes; this could include investing in traffic safety measures and providing more comprehensive traffic safety education for all users. When implementing a road pricing scheme, the District should also consider how drivers may reroute as a result. The scheme should be designed to reduce overall vehicle trips, rather than simply reroute drivers at existing VMT levels. It should also ensure that drivers are not encouraged to reroute to areas facing systemic transportation disinvestment, to prevent any increase in traffic violence risk for vulnerable road users in those areas.

EQUITABLE ROAD PRICING

Centering equity is the cornerstone of successful road pricing implementation. While Stockholm residents initially viewed the idea of road pricing as inequitable and unfair, after a seven-month congestion pricing pilot the city found that high-income individuals were affected more than low-income individuals, relatively few drivers paid the maximum of congestion charges (although they did pay occasionally), and young and low-income individuals benefited from lower transit fares (San Francisco County Transportation Authority, 2020).

Policy changes like road pricing will only be equitable if they don't penalize low-income families increasingly priced out of walkable neighborhoods near public transit and who are already spending a much higher percentage of their income on transportation (Cohen & Hoffman, 2019). Cities must employ thoughtful pricing structures and strategic revenue investment to ensure that road pricing does not restrict access to users. Similarly, if revenue goes to building new roads instead of enhancing other transit options, road pricing could lead to increased emissions and climate pollution (Cohen & Hoffman, 2019).

The District has the resources and ability to carefully design a road-pricing scheme that will achieve racially and economically equitable outcomes, especially given the severe problems of its current transportation networks. How to do so is the key focus of the 2020 study commissioned but not released by the District government.

HEALTHIER COMMUNITIES

Road pricing can also address systemic health inequities perpetuated, in part, by the inequitable built environments across the District's wards. Jurisdictions implementing road pricing systems have used these revenue structures to invest in public and active transportation, with additional benefits for public health. As one systematic review of low emission (LEZ) and congestion charging zones concluded, strategies that support both a reduction in private motorized vehicle traffic and increases in active travel and public transport use will likely yield the largest health benefits (Chamberlain et al., 2023).

IMPROVED PUBLIC TRANSPORTATION

Cities that have implemented road pricing typically invest the revenue in infrastructure for public and active modes of transportation and the enhancement of street safety. For example, Stockholm is tapping revenues to raise funds for new metro lines that will service affordable housing developments for its rapidly growing population (C40 Cities, 2015). At the launch of their congestion pricing program, Stockholm added 197 new buses (a 10% increase), 16 bus routes, 2,800 park-and-ride spaces, and built new bike/pedestrian infrastructure (Provonsha & Sifuentes, n.d.). Singapore has been investing revenues from their ALS and EPR systems in public transit, street safety, and transit-oriented development since 1975 (Provonsha & Sifuentes, n.d.). They increased bus and rail ridership by 15% by expanding these systems and constructing new intermodal transit hubs (Provonsha & Sifuentes, n.d.). They also created a comprehensive bicycle and pedestrian network with a focus on first-and-last mile connectivity projects (Provonsha & Sifuentes, n.d.). The initial ALS implemented in 1975 reduced vehicle traffic by 45%, and the ERP system reduced it by another 24% and increased vehicle speed despite significant population growth (Environmental Defense, n.d.; Provonsha & Sifuentes, n.d.).

In London, 300 new buses and 8,500 park-and-ride spaces were added within the first 13 years of congestion pricing implementation, with additional improvements in bus routes, frequency of buses, and bike/pedestrian infrastructure (Provonsha & Sifuentes, n.d.). These enhancements and reinvestments have contributed to a 30% decrease in bus wait times and a 60% decrease in traffic delay due to congestion in central London (Transport for London, 2004).

Moreover, by 2019, trips by private car were 14.7% below 2000 levels, while public transport use, walking, and cycling had all increased (C40 Knowledge Hub, 2022).

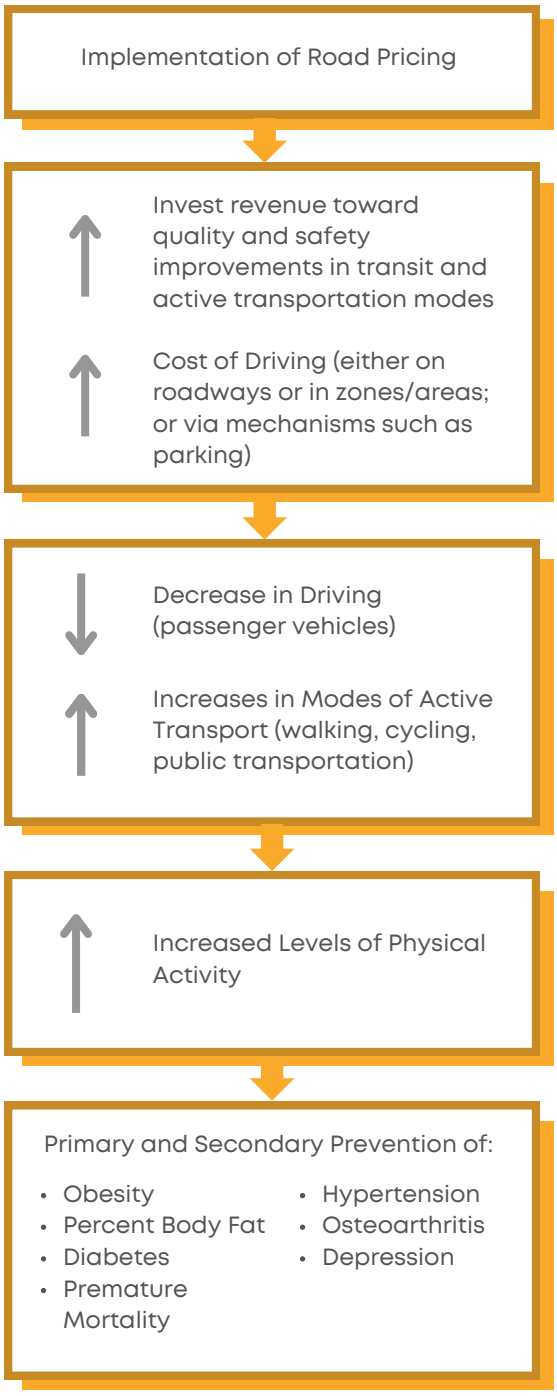
The District could similarly use road pricing revenue to finance its own public transit system and its expansion. Federal transportation funding continues to prioritize roads over public transit, yet estimates of traffic fatalities per mile in the U.S. suggest transport by Metrorail is 20 times safer and transport by bus is 60 times safer than driving (Litman, 2014; National Safety Council, n.d.). Metrorail expansions are the second-most costly infrastructure project in the region (second to highway express lanes) (Begley et al., 2022). WMATA's overall operating costs per District resident have increased since 2006 and operating costs per rail and bus trip "skyrocketed" during the pandemic (Begley et al., 2022). Road pricing would be a reliable revenue source to ensure that the District's public transportation system equitably serves all residents, with benefits for health through increased physical activity and connectivity.

INCREASED PHYSICAL ACTIVITY

Road pricing, when coupled with increased investment in public transportation and safer multimodal infrastructure, can also lead to shifts to healthier active transport modes and increased physical activity. A review evaluating the connection between congestion pricing schemes in London, Singapore, Stockholm, Milan, and Gothenburg and effects on physical activity found that there has been a limited recognition from researchers of the connection between transportation and health in these 'natural experiments' (Brown et al., 2015).

Though this connection between transportation and health has been underrecognized in cities with road pricing, the relationship between active transportation and improved health is well known. Transportation systems in which people predominantly travel by car lead to reductions in physical activity and increases in obesity (Swinburn et al., 2019). Such systems also impact the ways in which individuals traverse communities, interact in their social networks, and adopt behaviors (Swinburn et al., 2019). Switching from commutes by car to commutes by public or active transportation has been linked with reductions in body mass indexes (BMI) for some people (Flint et al., 2016). Furthermore, when compared with those who commute by car, individuals who prioritized active and public transportation had lower percentages of body fat and lower rates of diagnosed diabetes and hypertension (Laverty et al., 2015). Figure 1 presents a pathway by which the introduction of road pricing can lead to improved primary and secondary health outcomes.

Figure 1: Physical Activity Benefits of Road Pricing



Adapted from Brown et a. (2015)

INCREASED CONNECTIVITY

Road pricing can also improve accessibility and connectivity (Provonsha & Sifuentes, n.d.). Connectivity and accessibility are critical components to determining health. Individuals need to be able to access a variety of destinations, for example, grocery stores, health care services, schools and occupational settings, all of which contribute to overall well-being. In a study conducted by Hoehner et al. (2012), the authors found that long commute times contribute to decreases in physical activity, increased body mass indices, and increased blood pressure. Furthermore, a meta-analysis conducted by Ewing and Cervero (2010) found that increasing accessibility to jobs via public transportation reduced driving.

The District's current commuter-focused system creates transportation inequities. Since the COVID-19 pandemic began, Metrobus has retained higher ridership than Metrorail, showing that a reliable Metrobus system is particularly important for essential workers and for other trips perceived as necessary by residents. Half of Metrobus riders are low-income and 84% are people of color, and both these groups report having to walk farther and wait longer compared to white and/or higher-income residents (WMATA, n.d.). As noted in the District's Health Equity Report, transportation is a driver of health inequities in the District, as economic mobility, opportunities for social and economic success, and health itself can be dependent on transportation access, opportunities, and cost (Chetty et al., 2014). Transportation is the "connective tissue" that links us to opportunity, determining access to education and employment as well as health services and activities such as exercise, social connection, and restorative time in nature (Frumkin, 2005). Conversely, poor access to public transportation is linked to decreased income and higher unemployment (Kaufman, 2015). Increased investment in rail and bus service would achieve public health benefits through increased access to safe, reliable, and affordable transportation, allowing individuals and whole communities to enhance their health and quality of life.

CONCLUSION

The District of Columbia has set bold climate targets, including carbon neutrality by 2045. Significant mode shift away from vehicles toward active transportation is essential to achieving these goals. A road pricing scheme that manages demand for driving on urban roads, while also investing revenue into safe and equitable transportation infrastructure, has the potential to improve key public health outcomes in the District, such as reductions in adverse health effects from exposure to air and noise pollution, decreases in traffic-related injury and death, and improvements in transportation equity and community health. Pursuing a road pricing scheme in the District of Columbia would help the District further its climate, health, and equity-driven vision and demonstrate its leadership in prioritizing both climate and public health.

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About the Sumner M. Redstone Global Center for Prevention and Wellness
Located within the Milken Institute School of Public Health at The George Washington University, the Sumner M. Redstone Global Center for Prevention and Wellness recognizes that chronic disease, health inequities, and climate change are all interconnected and share common drivers. The Redstone Center works within the University and with community partners to support research, share expertise, and advance evidence-based policy solutions to address these interlinked public health threats.

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