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Congestion Pricing for Climate Capacity, or Communities?

Measuring the Environmental Justice Impacts of Congestion Pricing in Los Angeles

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Acronyms and Abbreviations Used

BRT	Bus Rapid Transit
CARB	California Air Resources Board
AB 32	California Assembly Bill 32
Caltrans	California Department of Transportation
SB 375	California Senate Bill 375
CO2	Carbon Dioxide
CO	Carbon Monoxide
CMS	Controlled Minimum Speed
GHG	Greenhouse Gas
GDP	Gross Domestic Product
EMFAC	Emissions Factor
EIR	Environmental Impact Report
HOT Lane	High-Occupancy Toll Lane
LA Metro	Los Angeles County Metropolitan Transportation Authority
MPO	Metropolitan Planning Organization
Mph	Miles Per Hour
NOx	Nitrogen Oxides
O3	Ozone
PM10	Particulate Matter less than 10 microns in diameter
PM2.5	Particulate Matter less than 2.5 microns in diameter
RTP/SCS	Regional Transportation Plan/Sustainable Communities Strategy
SCAG	Southern California Association of Governments
SO2	Sulfur Dioxide
USDOT	United States Department of Transportation
US EPA	United States Environmental Protection Agency
VMT	Vehicle Miles Travelled

Executive Summary

This research models vehicle travel and emissions in an effort to answer the question: **What are the potential environmental impacts of congestion pricing?**

Congestion pricing is a toll for driving on busy roads during peak hours with the intention of reducing traffic congestion. To measure how these policies might impact air pollution and community health, I built an emissions model using traffic data from the I-710 freeway, a polluted freight corridor in Los Angeles County which passes through many dense residential communities. I modeled Carbon Dioxide, a major contributor to global climate change, and Particulate Matter (PM 2.5), a component of vehicle exhaust responsible for increased rates of asthma, heart disease, and premature death in highway-adjacent communities, including those along the I-710.

My model found that **while trucks make up only 9.3% of trips on the corridor, they produce 33.8% of Carbon Dioxide emissions, and 84.1% of Particulate Matter emissions.** Automobiles are responsible for 62.6% of Carbon Dioxide emissions and 13.1% of Particulate Matter emissions on the corridor.

Based on modeling a hypothetical scenario of congestion pricing (with a controlled minimum speed of 40mph), I found that **congestion pricing could decrease Carbon Dioxide emissions from the I-710 corridor by 3,247 tons per day, and reduce peak-hour Particulate Matter emissions in congestion hotspots by 42%** (affecting communities such as Maywood, Bell, Commerce, Bell Gardens, and Long Beach).

Recognize Policy Conflicts

Automobiles produce the majority of Carbon Dioxide emissions on the I-710, while trucks produce the majority of Particulate Matter emissions. Priced lanes which are not open to all vehicle types will have a limited impact on total emissions. **Planners should find solutions which reduce emissions of all vehicle types.**

Prioritize Community Health

The health and environmental equity benefits from congestion pricing could be significant, but only if community health impacts are a project priority, rather than an afterthought. Transportation planners should take an "equity first" approach to congestion pricing.

Consider Changes in Behavior

Any form of congestion pricing will likely impact travel behavior and vehicle miles traveled (VMT). Some traffic may "spill-over" onto unpriced streets. **Planners should avoid projects that simply redistribute VMT and emissions to other areas and corridors.**

Plan Priced Lanes for Transit

Priced lanes should be prioritized as transit lanes which private vehicles can use for a fee. Implementation of congestion pricing should coincide with an expansion of regional bus rapid transit networks (such as the Metro Silver Line).

Use Revenue for Equity Goals

Congestion pricing would generate significant revenues. **These revenues should be used to increase public transit availability, promote vehicle electrification, and subsidize low-income drivers who would be most negatively impacted by priced lanes.**

Introduction

On February 28, 2019, the LA Metro Board of Directors voted unanimously to pursue a feasibility study of congestion pricing in Los Angeles County. Earlier that same month, the City and County of San Francisco voted to pursue a similar study for its downtown area. Less than a month later, the State of New York passed a budget with a plan to implement congestion pricing in lower Manhattan. As cities across the country move forward with studying and implementing congestion pricing projects, residents and policymakers are beginning to ask: What will the impacts be, and who will benefit?

While most of the discussions around congestion pricing focus on economic outcomes, this report focuses on the potential environmental and community health impacts of congestion pricing. Can reducing congestion lead to fewer emissions and improved health? This research uses the I-710 freeway, a polluted freight corridor in Los Angeles County, as a case study on the environmental justice impacts of congestion pricing.

What is Congestion Pricing?

Congestion pricing charges drivers a toll for using particular road segments during congested parts of the day. The price of the toll usually depends on the road's level of congestion, or the time of day (the toll is higher during more congested times, and lower during less congested times). The goal of congestion pricing is to reduce vehicle congestion in several ways by incentivizing carpooling, shifting driving to less congested times of day, and encouraging other modes of transportation such as public transit. Congestion pricing programs have been implemented in a number of cities across the globe including London, Singapore, Milan, and Stockholm.

In implementation, congestion pricing mechanisms include corridor pricing, facility pricing, and cordon pricing. Corridor pricing charges a toll to drive on specific roads or lanes. Facility pricing charges a toll when a vehicle passes through specific infrastructure such as a bridge or tunnel. Cordon pricing charges a toll to enter a designated area, such as a downtown district (Orr & Rivlin 2009). These forms of congestion pricing have different uses and goals and it is likely that a combination of pricing mechanisms can be useful to achieve congestion-reduction.

In additional to reducing traffic congestion, pricing can also have the effect of reducing vehicle emissions from congested roads. However, existing studies often lack a complete understanding of the impacts of congestion pricing on the environment, air quality, and community health. There is also limited research on how implementations of congestion pricing might promote environmental justice for communities who are most affected by freeway emissions.

What is Environmental Injustice?

Environmental injustice can be defined as the disproportionate exposure of low-income communities and communities of color to the health effects of pollution, as well as the unequal environmental protection provided through laws, enforcement, and policies (Maantay 2002). Put simply, the worst impacts of pollution often fall on disadvantaged communities who are least protected from these impacts.

Environmental justice, on the other hand, is the effort to prevent, remedy, and fight against patterns of environmental injustice. The environmental justice issues present in Los Angeles have been well-documented, particularly in communities near the ports and the I-710 freeway (Houston, Krudysz, and Winer 2008). Lower-income individuals are not only more likely to live near sources of pollution (because home values and rents are often lower in these areas), but are also less likely to have access to services (such as healthcare) to mitigate the health impacts of pollution, and are less likely to have the social and political capital necessary to fight against the effects of pollution through policy and regulation (Maantay 2002).

There are many ways that Los Angeles could advocate for environmental justice, including reducing harmful pollution in freeway-adjacent communities. If congestion pricing could reduce emissions by smoothing the flow of traffic from Los Angeles' most polluted freeways, congestion pricing policies could play a role in healing past injustices and promoting equity in the region's most vulnerable communities.

Research Question

Given the legacy of environmental injustice in Los Angeles, and the potential of congestion pricing to reduce emissions in communities most affected by pollution, this research seeks to answer the question: **What are the potential environmental justice impacts of congestion pricing on the I-710 corridor?** This research measures freeway vehicle emissions to quantify environmental justice impacts.

Using existing traffic and emissions data from the I-710 Freeway in Los Angeles County, this research models vehicle emissions under current conditions, as well as under hypothetical scenarios of congestion pricing to determine the potential emissions and environmental justice impacts of congestion pricing.

Study Area: the I-710 Corridor

This research focuses on the I-710 Freeway in Los Angeles County to better understand the relationship between congestion pricing and environmental justice. The I-710 is the primary freight corridor for the Los Angeles region, carrying over 32,000 trucks per day (Houston, Wu, Ong, and Winer 2006). The I-710 connects the Ports of Los Angeles and Long Beach to the south, intermodal rail yards to the north, and warehouses throughout the region.

The I-710 and surrounding communities (Image Source: LA Metro)

Equity and environmental justice are major concerns along the corridor. There are over 500,000 people living within one mile of the I-710 . These areas are predominantly working class communities of color, with 74% identifying as Latino or Hispanic (Human Impact Partners 2011). These communities are also exposed to dangerous levels of diesel particulate matter, a harmful form of pollution which has been directly tied to a number of serious health conditions (Currie and Walker 2011). Due to these high levels of exposure, the communities along the I-710 currently have the highest risk for cancer, heart disease, and childhood asthma in the region (Houston, Wu, Ong, and Winer 2006). Community exposure to pollution will only get worse as freight traffic along the corridor is expected to increase significantly over the coming decades.

The California Department of Transportation (Caltrans) has proposed widening the I-710 to reduce traffic congestion through increased capacity, though this plan has been met with strong criticism from environmental and community groups. Another option for reducing traffic is implementing congestion pricing. While the primary goal of congestion pricing proposals is reducing congestion, pricing may also significantly reduce vehicle emissions. In these cases, congestion pricing could be used as an environmental justice tool to improve the health in freeway-adjacent communities.

Congestion Pricing and Emissions

Congestion pricing can reduce vehicle emissions on freeways by limiting stop-and-go conditions that cause vehicles to accelerate, stop, and idle repeatedly. Vehicle engines operate more efficiently and produce fewer emissions at a constant speed than in stop-and-go conditions.

While vehicle emissions contain a toxic cocktail of pollutants, this research focuses on two specific pollutants: Carbon Dioxide and Particulate Matter 2.5.

Carbon Dioxide

Carbon Dioxide (CO_2) is common greenhouse gas (GHG) produced by all gasoline and diesel burning vehicles. According to the California Air Resource Board (CARB), transportation is responsible for 41% of the state’s CO_2 emissions. Despite a number of California state laws mandating a reduction in GHG emissions in all sectors, CO_2 emissions per capita from vehicles continue to increase. California’s climate regulators warn that the state will not be able to meet its 2030 goal of cutting CO_2 emissions 40% below 1990 levels without a major turnaround in the transportation sector (California Air Resources Board 2018).

Particulate Matter 2.5

Particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) is a byproduct of vehicle combustion engines. $PM_{2.5}$ not only contributes to poor air quality throughout the Los Angeles region, but is particularly devastating for residential communities living near congested freeways. $PM_{2.5}$ has been tied to low infant birth weights, increased rates of childhood asthma, increased incidence heart disease, and even premature death (Currie and Walker 2011). The communities along the I-710 corridor suffer from the highest concentrations of $PM_{2.5}$ in the Los Angeles region.

Reductions in vehicle emissions after the introduction of priced lanes have been observed in San Diego, London, Stockholm, and Singapore.

Reducing vehicle emissions on priced corridors in Los Angeles would not only cut down on the region's GHG pollution, but would also benefit communities living adjacent to freeways who currently suffer from health complications stemming from roadways emissions.

Intermodal rail yards (pictured above) and other industrial facilities contribute to freight traffic and PM2.5 emissions along the I-710 corridor. (Image Source: LA Metro)

Literature Review

Vehicle Speed, Traffic Behavior, and Emissions

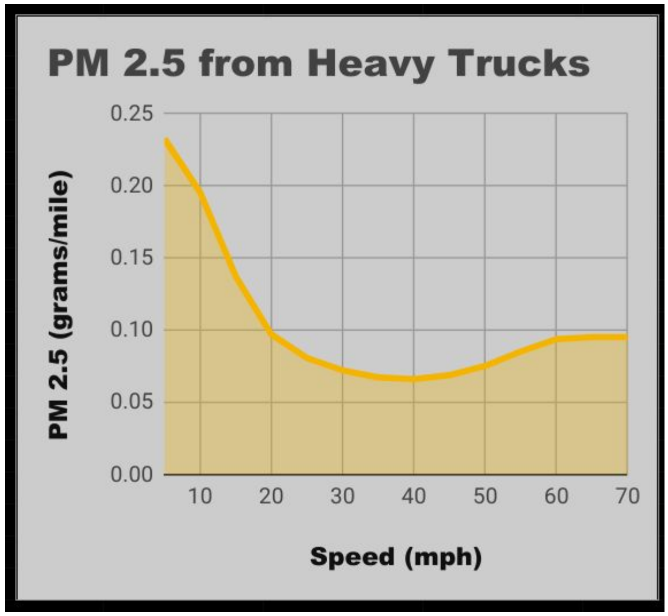
The impacts of congestion pricing on emissions are highly dependent on the conditions of the individual project, but existing research does highlight relationships between corridor speeds, traffic cycles, and vehicle emissions. Under an ideal scenario, congestion pricing could reduce emissions by increasing vehicle speeds and maintaining a free flow of traffic compared to congested traffic conditions.

Emissions and Vehicle Speed

Existing research has documented that very low traffic speeds generally cause higher levels of emissions per mile. Under congested conditions, average traffic speeds can fall significantly. This causes vehicles to take more time to travel an equivalent distance, increasing the total emissions per mile traveled. Additionally, most vehicle engines are less efficient at very slow speeds (10-30 miles per hour), which further increases emissions per mile. One study observed an increase in emissions when congestion caused average vehicle speeds to fall below 45 miles per hour (mph) in a freeway modeling scenario (Barth and Boriboonsomsin 2009). Similar research found that during periods of low speeds, even a small increase in speeds (e.g. 10 mph) could result in a significant reduction in emissions (Barth and Boriboonsomsin 2008). This suggests that if congestion pricing could increase the slowest freeway speeds above a certain speed threshold, vehicle emissions per mile would decrease.

However, while increasing average freeway speeds from the worst levels of congestion can reduce emissions, some minor congestion on freeways can also reduce emissions when average speeds are much higher. For instance: if moderate vehicle crowding brings average speeds down from 70 mph to 50 mph, this slowing can actually reduce emissions (Barth and Boriboonsomsin 2009). This is because maintaining a high speed is more demanding for most vehicle engines, resulting in less efficient fuel use, and ultimately higher tailpipe emissions per mile. (Barth, Sorca and Younglove 1999). This is especially important when considering an ideal minimum speed for congestion pricing programs. Increasing average speeds from 20 mph to 40 mph will likely reduce emissions, but increasing average speeds from 40 mph to 70 mph may actually increase emissions.

Speed (mph)	PM 2.5 from Heavy Trucks (grams/mile)
5	0.233
10	0.196
15	0.137
20	0.097
25	0.081
30	0.072
35	0.067
40	0.066
45	0.069
50	0.075
55	0.085
60	0.094
65	0.095
70	0.095



Emissions per mile by vehicle speed

In the above charts, data from CARB demonstrate the relationship between speed and emissions. Notice how emissions per mile are highest at very low speeds, lowest at mid-range speeds, and increase once again at the highest speeds. This relationship suggests that efforts to reduce maximum vehicle speeds, such as lowering speed limits, could also reduce emissions; however the goal of congestion pricing projects is almost always to increase minimum speeds, rather than to reduce speed maximums.

Emissions and Traffic Cycle

Average speeds alone do not paint a complete picture of congestion conditions or associated emissions. Two roads may have the same average speed, but very different emission profiles depending on their levels of congestion. For example, traffic on Road A may be operating at a steady speed of 30 mph, while vehicles on Road B may experience brief bursts of travel at 50 mph punctuated by frequent stops. Both roads may have an average speed of 30 mph, but Road B will likely have a higher level of emissions (Burt, Sowell, Crawford and Carlson 2010).

The cycle of braking, idling, and accelerating in heavy congestion is called the ‘traffic cycle’. Shorter traffic cycles result in more braking, idling, and accelerating per mile. Short traffic cycles increase total emissions for a number of reasons, including increased demand on vehicle engines from acceleration, increased periods of idling, and increased wear on tires and brakes (which produce non-tailpipe particulate matter emissions). Free-flowing traffic avoids these short traffic cycles, and therefore produces fewer emissions compared to stop-and-go traffic conditions (Burt, Sowell, Crawford and Carlson 2010). If congestion pricing can maintain a steady flow of traffic and reduce cycles of braking, idling, and accelerating, vehicle emissions per mile should decrease.

Trucks produce the greatest amount of emissions per mile in congested conditions.
(Image Source: LA Metro)

The Relationship Between Speed and Traffic Cycle

While free-flowing traffic produces fewer emissions than congested traffic at an equivalent average speed (Barth, Sorca and Younglove 1999), these effects are greatest when freeway congestion results in average traffic speeds around 10 to 30 mph. In these conditions, CO2 emissions can be reduced by almost 45% if traffic is smoothed to a steady-state (Barth and Boriboonsomsin 2008). Research using typical traffic conditions for Southern California found that if congestion pricing could be combined with other traffic-management strategies, such as variable maximum speed limits, total CO2 emissions could be reduced by approximately 30% (Barth and Boriboonsomsin 2009).

Effects of Congestion Pricing on Emissions and Health

Reductions in vehicle emissions after the introduction of priced lanes have been observed in San Diego, Minneapolis (Burt, Sowell, Crawford and Carlson 2010), London, Stockholm, and Singapore (Percoco 2015). While emissions in the priced zones fell in all cases, emissions in nearby zones increased in a few cases. This phenomenon, known as the ‘spillover effect’, occurs when driving and congestion increases in non-priced areas as a result of drivers choosing alternative routes to avoid the congestion fees.

After congestion pricing was implemented in central London, the overall traffic emissions of Nitrogen Oxides (NOx) fell by 13.4 percent, particulate matter less than 10 microns in diameter (PM10) fell by 15.5 percent, and CO2 fell by 16.4 percent (Burt, Sowell, Crawford and Carlson 2010). Levels of Ozone (O3) and Sulfur Dioxide (SO2) also fell in the priced district. However, there was an increase in the concentration of O3, PM2.5, and PM10 outside of the priced area, likely due to spillover effects. The congestion charge was determined to have “limited impact” on the net concentration of pollution across the entire city (Percoco 2015). It is important for planners to recognize that some implementations of congestion pricing might only redistribute congestion and pollution away from the priced zone to other areas of the region.

Reductions in vehicle emissions as a result of congestion pricing have been measured in London, pictured above. (Image Source: Engineering and Technology Magazine)

The urban core of Stockholm experienced a similar reduction of emissions after the implementation of its congestion pricing program. Researchers observed a 10-14% reduction in CO_2, 7% reduction in NO_x and a 9% decrease in harmful particulates. (Bhatt, Higgins, and Berg 2008)

Minneapolis, Minnesota has not implemented a congestion pricing cordon zone like London or Stockholm, but the city did add a high-occupancy toll lane (or HOT lane) to an existing freeway. This project, known as MnPass, allows single-occupancy vehicles to pay a toll to bypass congested general purpose lanes. High-occupancy vehicles can use the lane for free. The MnPass program reduced VOC, Carbon Monoxide (CO), NO_x, CO_2, and PM_{10} up to 14% without substantial impact on the air quality on alternative routes (Burt, Sowell, Crawford and Carlson 2010).

Emissions reductions from removing congestion have also been shown to have clear benefits to human health. One such case was observed with the implementation of E-Z Pass across the northeastern United States. Before E-Z Pass, all vehicles queued at tolling plazas, idling while waiting to pay their toll. E-Z Pass gave drivers the option to pay tolls electronically through a transponder device without stopping. E-Z Pass not only cut down on travel times for drivers, but also reduced vehicle emissions around toll plazas. This reduction in emissions had a direct impact on human health as the incidence of low infant birth weight (a known health effect of PM2.5) fell by 8.5–11.3 percent for communities near the toll plazas (Currie and Walker 2011).

Equity and Environmental Justice Concerns

While congestion pricing can be an effective policy to decrease traffic congestion and vehicle emissions, critics argue that it is not an equitable solution. A common criticism is that priced lanes provide an option for the wealthy to escape congestion while the less well-off must still suffer through traffic (Prasch 2004).

However, proponents of congestion pricing argue that priced lanes are actually socially progressive in nature. To drive, one needs to be able to afford a car and the associated costs: insurance, maintenance, gas, etc. Low-income individuals are less likely to own a car and often rely on public transportation, therefore many do not necessarily benefit from access to free roads. Michael Manville and Emma Goldman highlight this relationship, arguing that “free roads might be more accurately described as a subsidy to the affluent that *some* poor people enjoy” (Manville and Goldman 2017).

A study of Stockholm’s congestion pricing program found that “men, high-income groups and residents in the central parts of the city” would bear the greatest financial burden from the introduction of congestion pricing (Eliasson and Mattsson 2006). However, these groups may also have the most flexibility to make changes in their work commuting patterns, as compared with female commuters and low-income workers (Giuliano 1994).

An evaluation of Minneapolis's MnPASS program did not find any significant correlation between demographics and project benefits. The evaluation found that beneficiaries of the HOT lane included diverse populations across "all income, age, race/ethnicity, employment, and mode usage groups" (Burt, Sowell, Crawford and Carlson 2010).

There is considerable academic discussion and popular concern over issues of equitable access and exclusion from freeways due to congestion pricing, but there is a less-nuanced understanding of the environmental justice impacts of congestion pricing. Communities living adjacent to freeways in Los Angeles County have some of the highest rates of heart disease and childhood asthma in the region, likely due to pollution from vehicles (State of California Department of Transportation 2008). If congestion pricing could reduce vehicle emissions in these communities, the environmental justice benefits would be significant.

CO_2 emissions do not have an immediate health impact on exposed populations, but should nonetheless be considered an environmental justice concern. CO_2 is a primary contributor to global climate change, which will reshape the Earth's climate and ecosystems in yet unknown ways. The Intergovernmental Panel on Climate Change warns that climate change will be particularly devastating to "disadvantaged and vulnerable populations, [and] indigenous peoples" (Masson-Delmotte et al. 2018). Seen in this light, reducing vehicle emissions from congestion should be a goal of environmental justice

activists at both the local and global scales.

Communities adjacent to the I-710, such as the City of Bell, pictured above, suffer the most direct environmental and health impacts of the freight corridor.
(Photo taken by author)

Congestion and Economic Impacts

The economic impact of traffic congestion is difficult to measure given that congestion is itself the product of economically desirable areas. A 2015 study analyzing the impact of congestion on the location of new businesses found that “proximity does a great deal more work in accounting for neighborhood-level access to destinations than does speed” (Mondschein, Taylor, Osman 2015). The most congested areas of cities are also the most desirable because of their high densities and levels of activity (Mondschein, Taylor, Osman 2015).

However, congestion almost certainly has a negative effect on regional economies. In 2014, traffic congestion imposed an estimated $160 billion drag on the U.S. economy, or around 0.9% of total gross domestic product (GDP) (Schrank, Eisele, Lomax, and Bak 2015). Other estimates claim that traffic congestion generates a cost as high as 2 to 3% of U.S. GDP per year (Cervero 1988). Congestion pricing might be able to reclaim some of this time and productivity lost to congestion.

Technological Solutions

In addition to congestion pricing, another popular approach to reduce freeway emissions is through promoting cleaner vehicle fuel technologies such as natural gas and electric batteries. The communities adjacent to the I-710 corridor have specifically advocated to replace diesel trucks with electric trucks. Electric vehicles have zero tailpipe emissions, and depending on the source of electricity, generally emit less CO2 per mile travelled compared to vehicles powered by fossil fuels. Emerging research also suggests that electric vehicles and other "advanced powertrain" vehicles may perform more efficiently in congested conditions compared to conventional internal combustion engine vehicle due to their ability to recapture energy through braking (Bigazzi, Clifton, and Gregor 2015).

While electric vehicle technology can have a significant impact on emissions, adoption of new technologies is slow, especially for heavy duty trucks, whose diesel engines can last up to thirty years (Houston, Wu, Ong, and Winer 2006). A 2018 report by CARB concluded that the state of California could not meet its 2030 GHG reduction goals in transportation with new vehicle technologies alone. The report stated that even if sales of zero-emission vehicles increase tenfold, the state would still need to reduce vehicle miles traveled per capita by 25% to meet the 2030 goal (California Air Resources Board 2018). Policies which change driving behavior, such as congestion pricing, could help close this gap in GHG reductions in the near term (Barth and Boriboonsomsin 2008). It is also worth noting that electric vehicles are generally heavier due to the weight of batteries, and this increased weight can result in higher levels of particulate matter from brake and tire wear compared to non-electric counterparts (Timmers and Achten 2016).

Effects of Congestion Pricing on Vehicle Miles Traveled

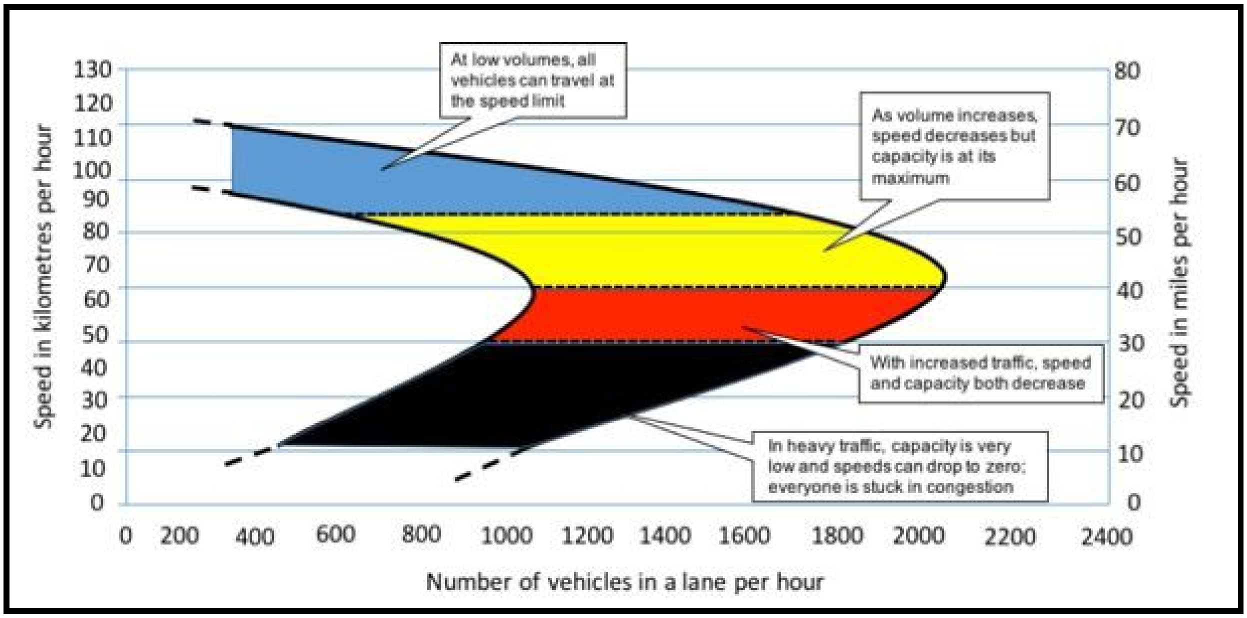
The Backward Bending Curve

A key to understanding the effect of congestion of traffic conditions is a phenomenon described by transportation planners and engineers as the "backward bending curve" (Jonathan Hall 2013). The backward bending curve graphs the relationship in road speeds (e.g. miles per hour) and corridor flow rates (e.g. vehicles per hour).

When there are only a few vehicles on a freeway, all vehicles can travel at their top speeds, for instance 60-70 mph. Even though the vehicles are moving very quickly, there aren't very many vehicles on the corridor, so the overall flow rate is comparatively low (e.g. 200 vehicles per hour).

As more vehicles enter the freeway, speeds begin to fall as traffic becomes slightly congested. Vehicles may be traveling at a reduced speed of 50 mph, but there are many more vehicles on the freeway than when speeds were higher. This results in a higher flow rate for the corridor (e.g. 1,000 vehicles per hour).

As even more vehicles enter the freeway, speeds plummet, and severe congestion reduces the free flow of traffic to stop-and-go conditions. The freeway is completely packed with vehicles crawling at an average of 20 mph. In these conditions, even though there are more vehicles on the road than there were at 50 mph, the number of vehicles per hour that can cross the corridor falls back to a similar rate as when there were only a few very fast cars on the freeway (e.g. 200 vehicles per hour). This rise and fall of flow rates as compared with speed is the backward bending curve.



A hypothetical view of the backward bending curve of traffic congestion by Kurt Naas (accessed from corneliuscornerblog.wordpress.com)

If congestion pricing along a very congested freeway could increase vehicle speeds, it's possible that congestion pricing could also improve the corridor flow rate (moving back up the backward bending curve). Fewer vehicles would be able to enter the freeway at a given time, but the vehicles on the freeway would be moving faster, opening up space for other vehicles to enter behind them. If corridor flow rates improve dramatically throughout the day, it's possible that the congestion pricing strategy might counterintuitively increase vehicle miles travelled (VMT) along the corridor over a 24-hour period. An increase in VMT has a beneficial effect for corridor efficiency and regional economy, but could have significant environmental costs (Komanoff 1997). It's also possible that corridor VMT might increase while regional VMT might stay steady or decrease, as the congested corridor pulls travelers from other roads in the region.

A well-implemented congestion pricing program could also reduce emissions while increasing flow rates and daily VMT by keeping traffic at a free flowing controlled speed, but planners should be wary of congestion pricing strategies that maximize flow rates and VMT without considerations of emissions and environmental effects.

Triple Convergence and Emissions

In addition to the backward bending curve, another important concept for understanding traffic congestion is called triple convergence. Triple convergence describes the phenomenon of traffic demand on a corridor rising to meet new supply (e.g. new roads or infrastructure). For example, a state department may try to reduce congestion on a freeway by building additional lanes thus increasing the freeway's capacity. This may reduce congestion in the short term but eventually drivers will notice the improvement and start driving at peak times rather than off peak, start driving rather than taking transit, or start driving on the newly upgraded freeway rather than more congested alternatives. This "triple convergence" eventually results in a freeway with more lanes, but with the same levels of congestion as before the new lands were added (Downs 2004).

Increasing public transit services has a similarly negligible effect on VMT and congestion, as any freed up capacity is consumed by additional driving (Handy and Boarnet 2014). This undermines the promises made by transportation planners to reduce congestion through new public transportation investments. Unless tackled directly through strategies like pricing, traffic congestion is here to stay.

Congestion Pricing and Land Use

It's also important to consider how a congestion pricing program will affect future land use and development patterns. Economic modeling predicts that although some firms may be motivated to decentralize to avoid priced areas, the overall effect of congestion pricing would be an increase in both employment and residential density near the center “to reduce the burden of tolls on commuting and shopping travel cost” (Anas and Xu 1999). If congestion pricing could increase density in urban centers, its emissions benefits may be complemented by a reduction in suburban sprawl and habitat destruction.

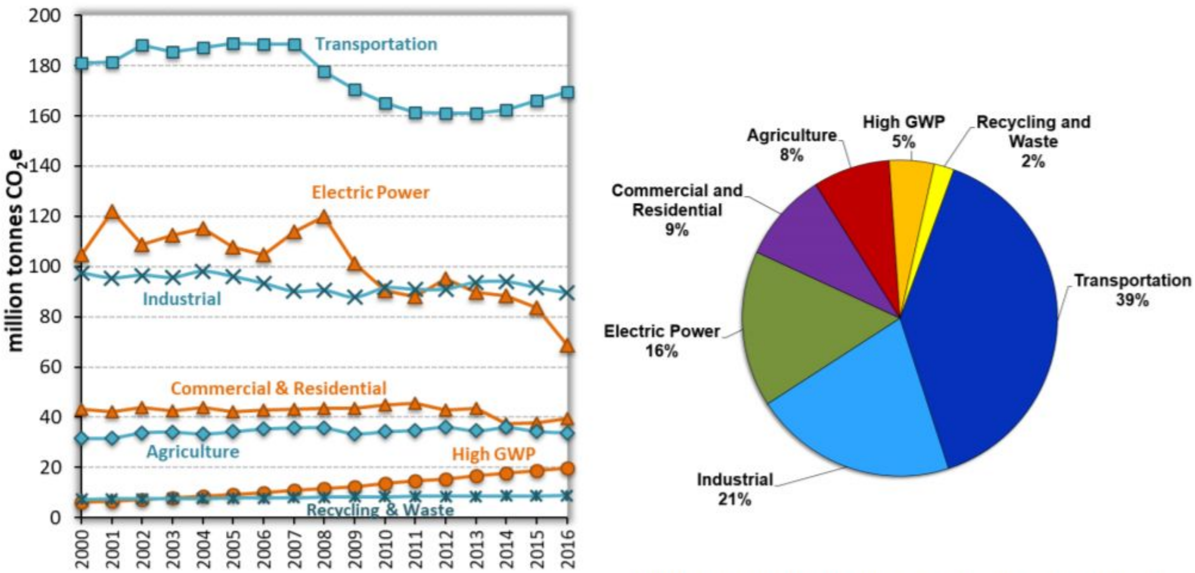
Policy and Politics

Greenhouse Gases

In California there are numerous laws and policies at the state and local level that regulate vehicle emissions, especially emissions of CO_2 and other GHGs. California Assembly Bill 32 (AB 32) was the nation's first law governing GHG emissions, and gives CARB authority over sources of GHGs, including cars and light trucks. In 2008, AB 32 was followed by Senate Bill 375: Sustainable Communities and Climate Protection Act (SB 375). SB 375 followed AB 32's lead, focusing on regional housing and transportation, and directed CARB to engage cities, counties, and Metropolitan Planning Organizations (MPOs) in the process of creating GHG goals (Institute for Local Government 2011).

Empowered by SB 375's mandate, the Southern California Association of Governments (SCAG) published the Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS) in 2012. SCAG's RTP/SCS GHG targets are to achieve a 9% reduction in transportation emissions by 2020 and 16% reduction by 2035 compared to the 2005 level on a per capita basis. (Southern California Association of Governments 2016).

While California is on-track to meet its 2020 GHG reduction goals, regulators warn that major improvement is needed in the transportation sector in order to meet the state's 2030 goals (Dillon 2018). Transportation currently accounts for almost 40% of California's GHG emissions, and while other sectors have been able to reduce their GHG emissions, GHGs from transportation have actually been rising since 2013 (California Air Resources Board 2018). There is also a need for better GHG data, modeling, and evaluation for the state to meet the goals of SB 375. The science of emissions measurement and modeling is relatively new and far from perfect (Matute 2011), especially in accounting for the contributions of traffic and varying levels of congestion (Barth and Boriboonsomsin 2009).



Above Left: Trends in California GHG emissions. Emissions from Transportation have been rising since 2013.
Above Right: 2016 GHG emissions by sector. Transportation makes up 39% of GHG emissions.
(Image Source: California Air Resources Board)

Congestion Pricing in Los Angeles County

Potential congestion pricing strategies have been debated in Los Angeles for decades, but progress toward realistic congestion pricing projects has been stalled by a lack of popular support and a breakdown of trust between local and regional governments (Manville and King 2012). Despite these political barriers, the United States Department of Transportation (USDOT), CalTrans, and the Los Angeles County Metropolitan Transportation Authority (LA Metro) created the ExpressLanes pilot program in 2008. ExpressLanes are HOT lanes on the I-110 and I-10 freeways which serve as a pilot for congestion pricing in Los Angeles

County. The ExpressLanes are also used by LA Metro's Silver Line Bus Rapid Transit (BRT) route to bypass freeway congestion. For instance, when Metro Silver Line buses shifted to HOT lanes, not only did bus speeds improve, but also bus ridership increased (Pessaro 2015).

LA Metro ExpressLanes during peak-hour traffic (Image Source: Los Angeles Magazine)

Recently, the LA Metro Board of Directors has been seriously considering congestion pricing at a number of board meetings. In 2018, LA Metro CEO Phil Washington announced, "We think that with congestion pricing done right, we can be the only city in the world to offer free transit service in time for the 2028 Olympics" (Chiland 2018). Despite voiced concerns around equity and the availability of quality public transit alternatives, the LA Metro Board voted unanimously on Feb 28, 2019, to pursue a study on the potential outcomes of congestion pricing in Los Angeles County (Chiland 2019).

Methods

In order to better understand the potential environmental benefits of congestion pricing along the I-710 corridor, I built an emissions model to quantify levels of CO2 and PM2.5 emissions under present conditions without congestion pricing, as well as under hypothetical conditions of congestion pricing. I compared emissions before and after congestion pricing scenarios to understand to what degree pricing could affect corridor emissions. I also compared five separate hypothetical scenarios of congestion pricing to determine the ideal implementation of pricing to minimize emissions.

To model vehicle emissions based on traffic conditions along the I-710 corridor, I combined traffic model outputs from SCAG with Emissions Factor (EMFAC) data from CARB.

Data Acquisition

In response to my request for information, SCAG provided model data from the I-710 corridor for the year 2018. SCAG's data breaks the I-710 into distinct segments (62 segments for southbound traffic, and 66 segments for northbound traffic) and reports traffic behavior data for each segment based on five times of day (AM peak, Midday, PM peak, Evening, and Night). Traffic data included: flow volumes based on vehicle type (automobiles, light trucks, medium trucks, and heavy trucks), average speeds in miles per hour, and length of each segment in miles. These data were created from the SCAG 2012 Regional Travel Demand Model, which is used by SCAG and other governments in the region to model traffic.

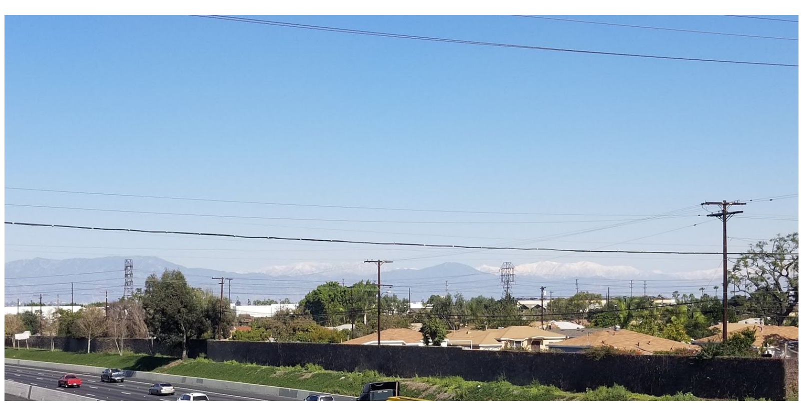
I accessed emissions factor data through CARB's EMFAC2017 Web Portal at https://www.arb.ca.gov/emfac/2017/. I downloaded data from the portal using the following parameters:

- Data Type: Emission Rates
- Region: County, Los Angeles
- Calendar Year: 2018
- Season: Annual
- Vehicle Category: EMFAC2011 Categories, All
- Model Year: Aggregated
- Speed: All Speeds
- Fuel: All

These data provided emissions factors (in grams per mile traveled) for key pollutants including CO_2 and PM 2.5 based on vehicle type and vehicle speed.

EMFAC outputs report emissions for over fifty vehicle sub-categories, but SCAG only used 4 vehicle categories (automobiles, light trucks, medium trucks, and heavy trucks). In order to translate EMFAC's vehicle sub-categories into SCAG's vehicle categories, I created composite, or averaged, emissions factors for each of SCAG's four vehicle types. For example: EMFAC reports emissions factors for LDT1, LDT2, LHD1, and LHD2 vehicles; however, all of these vehicle sub-categories fall under SCAG's Light Duty Truck category. I averaged emissions of LDT1, LDT2, LHD1, and LHD2 (weighted by the percent of total VMT each sub-category accounted for) to create a composite Light Duty Truck emissions factor. These composite emissions factors can be found in Appendix B: Composite Emissions Factors.

A note on buses: while both EMFAC and SCAG give data for busses,



busses account for less than 0.1% of emissions and less than 0.1% of vehicle trips on the I-710 corridor. For this reason I decided to omit busses from this model.

Many types of vehicles use the I-710 freeway, but heavy duty trucks are responsible for the majority of particulate matter emissions. (Photo taken by author)

Emissions Modeling

Using vehicle counts and corridor traffic speeds provided by SCAG, and emissions factors based on speed from CARB, I modeled emissions of the I-710 over the course of a day using the formula below:

$$\sum_{k,v,t,p} (E_p(S_{k,v,t}) \; * \; N_{k,v,t} \; * \; L_k)$$

Where:

E = emissions (grams per mile) per vehicle as a function of vehicle speed (S)

S = average speed (miles per hour) of vehicles on a segment by time of day

N = the number of vehicles on the segment by vehicle type and time of day

L = the length of the segment in miles

And:

k = segment of the I-710 (62 segments Southbound, 66 segments Northbound)

v = vehicle type (automobile, light truck, medium truck, or heavy truck)

t = time of day (AM peak, Midday, PM peak, Evening, or Night)

p = type of pollutant (CO2 or PM2.5)

The output of this model simulates emissions of both CO2 and PM2.5 from the entire I-710 freeway over the course of a 24 hour period.

This model and methodology replicates methods of existing research, including the methods used by Gan, Sun, Lin, et al. of UC Berkeley in their

2011 paper “Incorporating Vehicular Emissions into an Efficient Mesoscopic Traffic Model”. The authors validated their model against TransModeler software and found that their simplified emissions model yielded emissions results comparable to the more complex modelling software with fewer inputs needed and less computational time required.

While this model simulates the complex relationships between vehicle types, vehicle speeds, and vehicle emissions, it is not a perfect predictor of exact emissions and should not be taken as such. I have used a comparatively simple formula to model very complex interactions and, like all models, this model has significant limitations in predicting accurate counts of real-world emissions. For instance, the traffic data I use from SCAG are not observations, but rather the outputs of SCAG’s own traffic demand model. These data are yearly averages, they are not lane specific or day/week specific. Any assumptions or errors in SCAG’s data will affect my own model outputs. Similarly, I rely on 2017 emissions factor data from CARB. CARB updates its emissions factor data every few years based on research and it is possible that the emissions factors I used may overestimate or underestimate certain kinds of emissions.

It’s important to keep in mind that "All models are wrong, but some are useful" (George Box 1979). While this model is not perfect, it can still be used to understand general trends and relationships between vehicles and emissions on the I-710.

Finally, it is worth noting that this research focuses primarily on the effects of average vehicle speeds on tailpipe emissions. CARB’s EMFAC provides data for emissions based on vehicle speed but not based on traffic cycle (the cycle of acceleration, braking, and idling). CARB also does not provide data on particulate matter emissions from tires and brakes based on average speed (they are currently studying these effects). A model which took into account effects of the traffic cycle as well as the impacts of particulate matter from brakes and tires would likely predict much higher levels of emissions, especially in high levels of congestion.

Simulating Congestion Pricing

In order to simulate the impacts of potential congestion pricing projects on vehicle emissions, I created hypothetical traffic behavior scenarios using the model described above. The hypothetical scenarios use the same data and equations as the baseline scenario, with the introduction of a controlled minimum speed (CMS).

A CMS assumes that a congestion pricing program would be able to ensure that average vehicle speeds never fall below a predetermined threshold. For example: in a scenario with a CMS of 40 mph, all segment speeds that are below 40 mph in current conditions would be adjusted up to 40 mph. Segment speeds at or above 40 mph would not be altered. In order to understand the relationship between speed and emissions, I modeled emissions using 5 CMS thresholds: 20 mph, 30 mph, 40 mph, 50 mph, and 60 mph.

This methodology of simulating congestion management by adjusting traffic speeds up to a certain threshold replicates the methods of Barth and Boriboonsomsin of UC Riverside in their 2009 publication “Traffic Congestion and Greenhouse Gasses”. In a personal communication on November 21, 2018, Professor Kanok Boriboonsomsin of UC Riverside acknowledged that this method of simulating congestion pricing has limitations, but the methods were ultimately accepted and validated by an extensive peer review process.

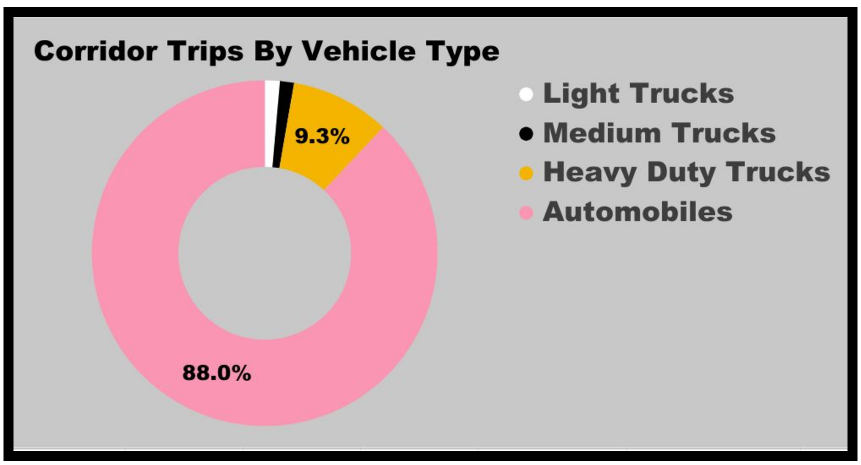
One limitation of Barth and Boriboonsomsin’s methods is that real-world congestion pricing would be unlikely to ensure that vehicle speeds never drop below 40 mph. Another limitation is that the hypothetical model does not take into account that congestion pricing would likely reduce the number of vehicles entering the freeway at peak times. However, this dynamic might be balanced out by improved flow rates (a greater number of vehicles per hour) on the corridor as a result of congestion pricing.

This methodology also does not take into account potential “spillover” effects from congestion pricing, such as drivers taking alternative routes, or vehicles queuing and idling in neighborhoods near freeway onramps. Like all traffic models, this simulation cannot fully account for the complicated impacts of congestion pricing on traffic behavior and emissions, but it can still yield useful data and shed light on the relationship between traffic speeds and vehicle emissions

Findings

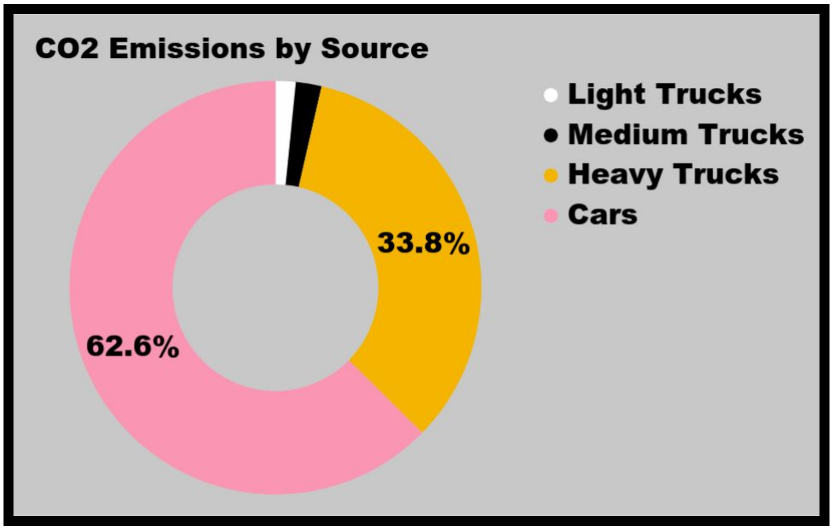
Finding #1 : Present Conditions and Sources of Emissions

Modeling existing conditions of traffic and emissions on the I-710 freeway reveals a number of insights about travel behavior on the corridor. A breakdown of flows by vehicle type shows that 88% of all trips are made by automobiles, and 9.3% of trips are made by heavy duty trucks. Light and medium trucks account for many fewer trips on the corridor, 1.4% and 1.3% respectively.

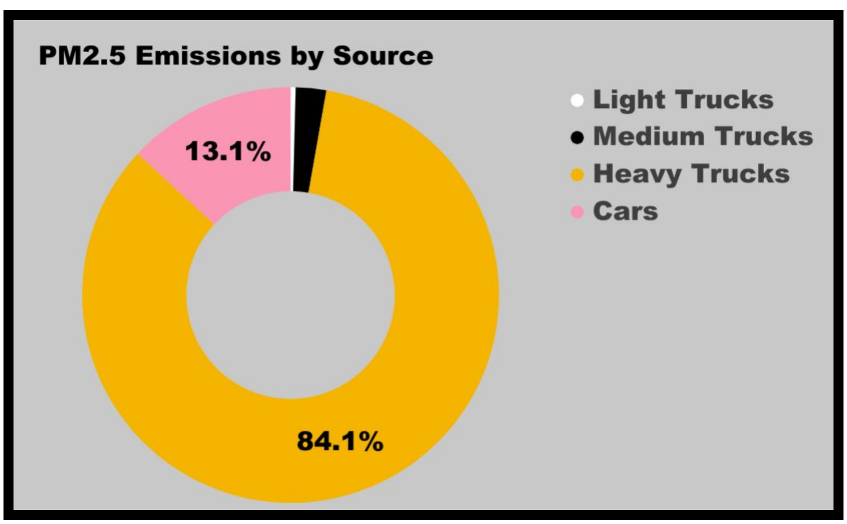


Despite heavy duty trucks representing only 9.3% of trips on the corridor in SCAG's traffic demand model, they account for a disproportionate amount of emissions. This is unsurprising given that engines of heavy duty trucks are much larger and generally carry heavier loads than other vehicles.

The analysis of CO_2 emissions along the corridor finds that automobiles produce 62.2% of CO_2 emissions, and heavy duty trucks produce 33.8% of CO_2 emissions. Light and medium trucks combined produce less than 4% of CO_2 emissions on the corridor.



Heavy duty trucks produce 84.1% of PM2.5 emissions and automobiles produce 13.1% of PM2.5 emissions along the corridor. Light and Medium trucks combined produce less than 3% of PM2.5 emissions on the corridor. The comparatively small number of heavy duty trucks produce such a large percentage of total particulate matter due to the nature of diesel engines and combustion.



These observations have a number of implications for policymakers. It is important to recognize that even though heavy duty trucks only make up 9.3% of corridor trips in SCAG's model, they account for 84.1% of the PM2.5 pollution which significantly impacts local health. For this reason, policies that focus on heavy duty trucks (such as truck electrification, or a dedicated freight corridor for trucks that could ensure free-flow travel conditions) are likely to have the greatest impact on PM2.5 emissions. If congestion pricing policies include only automobiles and not trucks (such as the current Metro ExpressLanes program), there will be a very limited resulting impact on PM2.5 emissions.

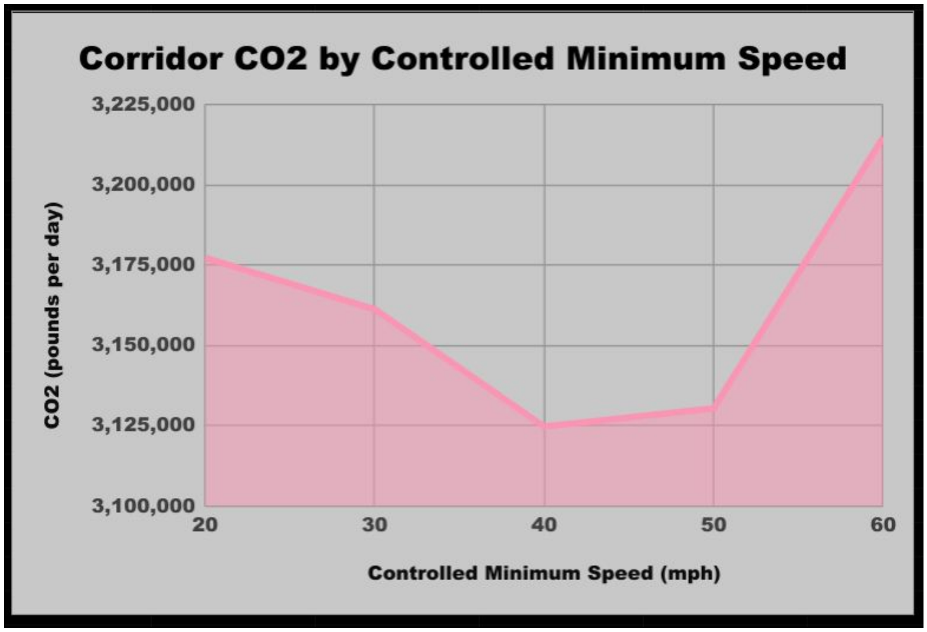
However, focusing policies exclusively on heavy duty trucks ignores the fact that 62.6% of corridor CO2 emissions are produced by automobiles. If policymakers want to significantly reduce CO2 emissions on the I-710 corridor, they must take automobiles into account. In order to reduce PM2.5 *and* CO2 emissions on the corridor, policymakers should consider interventions that affect both automobiles and heavy duty trucks.

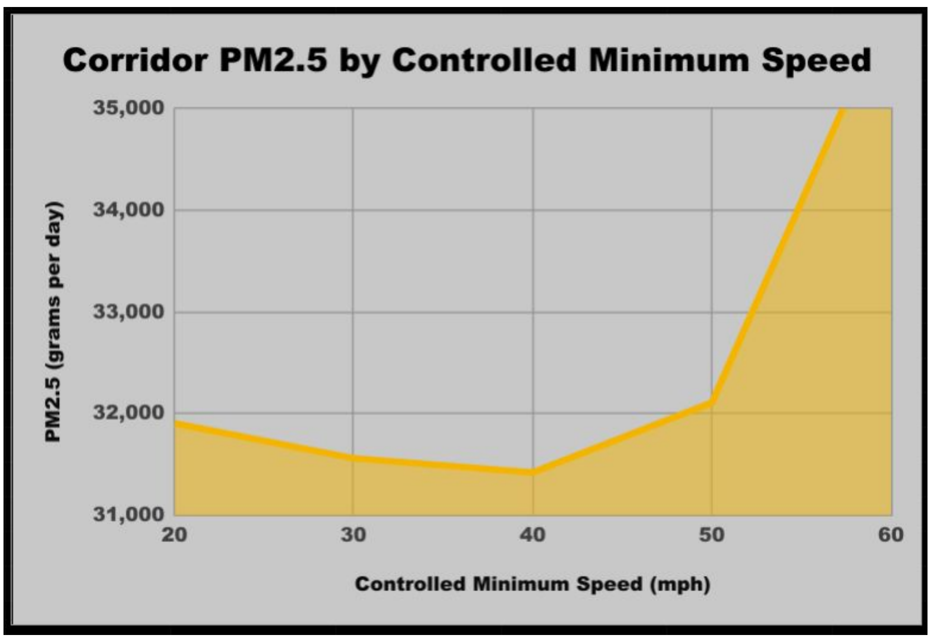
Finding #2 : Emissions Based on Controlled Minimum Speed

In order to understand how congestion pricing might affect emissions on the I-710, I created hypothetical scenarios of freeway traffic with a controlled minimum speed (CMS). I assume that a well-implemented congestion pricing program could ensure that vehicles speeds on the freeway never fall below a set threshold. For instance, a CMS of 40 mph would maintain a minimum speed of 40 mph. If average speeds begin to fall below 40 mph, the congestion pricing system could raise the toll to enter the corridor (a method known as dynamic pricing), or simply prevent new vehicles from entering until speeds return to 40 mph. A CMS does not affect maximum speeds, only minimum speeds. This CMS concept is similar to LA Metro's ExpressLanes practice of maintaining a minimum speed of 45 mph (ExpressLanes 2017).

I created hypothetical scenarios for five CMSs (20 mph, 30 mph, 40 mph, 50 mph, 60 mph) as described in the Methods section above. Emissions of PM2.5 and CO_2 follow a similar trend based on a hypothetical CMS.

A very low CMS such as 20 mph has very little impact on congestion because corridor average speeds rarely fall below 20 mph. Furthermore, vehicles operating at these low speeds produce higher amounts of emissions per mile compared to higher speeds. As the CMS moves from 20 mph, to 30 mph, to 40 mph, emissions of both CO_2 and PM2.5 fall as the most congested traffic speeds up and engine efficiency improves. At a CMS of 50 mph, emissions rise compared to a CMS of 40 mph. With a CMS of 60 mph, emissions of CO_2 and PM.25 rise sharply.





Comparison of CO2 and PM2.5 emissions based on five hypothetical controlled minimum speeds

Based on these hypothetical scenarios, the corridor produces the lowest emissions of both CO2 and PM2.5 when a CMS of 40 mph is enforced. Put another way, a congestion pricing system which could ensure that traffic speeds never fall below 40 mph would result in the greatest reduction of CO2 and PM2.5 emissions.

Why is 40 mph the magic number? It just so happens that automobiles (which produce 62.6% of CO_2 on the corridor) are most CO_2 efficient (producing the least amount of CO_2 per mile travelled) at 40 mph, and heavy trucks (which produce 84.1% of PM2.5 on the corridor) are most PM2.5 efficient at 40 mph.

Speed (mph)	CO2 from Automobiles (grams/mile)	PM 2.5 from Heavy Trucks (grams/mile)
5	689	0.233
10	558	0.196
15	457	0.137
20	380	0.097
25	325	0.081
30	288	0.072
35	267	0.067
40	**259**	**0.066**
45	260	0.069
50	268	0.075
55	277	0.085
60	285	0.094
65	293	0.095
70	308	0.095

The 40 mph "sweet spot" can be seen more clearly in the emissions factor table above.

This research suggests that if policymakers want to minimize the CO_2 and PM2.5 emissions on the I-710 corridor through congestion pricing, they should create a system that encourages average speeds of 40 mph. Policymakers should also be cautioned that if congestion pricing brings minimum speeds on the I-710 up to 50 mph or 60 mph, the corridor will likely produce more emissions than it would at a CMS of 40 mph. This may present a policy conflict if traffic engineers find that a CMS of 50 or 60 mph would generate the highest level of vehicle throughput (flow in vehicles per hour). However, it's also possible that a CMS of 40 mph would generate the highest level of throughput, in which case corridor efficiency could be maximized while CO_2 and PM2.5 would be minimized, a win-win-win.

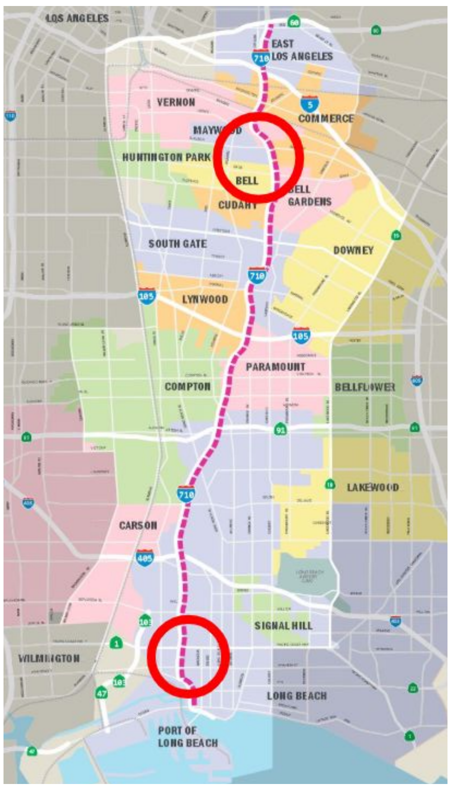
Finding #3: Impacts of a Controlled Minimum Speed of 40 mph

If a CMS of 40 mph would have the greatest impact on vehicle emissions, how large could these reductions be? Because the methods used in this research do not model exact amounts of emissions, but rather the relationship between vehicle behavior and emissions, it is hard to predict the exact amount of reductions, but general trends and relationships can still be observed. It's also important to note that this research only accounts for emissions reductions from controlling speed and not from smoothing traffic. It is likely that smoothing traffic from stop-and-go conditions of congestion to a free-flow would yield significant emissions reductions for both CO2 and PM2.5 at all speeds. Furthermore, this research only focuses on tailpipe emissions, and not PM2.5 emissions from tire and brake wear. Congestion pricing interventions which reduce cycles of braking and accelerating would further reduce these emissions.

With these caveats in mind, my research compares the emissions predicted at a CMS of 40 mph against the emissions from current conditions. A CMS of 40 mph produced a reduction in total CO2 of 1.65%, and a reduction in total PM2.5 of 1.51%. These numbers may seems small at first glance, but it is important to put them into perspective.

For instance, the I-710 corridor currently produces about 196,770 tons of CO2 per day (Human Impact Partners 2011). A 1.65% decrease in CO2 due to congestion pricing would result in a decrease in 3,247 tons of CO2 per day. The United States Environmental Protection Agency (US EPA) estimates that a typical automobile emits 4.6 tons of CO2 per year, or 0.0126 tons per day (United States Environmental Protection Agency 2018). Thus, a 3,247 ton per day decrease in CO2 emissions is equivalent to the emissions of about 257,698 cars. This estimate would almost certainly be greater if the effects of traffic smoothing from congestion pricing were taken into account.

And while this research only predicts a 1.51% decrease in PM2.5 over the course of a day from congestion pricing, the localized health impacts of PM2.5 necesitate further analysis. A CMS of 40 mph would reduce PM2.5 during peak traffic hours of 3pm to 7pm, when people are mostly likely to be outside, and most vulnerable to PM2.5, by 4.95%.



PM2.5 hotspots are highlighted in red above. (Base image source: LA Metro)

Average emissions along the entire corridor can be misleading, as some segments of the corridor carry less traffic and produces few emissions, while other segments are heavily congested and produce much higher levels of emissions. A 'hotspot' analysis of the most congested segments of the freeway during the most congested times of the day reveals a 42% decrease in PM2.5 in hotspot areas during peak times. Communities affected by emissions from these hotspots include Maywood, Bell, Commerce, Bell Gardens, and Long Beach.

Policy Considerations

This research suggests that congestion pricing programs can have a significant impact on freeway emissions, but the degree of impact depends greatly on the conditions of the corridor, and how congestion pricing would be implemented. I have identified five policy considerations that transportation planners and policymakers should be aware of when considering congestion pricing and freeway emissions.

1. Recognize Policy Conflicts

There may be inherent policy conflicts in designing congestion pricing projects. Planners should be clear about goals and priorities of their projects, and be aware of the trade-offs of policy decisions. For instance, if planners want to prioritize CO_2 reduction to meet state goals, they may focus policies only on passenger cars, which are the primary source of CO_2 from transportation. This strategy would have minimal impact on reducing $PM_{2.5}$, which is most harmful to freeway-adjacent communities. However, if planners prioritize $PM_{2.5}$ reduction to improve community health, they may focus only on heavy duty trucks, which produce the vast majority of $PM_{2.5}$ on freeways. This strategy would have a limited impact on reducing CO_2 and GHG emissions. Instead of focusing narrowly on only one form of pollution, planners should pursue holistic policies that affect both passenger cars and heavy duty trucks. Holistic approaches, such as corridor-wide congestion pricing, could have an impact on both CO_2 and $PM_{2.5}$.

There may also be a policy conflict in determining an ideal speed for congestion pricing. While increasing average speeds through congestion pricing can reduce vehicle emissions on a congested corridor, increasing speeds too much may result in higher emissions. The ideal speed to maximize throughput on a freeway might higher than the ideal speed to minimize emissions. Planners and engineers should discuss this conflict, and be careful not to use congestion pricing to maximize freeway capacity at the cost of increasing total emissions.

2. Prioritize Community Health

While modeling freeway traffic and emissions may seem like a primarily technical exercise, it is critical that planners engage and collaborate with communities living adjacent to polluted freeways. This practice not only gives a voice to disadvantaged communities, but is also important for sustained public support for projects.

When Caltrans released a draft environmental impact report (EIR) with plans to expand the I-710 freeway in 2008, community groups were shocked and concerned about the increased traffic and pollution from the corridor as well as the displacement that expansion would cause. Community groups collaborated with elected officials, traffic engineers, emissions experts, and academic researchers to push back against the Caltrans EIR and advocate for community preferred alternatives, including a zero-emissions freight corridor using electric trucks (Cortez 2019). A more detailed analysis of the I-710 EIR and proposed community alternative can be found in Appendix C: Analysis of I-710 EIR.

Planners too often overlook the environmental needs of vulnerable communities, prioritizing regional emissions GHG reductions rather than targeting localized pollution and health impacts. Planners should incorporate community health impact assessments into all major environmental and transportation decisions to protect vulnerable communities and regain public trust.

Communities near the I-710 have been fighting against pollution and injustice for decades. (Image Source: East Yard Communities for Environmental Justice)

3. Consider Changes in Driving Behavior

A major limitation of this research is the assumption of no change in VMT or travel patterns along the corridor and throughout the region. Congestion pricing would almost certainly change VMT and travel patterns depending on how and where pricing is implemented. Policymakers should thoroughly consider how potential pricing projects might affect regional VMT, travel, and the associated emissions.

Congestion pricing is traditionally viewed as an economic incentive against driving during peak times. In this way, pricing could be a tool to smooth traffic congestion, encourage individuals to take transit, and reduce automobile dependance. However, congestion pricing on a particular corridor might also encourage drivers to simply take alternate routes, rather than drive less or take transit. In this case, regional VMT and emissions are not reduced but merely redistributed. Planners should be wary of the environmental and equity impacts of this redistributed, or spillover, VMT.

It is also important to consider that heavy duty trucks have very different transportation needs and behaviors than passenger vehicles. Planners cannot assume that truck drivers will respond to priced corridors in the same way as commuters. This is especially important on freight corridors like the I-710. Similarly, planners should recognize that priced lanes which are only open to passenger vehicles (such as LA Metro's ExpressLanes) will not enable trucks to avoid congested conditions, and would therefore have limited impact on diesel particulate matter emissions.

4. Plan Priced Lanes for Public Transit

Rather than framing priced lanes as automobile infrastructure which public buses use occasionally, congestion priced lanes could be seen as dedicated lanes for transit vehicles which private automobiles can access for a price. Currently, most BRT lines operate in lanes closed to private automobiles. These lanes keep buses out of congestion, but are empty and unused when no buses are present. What if transit agencies could generate revenues and increase overall mobility from this excess capacity without slowing down transit vehicles? Priced BRT lanes represent such an opportunity.

One example of a BRT line sharing dedicated lane space with automobiles is the LA Metro Silver Line, which operates on the I-110 freeway. Starting in 2008, The Silver Line began using ExpressLanes (priced lanes) to traverse the corridor while avoiding traffic congestion. The result of this program was a significant increase in both speed and ridership on the SilverLine (Pessaro 2015).

I recommend the success of the Silver Line be replicated across Los Angeles. Currently LA Metro's buses operate in heavy congestion during most of the day, and this is only getting worse. Average bus speeds fell by 13% from 2005 to 2017 (Freemark 2017). Hybrid BRT / priced lanes could provide high-quality transit service while also relieving congestion for passenger vehicles.

The Silver

Line uses ExpressLanes to avoid congested freeways.
(Image Source: LA Metro)

5. Use Revenues for Equity Goals

Congestion pricing would likely generate significant revenues from road tolls. Phil Washington, CEO of LA Metro, has suggested that region-wide corridor pricing could generate as much as $52 Billion annually (Martin 2018). Investing these revenues in new roads or additional freeway lanes would likely increase regional emissions, but there are many other uses for this revenue which could reduce regional pollution while helping to mitigate the impacts of freeway emissions on nearby communities.

For instance, revenues could be used to pay for or subsidize electric trucks. Transitioning from diesel trucks to electric trucks would dramatically reduce emissions of PM2.5, and would likely reduce regional CO2 emissions as well. The degree of improvement in regional CO2 emissions would depend on how the electricity used by electric trucks is generated.

Revenues could also be invested in improved public transit service in the area around the priced corridor. This might reduce dependence on driving by providing high-quality alternatives. Some portion of revenues could be used on community health mitigations, such as installing air filters at schools. Finally, revenue from pricing could be used to help subsidize the cost of driving for low-income individuals who depend on driving and would be disproportionately burdened by congestion pricing. Policymakers could provide driving discounts for low-income families in the same way that transit agencies provide reduced transit fares for low-income individuals.

Conclusion

It is an exciting time for advocates of congestion pricing in Los Angeles. From LA Metro's recent decision to study congest pricing feasibility, to SCAG's 2019 "Go Zone" pricing feasibility study, to Richard Bloom's and Scott Wiener's Assembly Bill 3059 proposal in the California Legislature, it seems the metaphorical planets are aligning at the local, regional, and state levels to open new possibilities for congestion pricing policies.

But there is still reason to be wary. The economic, equity, and environmental justice impacts of congestion pricing projects depend greatly on how these projects are implemented. It's encouraging that LA Metro is moving forward with a study on the equity issues of congestion pricing, but community engagement and proactive planning must begin before the conversation gets bogged down in territorial politics.

My research suggests that congestion pricing could create significant reductions in local and global emissions while simultaneously reducing traffic congestion and improving corridor throughput. My modelling predicts that 40 mph would be the ideal controlled minimum speed to reduce CO_2 and PM2.5 on the I-710 corridor, but congestion pricing is not "one size fits all." Thoughtful analysis and community assessment must be conducted to fully understand the impacts of pricing on a specific corridor or zone.

Transportation planners have traditionally thought of congestion pricing first and foremost as a way to reduce traffic congestion, but this research provides evidence that if congestion pricing projects are designed to reduce vehicle emissions, they can have significant environmental and community benefits. I believe that the emissions and health benefits from congestion pricing should not be viewed as a side-effect of potential projects, but should be prioritized alongside traffic reduction when designing congestion pricing projects.

These community health benefits should also be highlighted when discussing congestion pricing with community groups and elected officials, who may be concerned with the equity impacts of congestion pricing. If planners can articulate how congestion pricing will not only benefit mobility, but also community, I believe planners can win popular support for controversial congestion pricing proposals, and create solutions that provide benefits for all.

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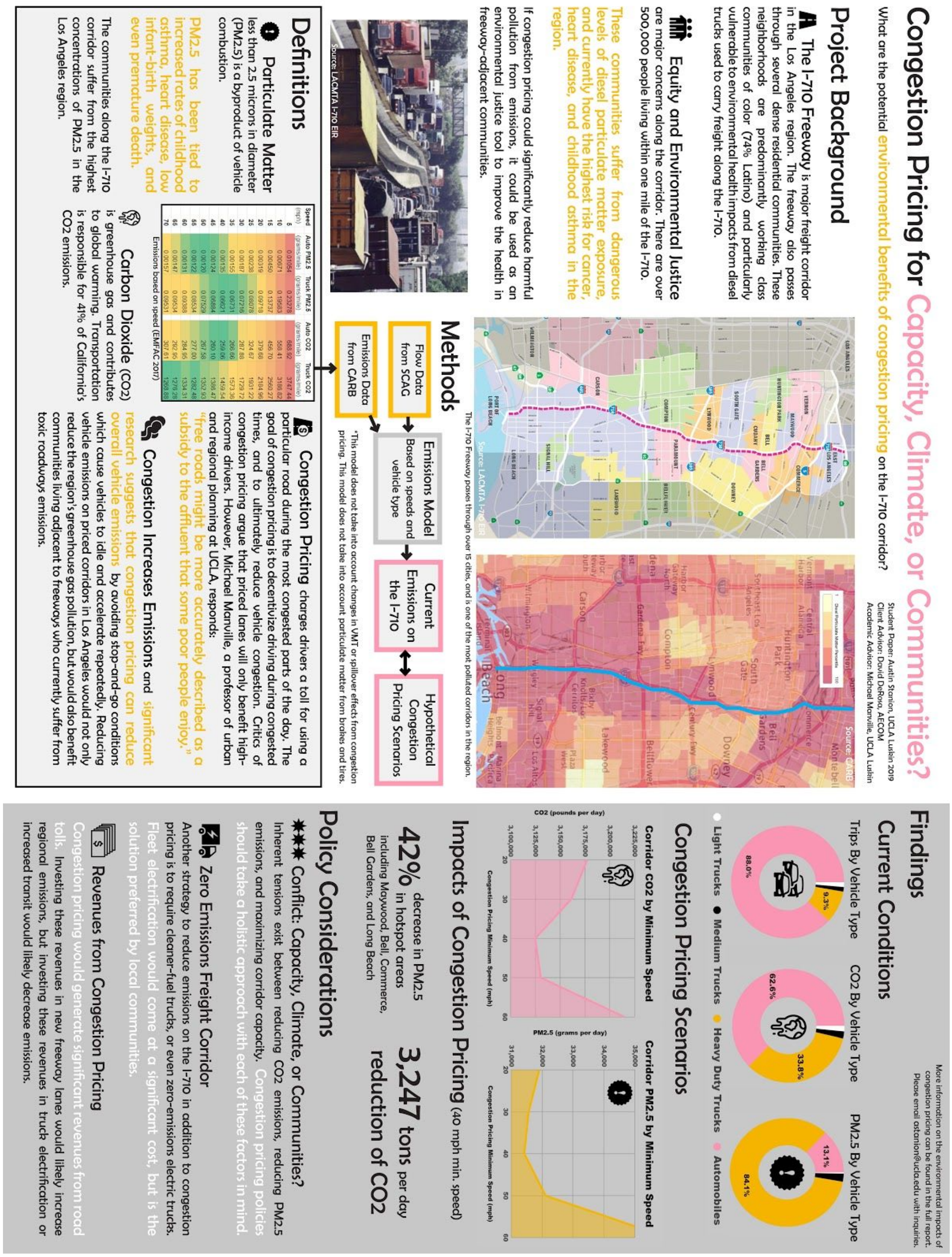
Appendix A: Research Poster



Appendix B: Composite Emissions Factors

Below are the composite emissions factors I created based on CARB's EMFAC subcategories, as described in the Methods: Data Acquisition section of the full report. Charts are colored to highlight the least polluting speeds (green) and most polluting speeds (red) of each vehicle type.

Speed (mph)	CO2 from Automobiles (grams/mile)	PM2.5 from Automobiles (grams/mile)	CO2 from Light Trucks (grams/mile)	PM2.5 from Light Trucks (grams/mile)
5	688.9236748	0.01053639993	963.4523745	0.01462745058
10	558.4143513	0.006711134688	782.9145717	0.009561114009
15	456.6953387	0.004503900067	633.5993013	0.006603596994
20	379.678328	0.003186487722	527.3283199	0.00479355019
25	324.673418	0.002375866049	451.6992451	0.003662835678
30	287.8827892	0.001867020805	401.0333672	0.00294457668
35	266.6639198	0.001545289049	372.9898564	0.002490397079
40	259.0550246	0.001346761893	362.0467042	0.002215464008
45	260.1014354	0.00123714294	362.7262458	0.002045923832
50	267.5752296	0.001195929134	373.4271502	0.001981782399
55	276.9954646	0.00121756087	387.1834955	0.002008776516
60	284.9536225	0.001305626793	399.0813266	0.002137421526
65	292.9495544	0.001474395464	410.2544001	0.002401427596
70	307.6147097	0.001570185292	431.540221	0.002996251555

Speed (mph)	CO2 from Medium Trucks (grams/mile)	PM2.5 from Medium Trucks (grams/mile)	CO2 from Heavy Trucks (grams/mile)	PM2.5 from Heavy Trucks (grams/mile)
5	1288.358741	0.04842520073	3747.436854	0.2327759751
10	1055.170323	0.03858615855	3186.821395	0.1958302954
15	860.1885138	0.02675479685	2560.273106	0.1373650765
20	717.5770965	0.01875996629	2184.962272	0.09717878941
25	617.6610588	0.01524946313	1931.223833	0.08078149327
30	549.5512969	0.01332094974	1729.723003	0.072164567
35	507.9096761	0.01218484712	1573.361366	0.06731370365
40	488.9488388	0.0117910918	1459.536125	0.06620899583
45	485.5115895	0.01199890586	1386.473247	0.06884127762
50	494.7749094	0.01289983282	1352.927843	0.07529209707
55	510.4112123	0.0144703902	1282.48403	0.08533925606
60	527.5039784	0.01561041341	1334.307683	0.09387884928
65	545.9981425	0.0159353498	1276.284892	0.09533944016
70	569.3452598	0.01859170976	1268.876617	0.09530678588

Appendix C: Analysis of I-710 EIR

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Introduction

In 2008, The California Department of Transportation (Caltrans) and the Los Angeles County Metropolitan Transportation Authority released a Draft Environmental Impact Report/ Environmental Impact Statement for the I-710 Corridor Project. This EIR/EIS represented over six years of study and analysis along an important freeway corridor in Los Angeles County. The following paper provides an overview of the project site, examines the air quality impacts assessment of the CEQA EIR, and summarizes the community reaction to the proposed project.

Project Description

The I-710 Freeway, also known as the Long Beach Freeway, is a major corridor in south Los Angeles County that passes through 15 cities. The study area of the EIR includes the portion of the 710 from Ocean Blvd in Long Beach to SR-60, a distance of approximately 18 miles.[1]

The 710 is the primary connection between the Port of Long Beach, the Port of Los Angeles, and intermodal rail yards in the cities of Vernon and Commerce.[2] For this reason, the 710 is a major corridor for freight traffic and heavy trucks traveling between the ports, rail yards, and warehouses. The vast majority of the heavy trucks on the corridor use diesel engines which produce diesel particulate matter (DPM), the greatest contributor to air-quality-related cancer risk in the region.[3] The 710 also passes through a number dense residential communities. These areas are predominantly working class communities of color, and particularly vulnerable to environmental health impacts[4]

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[1] State of California Department of Transportation 2008, Executive Summary, Page 1
[2] State of California Department of Transportation 2008, Executive Summary, Page 5
[3] State of California Department of Transportation 2008, Executive Summary, Page 2
[4] Rowangould, D., Karner, A., & Eldridge, M. 2012

The communities around the 710 and the ports currently have the highest risk for cancer in the region[5] and this will only get worse as freight traffic is expected to increase significantly in the coming decades.[6] In order to address the growing demands of freight traffic on the 710, and minimize the impact of emissions on human health, Caltrans has proposed a number of alternatives to overhaul and modernize the 710 corridor.

Proposals / Alternatives

The EIR analyzes four distinct alternatives as well as a 'no-build' scenario. The project alternatives are evaluated based on four project goals: 1. To Improve Air Quality & Public Health, 2. To Improve Traffic Safety, 3. To Modernize the Freeway Design, and 4. To Address Projected Growth in Population, Employment, and Goods Movement.[7] All alternatives are assessed using a baseline year of 2035.

Alternative 1 is the 'no-build' scenario which assumes no project is built as population grows and traffic worsens.

Alternative 5A includes adding new lanes to the freeway and modernizing key interchanges. This alternative also includes a number of traffic management improvements, including ramp metering and parking restrictions on arterial roads.

Alternative 6A includes improvements to the existing freeway as well as adding a dedicated freight corridor to keep trucks separate from automobile traffic. This Alternative also includes features to capture and treat the water runoff from the freight corridor.

Alternative 6B includes the same freight corridor as in Alternative 6A but would require all freight vehicles be zero-emissions vehicles. The EIR assumes that zero-emission electric trucks will receive electric power while traveling along the freight corridor via an overhead catenary electric power distribution system (road-connected power).

Alternative 6C includes the same zero-emissions freight corridor as in Alternative 6B but would impose a toll on the corridor. The toll pricing structure would provide for collection of higher tolls during peak travel periods. [8]

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[5] State of California Department of Transportation 2008, Executive Summary, Page 2
[6] State of California Department of Transportation 2008, Executive Summary, Page 3
[7] State of California Department of Transportation 2008, Executive Summary, Page 6
[8] State of California Department of Transportation 2008, Executive Summary, Page 7

Alternatives 6B and 6C also assume that all freight vehicles on the freight corridor would have an " automated control system that will steer, brake, and accelerate the trucks under computer control while traveling on the freight corridor. This will safely allow for trucks to travel in "platoons" (e.g., groups of 6–8 trucks) and increase the capacity of the freight corridor."[9]

Regulatory Environment

Like most large transportation infrastructure projects, the I-710 project would use both state and federal funds and thus is subject to both state and federal environmental reporting standards (CEQA and NEPA). To meet these two standards, Caltrans (the lead agency for the project) prepared a combined EIR/EIS.

Caltrans evaluated the project's impacts on air quality in relation to both the Federal Clean Air Act and the California Clean Air Act, which govern air quality nationally and at the state level respectively. The United States Environmental Protection Agency (U.S. EPA) and California Air Resources Board (ARB), set standards for the quantity of pollutants that can be in the air. Federal standards regulate emissions of carbon monoxide (CO), nitrogen dioxide (NO2), ozone (O3), particulate matter (PM10 and PM2.5), lead (Pb), and sulfur dioxide (SO2). In addition, State standards regulate visibility reducing particles, sulfates, hydrogen sulfide (H2S), and vinyl chloride.[10]

Because the I-710 Corridor falls within an attainment/maintenance area for CO and a nonattainment area for federal PM2.5 and PM10 standards, Caltrans was required to conduct a local hot-spot analyses for CO, PM2.5, and PM10.[11]

Requirements of CEQA

CEQA guidelines outline five questions to determine if a project would have significant air quality impacts. The 710 EIR addresses each of these questions, and assesses the potential

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[9] State of California Department of Transportation 2008, Executive Summary, Page 11
[10] State of California Department of Transportation 2008, Section 3.13, Page 1
[11] State of California Department of Transportation 2008, Section 3.13, Page 15

impacts of the project within each category. These questions, along with a summary of Caltrans's responses are included below[12]:

Would the project:

a) Conflict with or obstruct implementation of the applicable air quality plan?

The EIR identifies that the project fall under the South Coast Air Quality Management District (SCAQMD) Air Quality Management Plan/State Implementation Plan (AQMP/SIP) and the Southern California Association of Governments (SCAG) Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS). The EIR concludes that the project conforms to the emissions targets laid out in these plans, and that the "proposed project will not significantly contribute to or cause deterioration of existing air quality; therefore, mitigation measures are not required for the long-term operation of the project."[13]

b) Violate any air quality standard or contribute substantially to an existing or projected air quality violation?

Although the region is currently a nonattainment area for four criteria pollutants[14], the EIR explains that the Air Quality Management Plan/State Implementation Plan (AQMP/SIP) "will bring the region into conformance with the applicable air quality standards."[15] And because the 710 project conforms to the SIP, the proposed project "will not result in the violation of any air quality standard or contribute substantially to an existing or projected air quality violation; therefore, impacts are less than significant."[16]

c) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non- attainment under an applicable Federal or state ambient air quality standard (including releasing emissions which exceed quantitative thresholds for ozone precursors)?

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[12] State of California Department of Transportation 2008, CEQA Evaluation, Page 16
[13] State of California Department of Transportation 2008, CEQA Evaluation, Page 14
[14] State of California Department of Transportation 2008, Section 3.13
[15] State of California Department of Transportation 2008, CEQA Evaluation, Page 15
[16] State of California Department of Transportation 2008, CEQA Evaluation, Page 15

For determining significance under CEQA, the project would result in a potentially significant impact if the region was in nonattainment under applicable ambient air quality standards and the project contributed to such a designation. However, according to the EIR's Air Quality/Health Risk Assessment, the project area will be in attainment with applicable air quality standards in design year 2035. As such, Caltrans determined that the project would not result in a cumulatively considerable increase in criteria pollutants.[17]

d) Expose sensitive receptors to substantial pollutant concentrations?

For determining significance under CEQA, any increase in Mobile Source Air Toxics (MSAT) concentrations at a sensitive receptor is considered significant.[18] Although the proposed project would reduce overall emissions at the regional level, and across the 710 study area overall, it would likely lead to increased emissions at "near roadway locations"[19] including areas with sensitive receptors. The EIR also states that emissions from construction activity for the project would exceed air quality standard thresholds, and that these emissions from construction would be unavoidable without significantly delaying the project and causing other environmental harms.[20] Caltrans Ultimately concluded that these localized short term and long term emissions were "potentially significant and unavoidable."[21]

e) Create objectionable odors affecting a substantial number of people?

Caltrans claims that "road widening projects do not typically produce odors that would affect off-site sensitive receptors," and commits to addressing short-term odor impacts from the project.[22]

Controversy / Community Alternative

[17] State of California Department of Transportation 2008, CEQA Evaluation, Page 15
[18] State of California Department of Transportation 2008, CEQA Evaluation, Page 40
[19] State of California Department of Transportation 2008, CEQA Evaluation, Page 40
[20] State of California Department of Transportation 2008, CEQA Evaluation, Page 41
[21] State of California Department of Transportation 2008, CEQA Evaluation, Page 40
[22] State of California Department of Transportation 2008, CEQA Evaluation, Page 16

Caltrans ultimately chose Alternative 5A (widening the freeway) as the preferred alternative for the project. This assessment was met with significant backlash from community advocates and health planners. A coalition of over a dozen environmental organizations and community groups, including the Natural Resources Defense Council, the Coalition for Clean Air, and the East Yard Communities for Environmental Justice responded with a "Community Alternative" document outlining the community's preferred alternative for the project as well as a technical critique of the analysis and findings of Caltrans's draft EIR.

The Community Alternative states that "while both NEPA and CEQA legally require health impacts (including health impacts related to social and economic effects) to be addressed, […] traditional Environmental Impact Assessments have failed to comprehensively address human health impacts,"[23] and demands a more detailed health impact analysis. The Community Alternative also includes seven components: 1) No I-710 Widening (No Additional General Purpose Lanes); 2) Comprehensive Public Transit Element; 3) Mandatory Zero-Emission Freight Corridor; 4) Public Private Partnership – Operator of the "Freight Corridor System;" 5) River Improvements; 6) Comprehensive Pedestrian and Bicycle Element; and 7) Community Benefits[24].

The Community Alternative also includes nine attachments critiquing various aspects of the EIR analysis and process, including Attachment C (Review of Transportation and Air Quality Analysis. This report highlights that the assumptions made in the EIR for growth of goods movement and port-related activity "inflate the performance of the project alternatives relative to no-build." The report also questions the decision of Caltrans to rule out lower cost alternatives which did not include road widening, and asks "How would lower cost alternatives (e.g., alternatives 2 and 4) fare in managing increased freight traffic, particularly under lower projections?"[25]

<u>Conclusion</u>

[23] East Yard Communities for Environmental Justice, 2009
[24] Coalition for Environmental Health and Justice, 2012
[25] Rowangould, D., Karner, A., & Eldridge, M. 2012

Although the I-710 Draft EIR/EIS was published by Caltrans over ten years ago in 2008, the future of the project remains uncertain and surrounded in controversy. The Community Alternative was published by East Yard Communities for Environmental Justice (EYCEJ) in 2012. In 2018 the Los Angeles County Metropolitan Transportation Authority (LA Metro) released a staff report which included a "locally preferred alternative" for the project. However, LA Metro's proposal diverges significantly from EYCEJ's Community Alternative. The final EIR is scheduled to be released in the Spring of 2019. Transportation planners, environmental activists, and community advocates are all eager to see what comes out of the process, and what happens next.

Appendix C Sources

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