2040FREIGHT
DEMOGRAPHICS, EQUITY & ENVIRONMENTAL JUSTICE - PART I

Examining the Intersections of Freight & Environment and Health Wellbeing.

February 2022

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EXECUTIVE SUMMARY

This analysis is part of a broader State of the System Report intended to inform the 2040 Portland Freight Plan (2040Freight). The Portland Bureau of Transportation (PBOT) is working with community members and local freight experts to develop the 2040 Portland Freight Plan, which seeks to improve goods movement throughout the City in ways that meet Portland's goals for a safe multimodal transportation system that supports economic prosperity, human and environmental health, equity, and resilience.

The Portland region is heavily trade dependent and the freight industry is critical to meet the daily needs of all who live and work in Portland. The freight industry simultaneously shapes and is shaped by evolving consumer trends. It is expected that COVID-19 is likely to have lasting effects on consumer behavior as the global pandemic accelerates a shift towards e-commerce. For example, in the United States, e-commerce increased from 9.6% to 11.8% (a 23% change) over the past two years between the first quarter of 2018 to the first quarter of 2020; however, in the face of lockdowns and stay-at-home orders, e-commerce spiked to 16.1% (a 36% change) in a single quarter, between the first and second quarter of 2020[1 2].

The 2040 Portland Freight Plan aims to meet the needs of today, while being forward-thinking and nimble enough to meet the needs of tomorrow. Local freight movement relies heavily on the ability of trucks, vans, cars, bikes, people, and other vehicles to maneuver on local streets and park, load, and unload freight, which occurs on transportation system infrastructure that the PBOT oversees. PBOT's domain includes assets in the public right-of-way, including streets, bridges, loading zones, and other freight-related infrastructure. As such, this report focuses primarily on the local component of goods movement (sometimes referred to as "road freight"), rather than maritime, rail, and aviation, which are more closely overseen by the Port of Portland and Metro.

Core to PBOT's work are goals to improve safety, move people and goods efficiently, and maintain transportation system assets in ways that reduce carbon emissions, address structural racism, and advance equity. Given these priorities, an analysis of the freight industry's impacts on local health, economy, and environment, especially as they relate to climate and equity, is a necessary component of the Freight 2040 planning process.

This analysis explores some of the ways in which the freight industry affects Portland by focusing on the economy, environment, and health. This document explores the freight industry's impact on the environment and health through spatial analysis of air and noise pollutants and longitudinal traffic safety data. The key findings of this report shed light on the health, and environmental disparities that exist across time, geographies, racial and ethnic groups, genders, and education levels.

Picture 1.1: A single white and red freight truck dirving on a freeway. The highway is surrounded by lush green hills. The sky is blue with several white, fluffy clouds visible. [Source: unknown]

1 Organization for Economic Cooperation and Development (OECD). 2020. "E-Commerce in The Time of COVID-19." http://www.oecd.org/coronavirus/policy-responses/e-commerce-in-the-time-of-covid-19-3a2b78e8/.

2 http://www.oecd.org/coronavirus/policy-responses/e-commerce-in-the-time-of-covid-19-3a2b78e8/.

United States Census Bureau. 2020. "Quarterly Retail E-Commerce Sales- 3rd Quarter 2020." https://www.census.gov/retail/mrts/www/data/pdf/ec_current.pdf

ENVIRONMENT & HEALTH

1. **Portland has some of the highest rates of diesel emissions exposure in the country**

a. Portland-area residents are exposed to diesel emissions at a rate 10-times higher than the Oregon health-based particulate exposure standard.

b. Three Portland neighborhoods, Upper Waterfront, the Pearl District, and Cully are considered to have diesel particulate matter concentrations that rank among the top 2% in the country

2. **On-road diesel vehicles, such as heavy-duty trucks, account for about 15% of total diesel emissions** in the Portland area

3. **Areas with high levels of diesel particulate matter often correspond with vulnerable areas** (determined by race, income, and English proficiency) and those which are bisected by regional freight routes (i.e., Regional & Priority Truckways as defined by the Transportation System Plan (TSP))

a. Majority-BIPOC neighborhoods are found to be exposed to diesel emissions between two- and three-times the rate of the average Portland-area resident.

b. Asian communities and populations living below the poverty line experience the greatest impacts from on-road diesel emissions (e.g. diesel trucks & freight activity)

c. 150 schools are located within 500 meters of a freeway in Portland, a distance which poses increased health risks, especially among vulnerable populations, such as children.

d. Most schools with higher BIPOC student populations are within a quarter-mile of a designated freight route.

4. **High levels of noise pollution are present near freight-related infrastructure** such as motorways, arterials, and the airport.

5. Health Impacts

a. **Exposure to diesel exhaust (diesel particulate matter, nitrogen oxides, other toxics) is shown to increase the risk of multiple health problems**, including heart attack, stroke, cardiovascular disease, asthma, low-weight and preterm births, cognitive and developmental impacts, decreased lung function and impaired lung development, and lung, breast, and blood system cancers.

b. **Exposure to noise pollution can lead to cognitive impairment, insomnia, lack of sleep and associated health issues**, and is associated with increased risk of cardiovascular disease and hypertension.

c. **Certain populations are more vulnerable to the effects of noise and air pollution from freight activity.** Children, elderly, and people experiencing chronic illness suffer most from noise pollution and children are particularly vulnerable to cognitive impairment and other developmental issues from noise pollution. Similarly, diesel emissions are especially harmful to children, as exposure can cause permanent damage to lungs that are still developing, leading to reduced lung capacity through adulthood.

d. Injuries from crashes involving freight vehicles have been trending upward over the past 20 years.

6. Climate Impacts

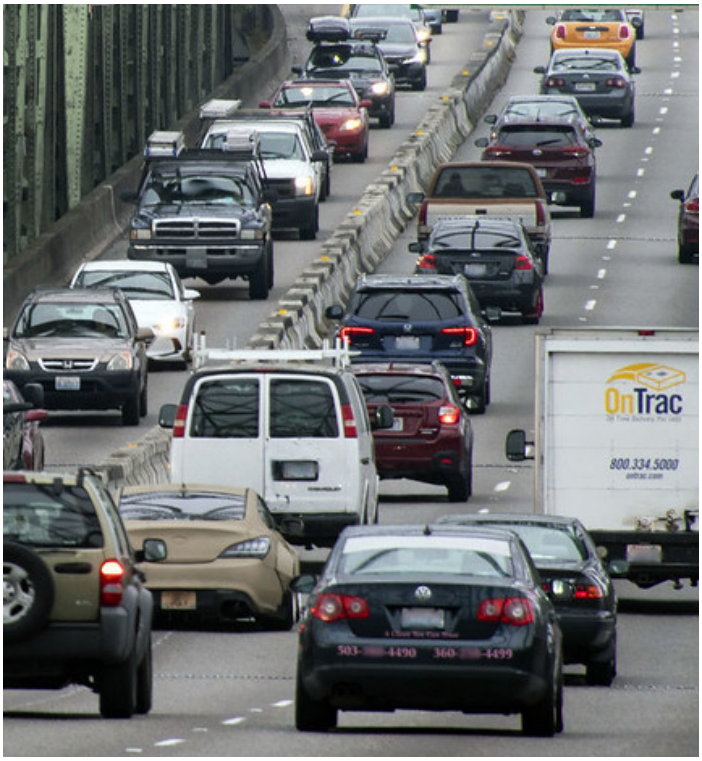
a. **Diesel fuel emits approximately 14% more carbon dioxide (CO2) than gasoline** on a per gallon basis.

b. Black carbon, a potent short-lived climate pollutant, accounts for approximately 70% of diesel particulate matter emitted from diesel fuel.

c. Given the short-lived nature of black carbon, reducing diesel emissions can create substantial near-term climate benefits.

d. On-road heavy duty diesel vehicles are the second largest contributor to nitrogen oxides in Oregon, an ozone precursor (2014 National Emissions Inventory). Both nitrogen dioxide and ozone have negative health impacts. Ozone trends are on the rise across the Willamette Valley including Portland. As the number of hot sunny days keep increasing in Portland due to climate change, actions to reduce ozone and protect health need to be strengthened.

This analysis serves to aid PBOT in developing a more robust understanding of the impacts of freight on the people and environment of the Portland region. The findings included herein must be considered as part of the planning process to ensure that human and environmental harm are mitigated as part of the 2040 Freight planning process.



Picture 2.1: Various passangers trucks driving on a congested highway. One white freight truck is visible on the right center of the image. [Source: ODOT]

BACKGROUND

The freight industry is at once a source of jobs, economic activity, and environmental hazards. Analyzing the impacts of freight through the lenses of the economy, environment, and health is helpful to understand the opportunities, risks, and tradeoffs inherent in this complex industry. As part of the City of Portland's 2040Freight planning process, the following report examines the environmental and health implications of freight activity in Portland.

In an increasingly globalized economy reliant on trade and the movement of goods and services, freight is the glue that binds the modern world. In 2015, the US logistics industry moved more than 49.5 million tons of goods worth nearly $52.7 billion every day, translating to more than 56 tons of freight per-person per-year.[3] Oregon is the ninth most trade-dependent state in the United States, with the success of many industries relying on participation in domestic and international markets.

However, air pollution from freight contributes to smog, poor air quality, climate change, and environmental injustices which can have negative impacts on the health and welfare of people and the environment locally and globally. In the US, the transportation sector is responsible for pollutants that contribute to poor air quality, including over 50% of nitrogen oxides (NOx), over 30% of volatile organic compounds (VOCs), and over 20% of particulate matter (PM). Within transportation, heavy-duty trucks are the fastest-growing contributor to emissions[4]. Legacies of racist planning decisions routing major roadways through neighborhoods of

3 Environmental Protection Agency (EPA). "Why Freight Matters to Supply Chain Sustainability." Accessed 16 July 2020. https://www.epa.gov/smartway/why-freight-matters-supply-chain-sustainability.

4 EPA. "Why Freight Matters to Supply Chain Sustainability."

Black, indigenous, and people of color (BIPOC) and low-income communities mean that these communities are often disproportionately affected by transportation emissions and freight activity.

The Portland Bureau of Transportation (PBOT) is leading the 2040Freight planning process and the scope of this report is most closely concerned with the parts of the transportation system that PBOT oversees. PBOT oversees assets in the public right-of-way, including streets, bridges, and loading zones, and other freight-related infrastructure that affects the ability of trucks, vans, and other on-road vehicles to maneuver on local streets and park, load, and unload freight. As such, this report focuses primarily on the local component of goods movement (sometimes referred to as "road freight"), which exists at the intersection of Portland's transportation system and the freight industry.

Equity Framing

PBOT's 2019-2022 Strategic Plan, which guides Bureau work, is built around three core goals:

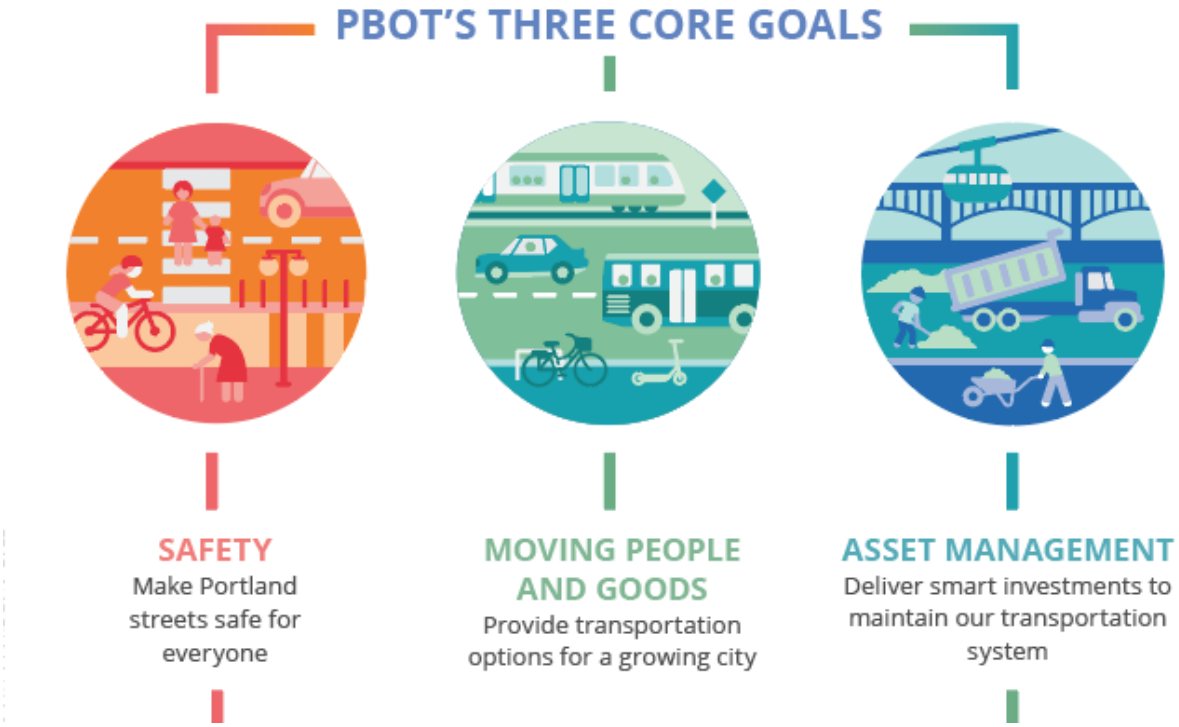
- Safety: Make Portland streets safe for everyone
- Moving People & Goods: Provide transportation options for a growing city
- Asset Management: Deliver smart investments to maintain our transportation system

PBOT aims to achieve these goals in ways that reduce carbon emissions and improve equity. Accordingly, PBOT staff use the following questions to guide all Bureau work and plans:

- Will it advance equity and address structural racism?
- Will it reduce carbon emissions?

The analysis in this report provides a detailed look into the human, environmental, and economic impacts of the freight industry and aims to help inform answers to these questions in the context of the 2040Freight planning process.

Figure 1. PBOT Strategic Plan, Three Core Goals



Social Determinants of Health Framing

The Office of Disease Prevention and Health Promotion within the United States Department of Health and Human Services defines social determinants of health as "the conditions in the environments where people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks" (**Figure 2**).[5] Inequitable social determinants of health, such as: unequal access to quality education and health care, economic stability, neighborhoods and built environment, and social and community context contribute to wide health disparities. Promoting healthy choices at an individual level is insufficient to bridge existing health disparities; instead, public health organizations, and other government agencies responsible for education, transportation, and housing must also take action to improve the conditions in people's environments. [6]

5 United States Department of Health and Human Services, Office of Disease Prevention and Health Promotion. "Social Determinants of Health." Accessed 6 November 2020. https://health.gov/healthypeople/objectives-and-data/social-determinants-health.

6 United States Department of Health and Human Services, Office of Disease Prevention and Health Promotion. "Social Determinants of Health." Accessed 6 November 2020. https://health.gov/healthypeople/objectives-and-data/social-determinants-health.

Recognizing the myriad factors that influence health and quality-of-life, the 2040Freight planning process seeks to understand and mitigate the negative impacts and promote the positive benefits of freight on the livelihoods of Portlanders.

Fundamental to economic stability is steady employment. People with steady employment are less likely to live in poverty and more likely to be healthy given increased access to healthy foods, health care, and housing. Freight industry employment and wage analysis aims to understand the role of the freight industry in providing steady employment and wages within the Portland economy and the demographics of those working in the freight industry by race and ethnicity, educational attainment, and gender.

The US Department of Health and Human Services also recognizes that the neighborhoods people live in have a major impact on health and well-being. Metrics used to understand the relative health and safety of neighborhoods include exposure to unhealthy air, the amount of toxic pollutants in the environment, injuries and deaths from motor vehicle crashes, asthma rates, and hearing loss due to noise exposure. Using these metrics as a guide, this report analyzes the air and noise pollution, road safety, and climate impacts of freight.

Figure 2. Social Determinants of Health

Externalities of Freight

The consequences, positive or negative, that affect other parties without being reflected in the cost of goods or services involved, are known as externalities. Externalities of freight include:

	Positive Externalities	Negative Externalities
Economy	• Underpins economic activity • Creates jobs • Source of jobs for those with lower educational attainment	• Jobs are not evenly distributed • Loading and unloading activity may impede commercial activity during busy times in certain areas
Environment & Health	• Steady employment can improve health outcomes	• Air pollution • Noise pollution • Climate pollution • Traffic injuries and safety • Non-represented freight workers may face unsafe working conditions

ENVIRONMENT & HEALTH: FREIGHT-RELATED POLLUTANTS IN PORTLAND

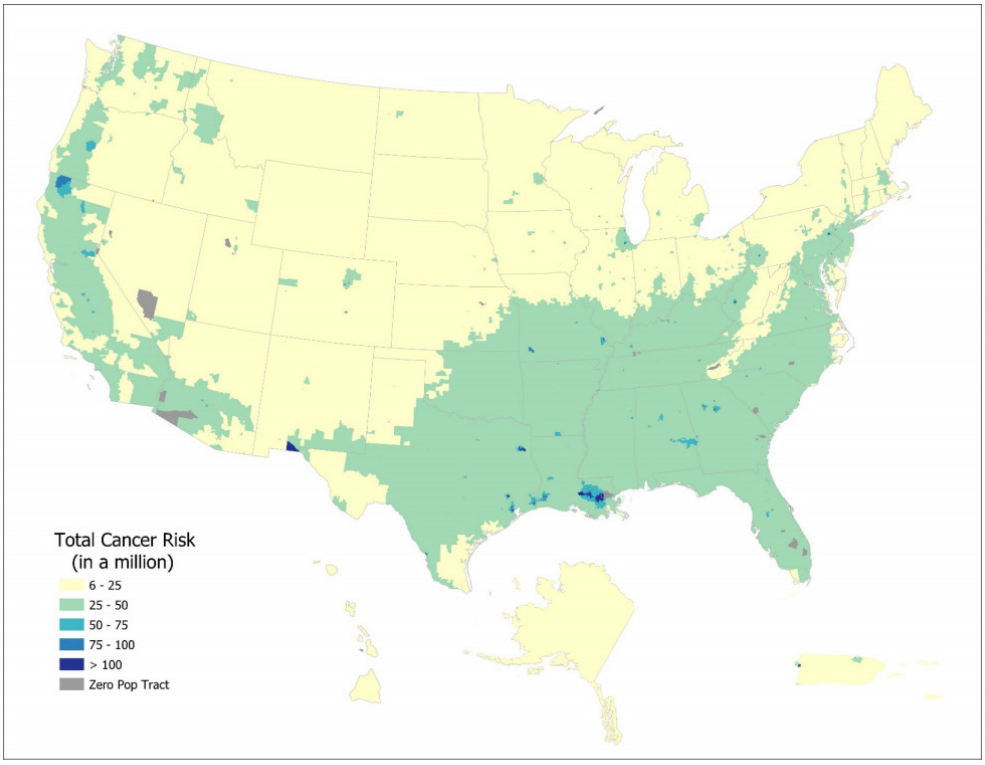
Freight's Impact on the Environment & Health

The Portland region's population has the highest risk from air toxics in Oregon due to the higher population and development compared to the rest of the state.[7] The largest air quality concerns from freight arise from pollutants is diesel exhaust. Diesel exhaust is a mixture of gas and particles with a number of health and environmental impacts from both short and long-term exposures. Portland has similar air toxic levels compared to other U.S. cities of similar size,[8] and in 2018, the US Environmental Protection Agency (EPA) National Air Toxics Assessment (NATA) released estimated cancer risks from air toxics across the nation (**Figure 3**). The NATA results show that the entire city of Portland and many of the surrounding areas have an estimated total cancer risk from air toxics of 25-50 in one million people developing cancer after 70 years of exposure. In this study, the EPA identified formaldehyde as a pollutant with some of the highest risk, and benzene and 1,3-butadiene as 2 of the 6 top national pollutants that pose health risks. Formaldehyde, benzene, and 1,3-butadiene are all pollutants found in motor vehicle exhaust, including diesel exhaust.

7 State of Oregon Department of Environmental Quality (DEQ), Portland Air Toxics Solutions Report and Recommendations, May 2012. *Portland Air Toxics Solutions Report and Recommendations (oregonconsensus.org)

8 Oregon Department of Environmental Quality (DEQ) Portland Air Toxics Solutions Report and Recommendations Fact Sheet. (2012) Portland Air Toxics Solutions Report and Recommendations (oregonconsensus.org)

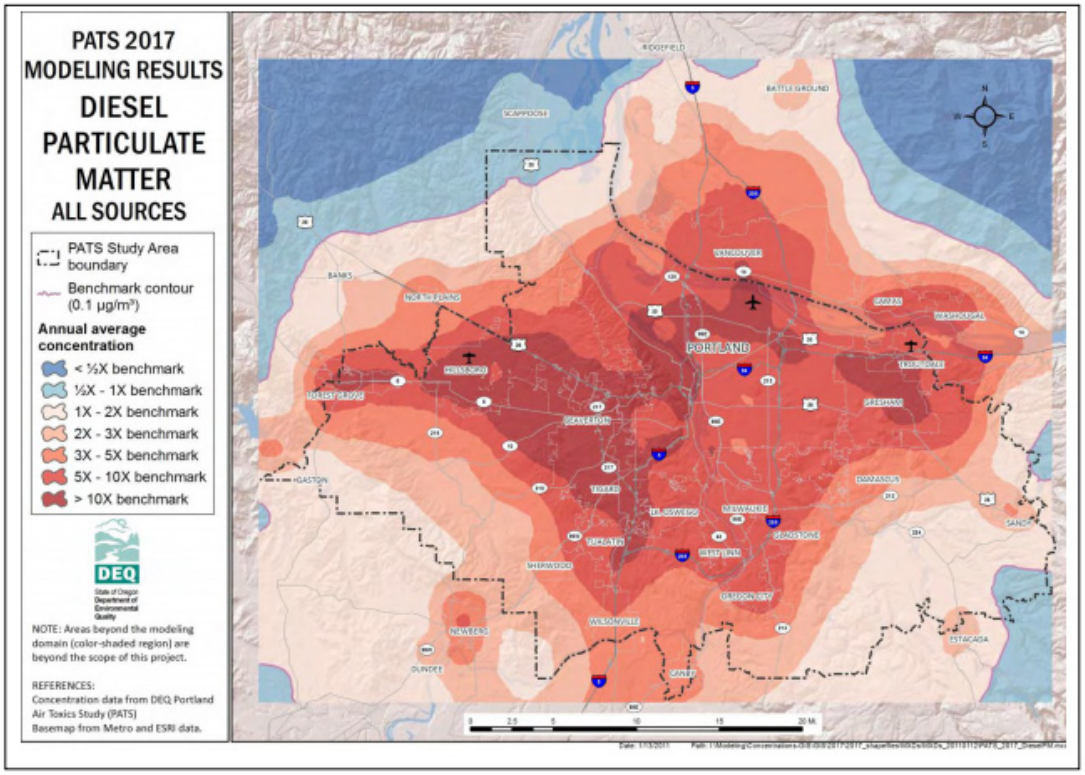
Figure 3. US EPA NATA 2014 estimated cancer risks from air toxics



U.S. cancer risks from air toxics as estimated by the 2014 NATA.

Source: U.S. Environmental Protection Agency (EPA) 2014 National Air Toxics Assessment (NATA) (2018). https://www.epa.gov/sites/production/files/2020-07/documents/nata_2014_summary_of_results.pdf

Figure 4. Diesel Particulate Matter Modeling Results (2017)



Source: Oregon Department of Environmental Quality (DEQ). 2011. "Portland Air Toxics Solutions (PATS) 2017 Pollutant Modeling Summary. https://www.dropbox.com/s/4qpwz1mvvni3ba4/PATS_15pollutantsAboveSummary.pdf?dl=0.

Air pollution impacts of freight are large. For example, 60-70% of particulate emissions from all vehicles are attributed to diesel powered vehicles, even though they represent only 6% of vehicles on the road in Oregon.[9] Portland-area residents are exposed to diesel particulate matter emissions that are more than ten times higher than Oregon's health-based ambient benchmark concentration. The ambient benchmark concentration in Oregon was adopted in 2006 and is based on the average levels of a toxic chemical in the air, such as diesel exhaust, that would cause a cancer risk of one-in-a-million additional cancers through a lifetime of exposure.[10]

In Oregon, the ambient benchmark concentration for diesel exhaust is 0.1 μg/m3[11]. Ambient benchmark concentrations for diesel particulate matter in the Portland region are reflected in the Department of Environmental Quality (DEQ)'s Portland Air Toxics Solutions (PATS) model results (**Figure 4**).[12] Modeling for 2017, the DEQ PATS study estimated a total of 472 metric tons of annual diesel emissions in Portland emitting sources, and found an 86% reduction in diesel particulate matter is needed to meet ambient benchmark concentrations.[13]

9 The Concerns about Diesel Engine Exhaust, State of Oregon Department of Environmental Quality,February 2015. https://www.oregon.gov/deq/FilterDocs/DieselEffectsReport.pdf

10 The Concerns about Diesel Engine Exhaust, State of Oregon Department of Environmental Quality,February 2015. https://www.oregon.gov/deq/FilterDocs/DieselEffectsReport.pdf

11 State of Oregon Department of Environmental Quality (DEQ), Ambient Benchmark Concentrations (ABCs), May 2018. https://www.oregon.gov/deq/FilterDocs/airtox-abc.pdf

12 Oregon Department of Environmental Quality (DEQ). 2011. "PATS 2017 Pollutant Modeling Summary." https://www.dropbox.com/s/4qpwz1mvvni3ba4/PATS_15pollutantsAboveSummary.pdf?dl=0

13 Oregon Department of Environmental Quality (DEQ). 2012. "Portland Air Toxics Solutions (PATS) Committee Report and Recommendations." https://www.oregon.gov/deq/FilterDocs/PATS2012.pdf.

Pollutants in diesel exhaust affect human and environmental health. Pollutants, such as black carbon and fine particulate matter can enter the lungs and bloodstream and can have negative prenatal impacts as well as negative impacts on respiratory, cardiovascular, and nervous systems which can lead to and exacerbate other health problems. Nitrogen oxides, a predominant component of diesel, can lead to and exacerbate adverse respiratory impacts in short and long term exposure. Diesel exhaust includes a mixture of various air toxics including diesel particulate matter, volatile organic compounds (VOCs), benzene, and polycyclic aromatic hydrocarbons (PAHs). Many of these are known carcinogens, possible or probable human carcinogens according to the Environmental Protection Agency and World Health Organization.[14, 15] Diesel exhaust is also a potent climate-forcing pollutant that negatively impacts the climate. Reducing emissions locally can have benefits globally as the impacts of climate change are not limited to the geographic source of emissions.

14 International Agency for Research on Cancer (IARC), World Health Organization. Human Cancer: Known Causes and Prevention by Organ Site, monograph: https://monographs.iarc.who.int/wp-content/uploads/2019/12/OrganSitePoster.PlusHandbooks.pdf

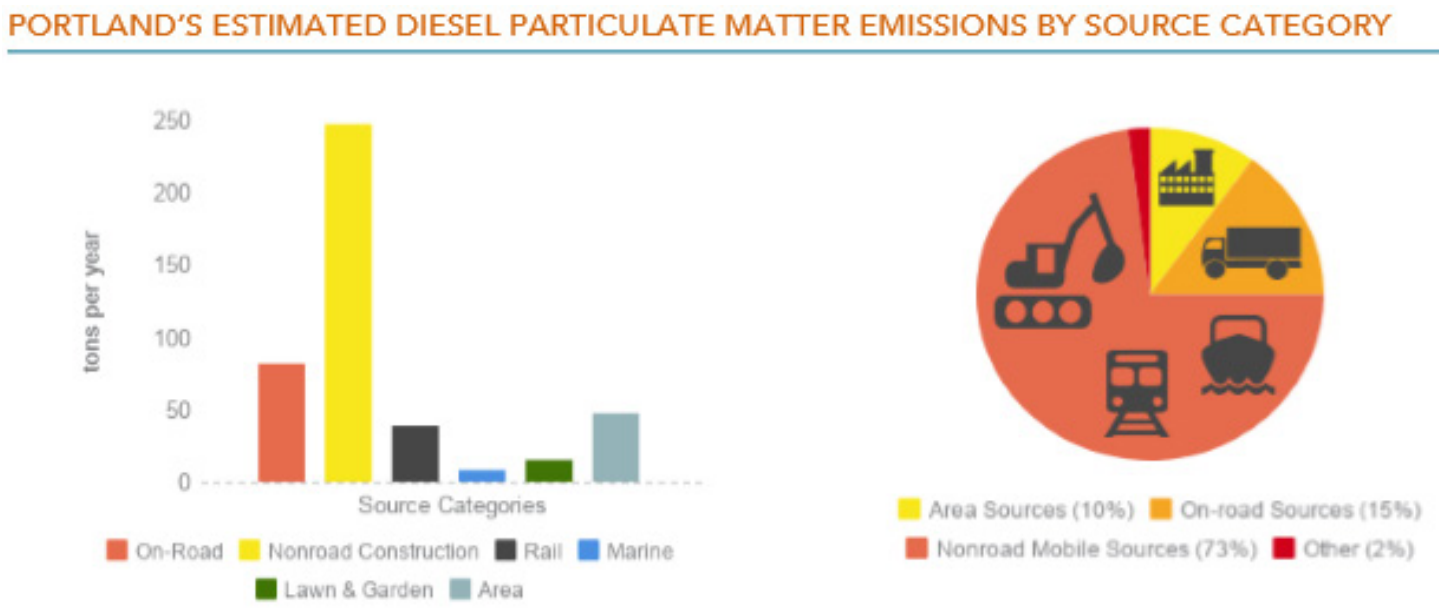
15 American Cancer Society, www.cancer.org, Known and Probable Human Carcinogens, 2019. https://www.cancer.org/cancer/cancer-causes/general-info/known-and-probable-human-carcinogens.html

The Connection between Freight & Diesel Emissions

A significant portion of these emissions can be attributed to freight transportation, such as medium- to heavy-duty trucks and heavy rail. There are several sources of diesel pollution in the Portland area, including on-road, non-road construction machinery, marine, rail, lawn and garden, and area sources. The distribution of annual emissions for each of these sources is shown in **Figure 5**. On-road sources are the second largest emitters of diesel particulate matter in the Portland region, emitting 81.7 tons per year. Oregon DEQ reports that on-road diesel trucks account for about 15% of total diesel emissions in the area, whereas non-road sources like rail, marine, and construction vehicles and machinery account for about 73%.

Recent state legislation should help curb diesel emissions from on-road sources in the Portland area. Diesel engines are long lasting and turnover for newer models is much slower than for light-duty vehicle engines. House Bill 2007 (2019) prohibits registration of old diesel powered trucks (pre 1997) in Multnomah, Clackamas, and Washington Counties by 2023. By 2029, registration of all medium-duty and publicly-owned heavy-duty trucks with diesel engines manufactured before 2010, and private heavy-duty trucks must have engines from 2007 or newer, will be prohibited. (Exceptions are made for trucks that are fitted with certain exhaust control systems equipment.) Phasing out older engines will help to ensure better fuel efficiency and emissions filtering, and therefore less pollution per heavy-duty truck. Despite these improvements for regulating diesel emissions, however, commercial truck owners with fleets of five or fewer are exempt and there is limited funding to support other fleet owners with the transition.

Figure 5. Sources of Diesel Emissions in Portland



Figures from Schlusser, A., Blumenstein, L. and N. Smith. 2019. "Deconstructing Diesel: A Law and Policy Roadmap for Reducing Diesel Emissions in the Portland Metropolitan Area." Green Energy Institute at Lewis and Clark Law School. Based on data from the DEQ PATS Modeling Study.

Recent state legislation should help curb diesel emissions from on-road sources in the Portland area.[16] Diesel engines are long lasting and turnover for newer models is much slower than for light-duty vehicle engines. House Bill 2007 (2019) prohibits registration of old diesel powered trucks (pre 1997) in Multnomah, Clackamas, and Washington Counties by 2023. By 2029, registration of all medium-duty and publicly-owned heavy-duty trucks with diesel engines manufactured before 2010, and private heavy-duty trucks must have engines from 2007 or newer,[17] will be prohibited. (Exceptions are made for trucks that are fitted with certain exhaust control systems equipment.) Phasing out older engines will help to ensure better fuel efficiency and emissions filtering, and therefore less pollution per heavy-duty truck. Despite these improvements for regulating diesel emissions, however, commercial truck owners with fleets of five or fewer are exempt and there is limited funding to support other fleet owners with the transition[18].

16 EPA. "National Ambient Air Quality Standards (NAAQS)." Accessed 16 June 2020. https://www.epa.gov/criteria-air-pollutants/naaqs-table

17 Oregon Legislative Assembly. 2019. House Bill 2007. https://olis.leg.state.or.us/liz/2019R1/Downloads/MeasureDocument/HB2007/Introduced.

18 Portland Clean Air. 2019. "Oregon Diesel Bill Passed 06/30/19: Analysis of House Bill 2007." http://portlandcleanair.org/files/reports/PCA_HB2007_report.pdf.

Finally, the Oregon Environmental Quality Commission (ODEQ) approved the Clean Truck Rules in November 2021. This rulemaking adopted two main medium- and heavy-duty diesel engine standards adopted in California beginning in model year 2025:

- The Advanced Clean Trucks rule, which requires manufacturers of medium- and heavy- duty vehicles, like large pickup trucks, buses and tractor-trailer cabs, to sell a certain percentage of zero emission vehicles.
- The Heavy Duty Low NOx Omnibus rules which strengthen NOx and particulate matter (PM 2.5) emission standards for new truck engines (both diesel and non-diesel engines).[19]

Pollutants in Diesel Exhaust

Diesel vehicles and engines emit a variety of air pollutants, including particulate matter specifically black carbon, ultrafine and fine particulate matter, nitrogen oxides, sulfur oxides, volatile organic compounds (VOCs), benzene, formaldehyde, 1,3-butadiene, and polycyclic aromatic hydrocarbons (PAHs). These pollutants are of concern because they either negatively impact human health or contribute to climate change, and some both. In the Portland metropolitan area, emissions from on-road sources, such as heavy-duty trucks, account for around 15% of diesel emissions.[20] It is estimated that for Portland to achieve Oregon's health-based ambient benchmark concentration for diesel particulate matter, diesel particulate matter emissions must be reduced by 86%.[21]

19 Oregon Department of Environmental Quality (DEQ). "Clean Truck Rules 2021". Accessed 20 January 2022.

https://www.oregon.gov/deq/rulemaking/Pages/ctr2021.aspx

20 Oregon Department of Environmental Quality (DEQ). 2011. "PATS 2017 Pollutant Modeling Summary." https://www.dropbox.com/s/4qpwz1mvvni3ba4/PATS_15pollutantsAboveSummary.pdf?dl=0

21 Oregon DEQ. 2011. "PATS 2017 Pollutant Modeling Summary."

Particulate Matter

Fine particulate matter is the most prevalent air pollutant in diesel exhaust. Particulate matter is a designated criteria pollutant under the United States Clean Air Act (CAA) and is subject to National Ambient Air Quality Standards (NAAQS). Diesel exhaust is also classified as a known human carcinogen by the International Association for Research on Cancer, an intergovernmental agency as part of the World Health Organization. [22]

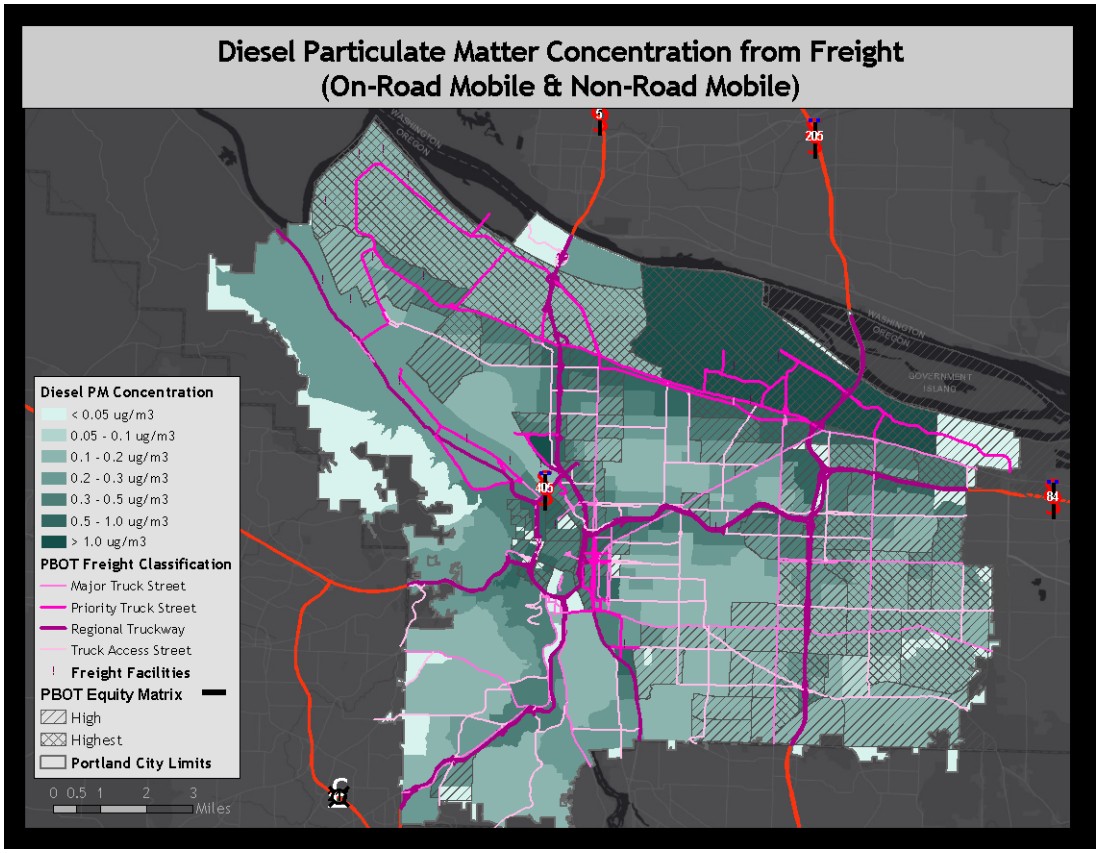
Particulate matter is composed of microscopic particles of various compounds, such as dust, air toxics, smoke, and soot, that are easily inhaled deep into the lungs.[23] Diesel exhaust is primarily composed of ultrafine particulate matter less than 0.1 micrometer (100 nm), the smallest and potentially the most dangerous type of particulate matter. PM2.5 (fine particulate matter, 2.5 micrometers or less), are the smallest particles regulated. Ultrafine and fine particles can enter the bloodstream, where they can be transported to other areas of the body, negatively impacting the respiratory, cardiovascular, and nervous systems.

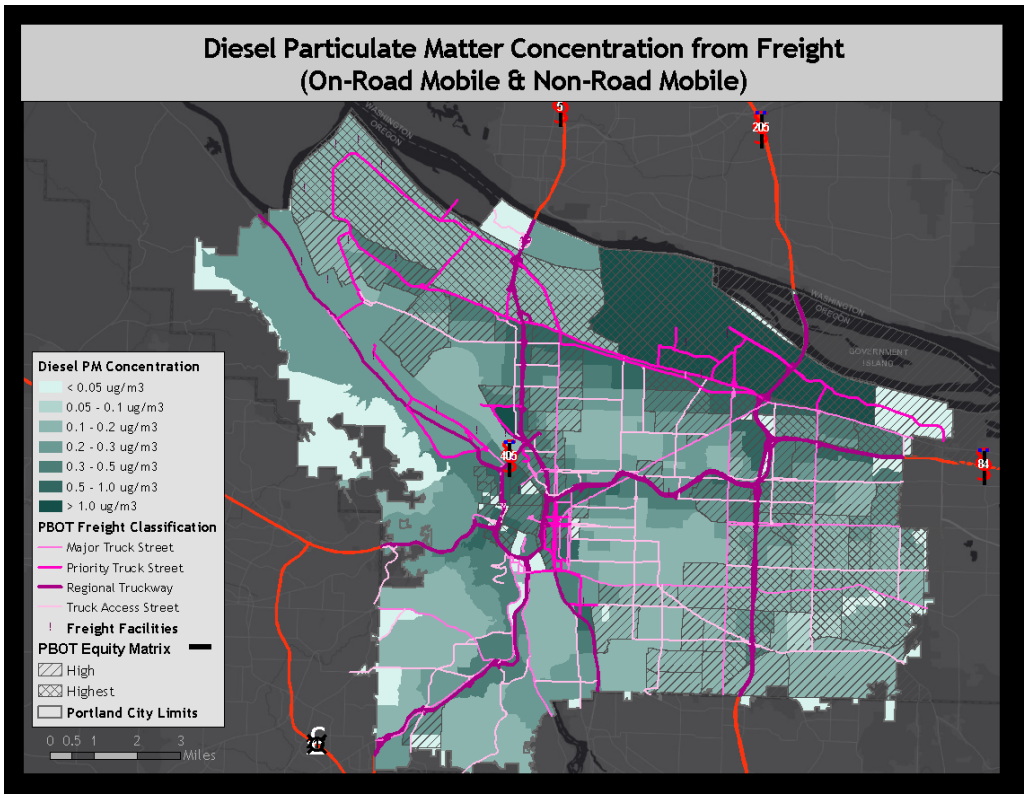
Figure 6 shows on-road mobile and non-road mobile diesel particulate matter (DPM) concentrations as estimated above the ambient benchmark concentrations in Portland by census block group. The darker the color, the more times the DPM concentration is above the benchmark. **Figure 6** illustrates how high levels of diesel particulate matter often correspond with vulnerable areas. These maps show higher concentrations of diesel PM are present in the central city and near the airport and correspond with areas of high vulnerability, as defined by the PBOT Equity Matrix. The Equity Matrix is shown on several maps in this report and a separate map of the Equity Matrix overlayed with the percentage of BIPOC (Black, Indigenous, and People of Color) and low income residents is available in the appendix.

22 International Association for Research on Cancer. (2012). Diesel and gasoline engine exhausts and some nitroarenes. Lyon, France: IARC.

23 EPA. "Particulate Matter (PM) Pollution." Accessed 16 June 2020. https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM.

Figure 6. On-Road Mobile and Non-Road Mobile Diesel Particulate Matter & Freight Routes in Portland





Sources:

Oregon Department of Environmental Quality (DEQ). 2012. "Portland Air Toxics Solutions (PATS) Committee Report and Recommendations." https://www.oregon.gov/deq/FilterDocs/PATS2012.pdf.

PBOT Equity Matrix. 2021. https://www.portlandoregon.gov/transportation/index.cfm?&c=74236.

Portland Transportation System Plan (TSP). https://pdx.maps.arcgis.com/apps/webappviewer/index.html?id=d1d5e545ca6f436fb119932d710ff2fb.

Black Carbon

Black carbon is a type of particulate matter that absorbs sunlight due to its dark color. Approximately 75% of the particulate matter emitted from diesel engines is black carbon. Black carbon is a potent climate-forcing pollutant that warms the atmosphere by absorbing solar radiation and re-emitting it as heat.[24] Black carbon emissions are second only to carbon dioxide (CO2) emissions in their impact on anthropogenic climate change.[25] Diesel vehicles are one of the largest sources of black carbon emissions in the United States; in 2005, diesel engines produced nearly 50% of US black carbon emissions. [26]

Diesel engines are the largest source of black carbon emissions in North America, accounting for about 6% of global black carbon emissions. Black carbon has a shorter atmospheric lifetime than carbon dioxide, but it also has direct climate-forcing effects in snow-covered regions. Researchers have found that black carbon accelerates snow melt in the Arctic because as the particles settle on snow and ice, the dark color reduces the albedo of the surface and causes more sunlight absorption. Black carbon emissions as far south as Oregon have been linked to contributing to such melt in the Arctic. Additionally, researchers have confirmed that this same effect from black carbon has occurred in the Cascades and Sierra Nevada mountains, impacting water resources in the Pacific Northwest.[27]

24 EPA. 2012. "Report to Congress on Black Carbon."

25 DEQ. 2015. "The Concerns about Diesel Engine Exhaust

26 EPA. 2012. "Report to Congress on Black Carbon."

27 DEQ. 2015. "The Concerns about Diesel Engine Exhaust."

Nitrogen Oxides

Nitrogen oxides (NOx) are a category of gases that react with other air pollutants to create ground-level ozone, particulate matter, and acid rain.[28] Nitrogen dioxide (NO2), like particulate matter, is also a designated criteria pollutant subject to NAAQS.[29] Short term health effects of breathing NOx can include: irritation of the respiratory system, skin, and eyes, difficulty breathing and aggravation of respiratory diseases, particularly asthma, coughing and choking, nausea, headache, abdominal pain. [30]

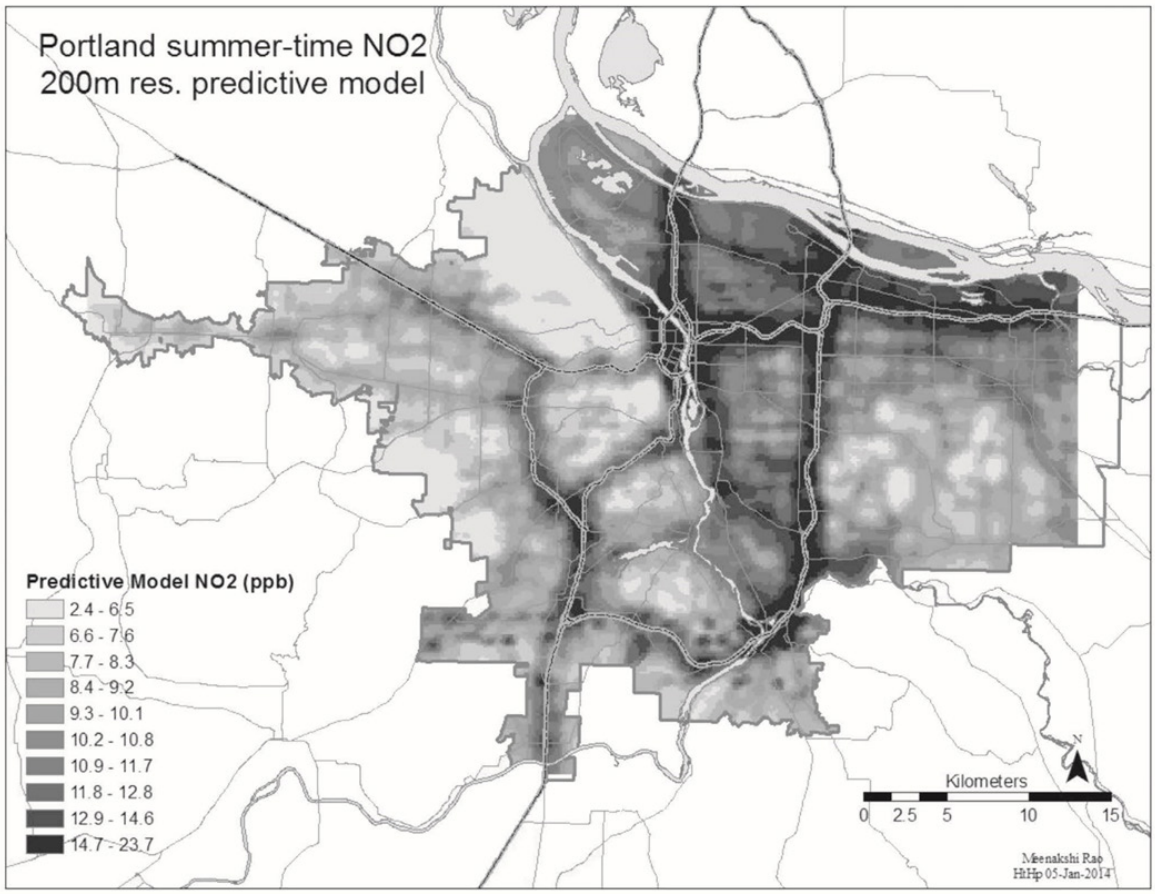
Long term exposure to low levels of NO2 can irritate or damage the respiratory system, cause infections and exacerbate asthma. NOx, including NO2, can combine with volatile organic compounds (VOCs) to create ground-level ozone (smog), which can also cause respiratory issues. VOCs are also a component of diesel exhaust (more predominant in on-road gasoline emissions) that lead to adverse respiratory, cardiovascular, organ specific impacts and certain VOCs are carcinogenic. Portland NO2 estimates from a land use regression model and passive sampling show the pattern of higher concentrations in closer proximity to major roads (Rao et al. 2014), shown in **Figure 7** below.

28 DEQ. 2017. "VW Environmental Mitigation Plan for the State of Oregon." https://www.oregon.gov/deq/FilterDocs/VWenviroMitPlan.pdf.

29 EPA. "National Ambient Air Quality Standards (NAAQS)."

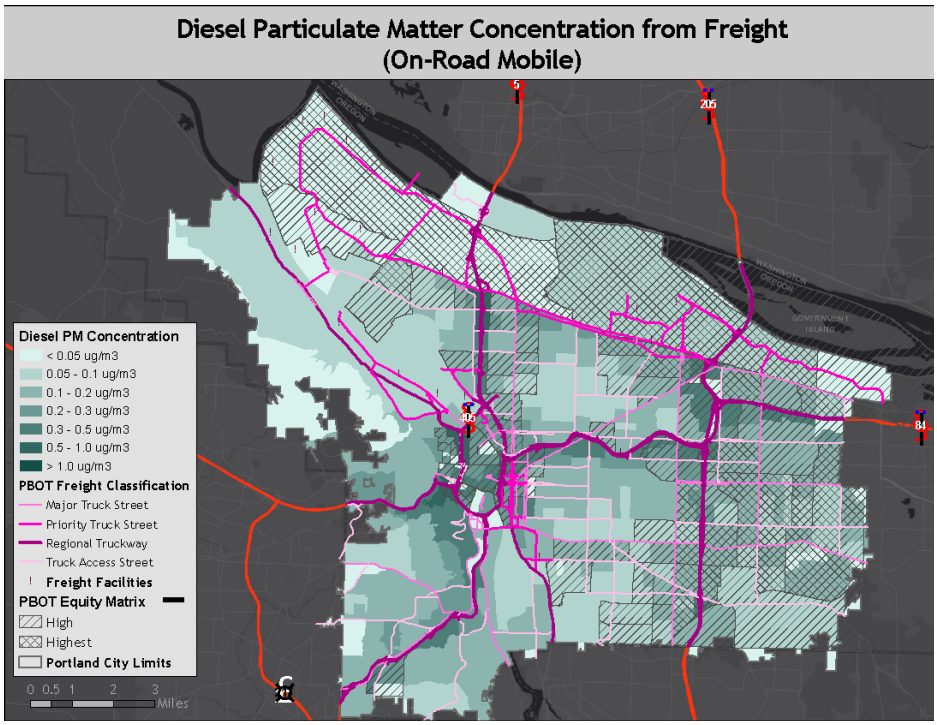
30 EPA. "National Ambient Air Quality Standards (NAAQS)."

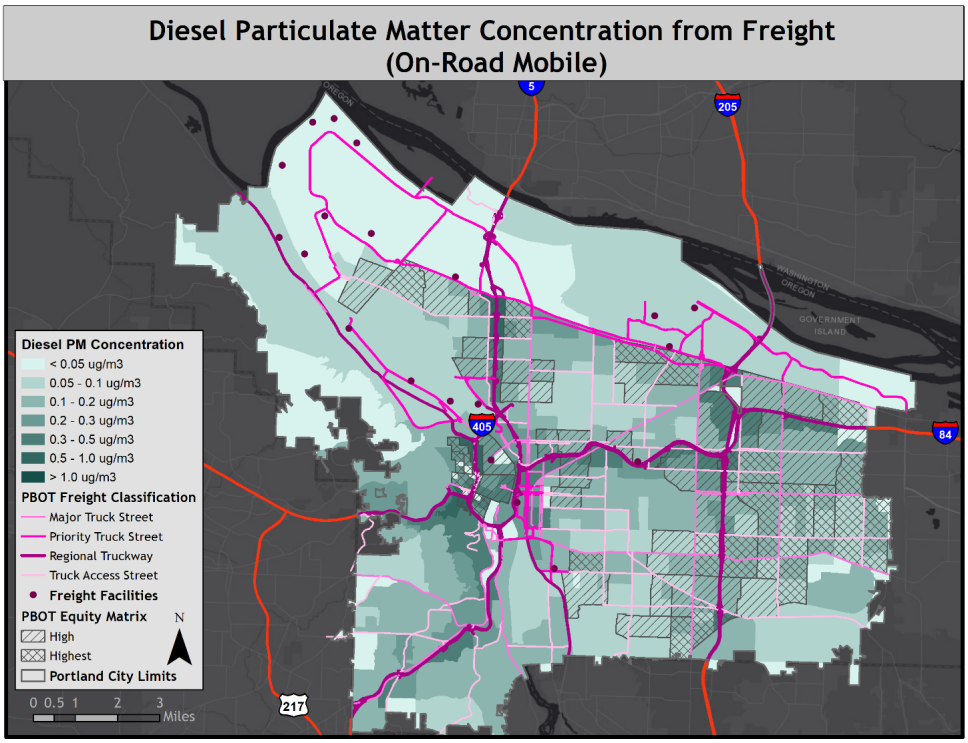
Figure 7. Nitrogen Dioxide Concentrations, Portland, Oregon



Source: Rao, M., George, L. M., Rosenstiel, T. N., Shandas, V., and A. Dinno. 2014. "Assessing the Relationship Among Urban Trees, Nitrogen Dioxide, and Respiratory Health."

Figure 8. On-Road Mobile Diesel Particulate Matter and Freight Routes in Portland





Sources:

Oregon Department of Environmental Quality (DEQ). 2012. "Portland Air Toxics Solutions (PATS) Committee Report and Recommendations." https://www.oregon.gov/deq/FilterDocs/PATS2012.pdf.

PBOT Equity Matrix. 2021. https://www.portlandoregon.gov/transportation/index.cfm?&c=74236.

Portland Transportation System Plan (TSP). https://pdx.maps.arcgis.com/apps/webappviewer/index.html?id=d1d5e545ca6f436fb119932d710ff2fb.

Environmental Justice

Marginalized and vulnerable populations, such as BIPOC communities and low-income people, are often disproportionately impacted by environmentally harmful activities, including exposure to pollutants from diesel exhaust. The United States' Environmental Protection Agency (EPA) defines Environmental Justice as "the fair treatment and meaningful involvement of all people, regardless of race, color, national origin, or income with the respect to the development, implementation, and enforcement of environmental laws," where fair treatment means no group of people should bear a disproportionate share of the negative environmental consequences resulting from industrial, governmental, and commercial operations or policies[31]. The environmental justice movement arose in the 1960's in response to growing recognition that many BIPOC communities "whether by conscious design or institutional neglect...face some of the worst environmental devastation in the nation.[32]"

Freight industry activity directly impacts the health of surrounding communities. Thus, the 2040Freight Plan must address the negative environmental and health impacts caused by freight activity, which disproportionately affects Portland's BIPOC and low-income communities who experience the City's highest air toxics exposure rates.[33] One study indicates majority-BIPOC neighborhoods are exposed to diesel emissions at two-to-three times the rate of the average Portland-area resident.[34] A PATS environmental justice analysis finds disproportionate impacts from air toxics on BIPOC and low-income populations in the Portland area, with Asian communities and populations living below the poverty line experiencing the highest impacts from on-road mobile emissions (i.e. freight), Hispanic and Latinx communities from residential wood combustion emissions, and the Black and African American population from area source emissions.[35] Given commercial trucks' contribution to diesel emissions in Portland (15%), a significant portion of these emissions can be traced to on-road freight transport.

Figure 8 illustrates a substantial overlap between on-road mobile diesel emission concentrations, freight routes (classified by Portland's Transportation System Plan), and census tracts. Census tracts are scored using the PBOT Equity Matrix, which is an index based on race, income, and limited English proficiency[36]. Most vulnerable tracts have at least one freight route passing through. Additionally, census block groups with the highest diesel and air toxics are bisected by several Regional and Priority Truckways, further indicating freight transport's potential contribution to diesel/air toxics pollution and disproportionate freight activity in low-income neighborhoods, BIPOC communities, and limited-English Proficiency areas.

Figure 8 shows all schools in Portland mapped over on-road diesel particulate matter concentrations and freight routes. Numerous schools are located near freight routes and in areas with levels of diesel PM above the ambient benchmark concentration. Given the many negative health impacts of particulate matter from diesel (respiratory, cardiovascular, cognitive, and cancer), special care should be taken to avoid locating schools, as well as other sensitive or vulnerable populations, such as elder care facilities, near sources of diesel exhaust.

Freight emissions are especially harmful to children, as exposure to diesel pollution can cause permanent damage to lungs that are still developing and can lead to reduced lung capacity that persists through adulthood.[37] Other forms of air pollution generated from freight activity are known to limit lung development in children and teens, such as ozone. [38]

31 EPA. "Environmental Justice." Accessed July 20, 2020. https://www.epa.gov/environmentaljustice.

32 EPA. 2017. "Environmental Justice Timeline." Accessed 27 July 2020. https://www.epa.gov/environmentaljustice/environmental-justice-timeline.

33 Oregon DEQ. 2013. "Portland Air Toxics Solutions Report and Recommendations." https://oregonconsensus.org/wp-content/uploads/2013/12/PATSfactsheet.pdf

34 Multnomah County Health Department. 2014. "Report Card on Racial and Ethnic Disparities." https://multco.us/file/37530/download.

35 Oregon DEQ. 2012. "Portland Air Toxics Solutions Committee Report and Recommendations." https://www.oregon.gov/deq/FilterDocs/PATS2012.pdf

36 Portland Bureau of Transportation (PBOT). 2016. "Equity Matrix." https://www.portlandoregon.gov/transportation/74236

37 Mudway, I. S., et al. (2019). "Impact of London's Low Emission Zone on Air Quality and Children's Respiratory Health: A Sequential Annual Cross-Sectional Study." The Lancet Public Health, 4(1), e28-e40. https://www.thelancet.com/action/showPdf?pii=S2468-2667%2818%2930202-0.

38 American Lung Association. "Children and Air Pollution." Accessed July 21, 2020. https://www.lung.org/clean-air/outdoors/who-is-at-risk/children-and-air-pollution.

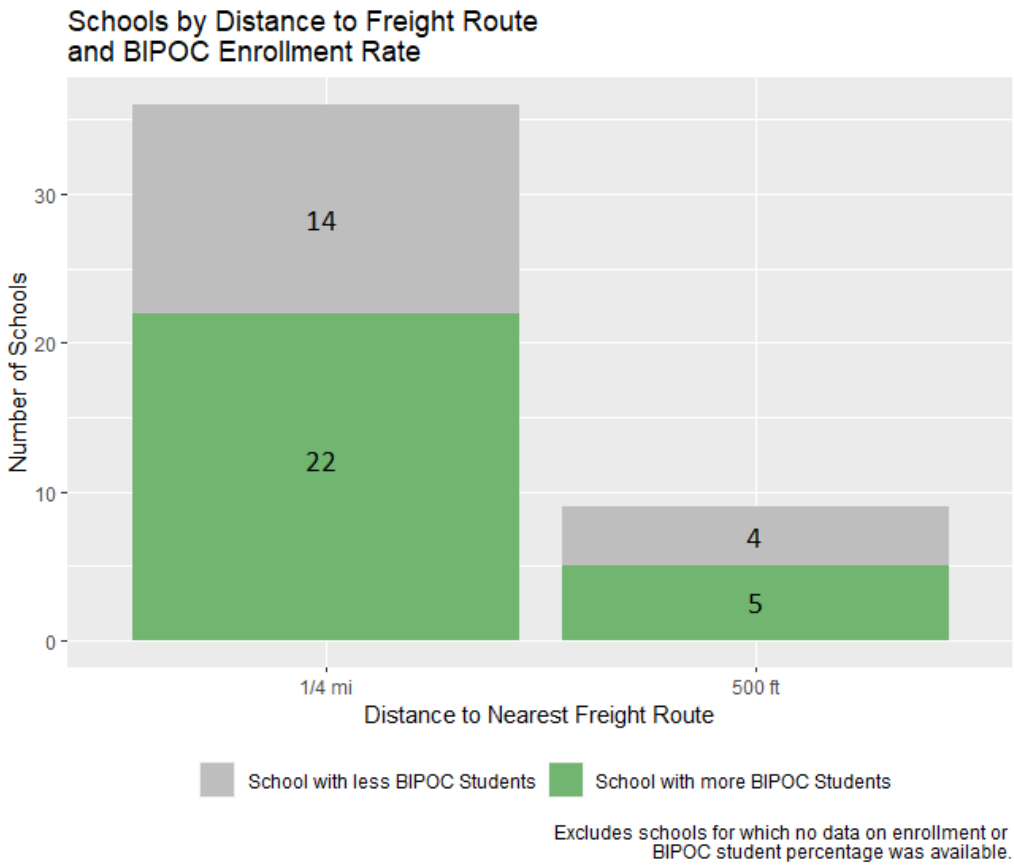
Many children in Portland may be exposed to significant concentrations of pollution from freight activity. A 2018 study by Portland State University and Portland Public Schools found that Harriet Tubman Middle School, located in Northeast Portland about 50 feet from Interstate 5, has substantially elevated levels of black carbon and NO2, especially on the interstate-facing side of the school.[39] While Tubman Middle School is the closest school to a highway, 149 other schools are found to operate within 500 meters of a freeway in Portland, a distance which poses increased health risks.[40]

39 Gall, E. T., George, L. A., Cal, R. B., and A. Laguerre. 2018. "Indoor and Outdoor Air Quality at Harriet Tubman Middle School and the Design of Mitigation Measures: Phase 1 Report." https://s3.amazonaws.com/arc-wordpress-client-uploads/wweek/wp-content/uploads/2018/07/05143206/Tubman-PSU_HTMSReport_Phase1-Outdoor-Monitoring_Final.pdf.

40 Multnomah County. 2019. "County Air Low on Heavy Metals, High on Toxic Diesel Pollution, Research Finds." https://multco.us/multnomah-county/news/county-air-low-heavy-metals-high-toxic-diesel-pollution-research-finds.

When considering schools in Portland, excluding universities and colleges, 16 schools are located within 500 feet of a Regional, Primary, or Major Truckway, while 48 schools are within 0.25 miles of these roadways. Public schools have student demographic information available, which is used in this report to understand populations of students impacted by freight emissions. Of the 16 schools located within 500 feet of the top three freight route classifications, nine had demographic information available. And of the 48 schools located within 0.25 miles of a freight route, demographic information was available for 36. **Figure 9** summarizes the number of schools within 500 ft and 0.25 mi of freight routes by BIPOC student enrollment rates. **Within both distances to freight routes, there seems to be a slightly higher percentage of schools with higher proportions of BIPOC students within 500 ft (61%) and 0.25 miles (55%) based on the available data.** However, further analysis considering the total population and the ratio of BIPOC students for each school must be performed to evaluate this trend.

Figure 9. Number of Schools within 0.25 mi and 500 ft of Freight Routes in Portland by BIPOC Enrollment Rates



Sources:
1. Portland Public Schools (PPS) 2019 Student Enrollment https://www.pps.net/cms/lib/OR01913224/Centricity/Domain/207/Enrollment%20Summary%202019-20.pdf

2. Parkrose School District 2019 Student Enrollment http://web.parkrose.k12.or.us/files/about/state_report_cards/do/1819-ReportCard-2181.pdf
3. David Douglas School District Portland Transportation System Plan (TSP). https://pdx.maps.arcgis.com/apps/webappviewer/index.

The proportion of BIPOC students at each school are compared to the overall school district enrollment demographics. In Portland, 45 schools are located near freight routes, within at least 0.25 mi as described above, out of the 112 schools citywide with student demographic information. Twenty-seven (60% of 45 schools within 0.25 miles) of these schools near freight routes have higher proportions of BIPOC students enrolled, as opposed to 18 schools (40% of 45 schools within 0.25 miles) with less than districtwide BIPOC enrollment. This data indicates that a higher share of schools with a higher share of BIPOC are located in proximity to the major freight network elements.

Table 1. Schools within 0.25 mi and 500 ft of Freight Routes in Portland by BIPOC Enrollment Rates

School Demographics	Number of Schools Near Freight Routes	Number of Schools in Portland	% of Schools	Total Number of Students Near Freight Routes
More BIPOC Students	27	47	57.4%	14,238
Less BIPOC Students	18	65	27.7%	11,842
Total	45	112	40.2%	26,080

Sources:
1. Portland Public Schools (PPS) 2019 Student Enrollment https://www.pps.net/cms/lib/OR01913224/Centricity/Domain/207/Enrollment%20Summary%202019-20.pdf
2. Parkrose School District 2019 Student Enrollment http://web.parkrose.k12.or.us/files/about/state_report_cards/do/1819-ReportCard-2181.pdf
3. David Douglas School District
4. Reynolds School District https://www.reynolds.k12.or.us/district/fast-facts
5. Centennial School District https://www.csd28j.org/domain/45
6. Portland Transportation System Plan (TSP). https://pdx.maps.arcgis.com/apps/webappviewer/index.html?id=d1d5e545ca6f436fb119932d710ff2fb.

Other Pollutants Related to Freight

Noise

As noise pollution can be challenging to measure and enforcement is limited, it is an often overlooked form of pollution; however, it can have numerous negative health effects. Several studies find excessive noise exposure is associated with sleep disturbance, negative impacts on cognitive functioning in children, hypertension and cardiovascular issues, and many other health issues.[41] Using noise estimates from the US Department of Transportation, Figure 10 below shows widespread high decibel levels along the City's major freight corridors (i.e. North and Northeast Portland near the airport, in downtown Portland along I-405, and surrounding major motorways and arterials,) signifying a high level of noise pollution in the immediate vicinity of such freight-related infrastructure[42].

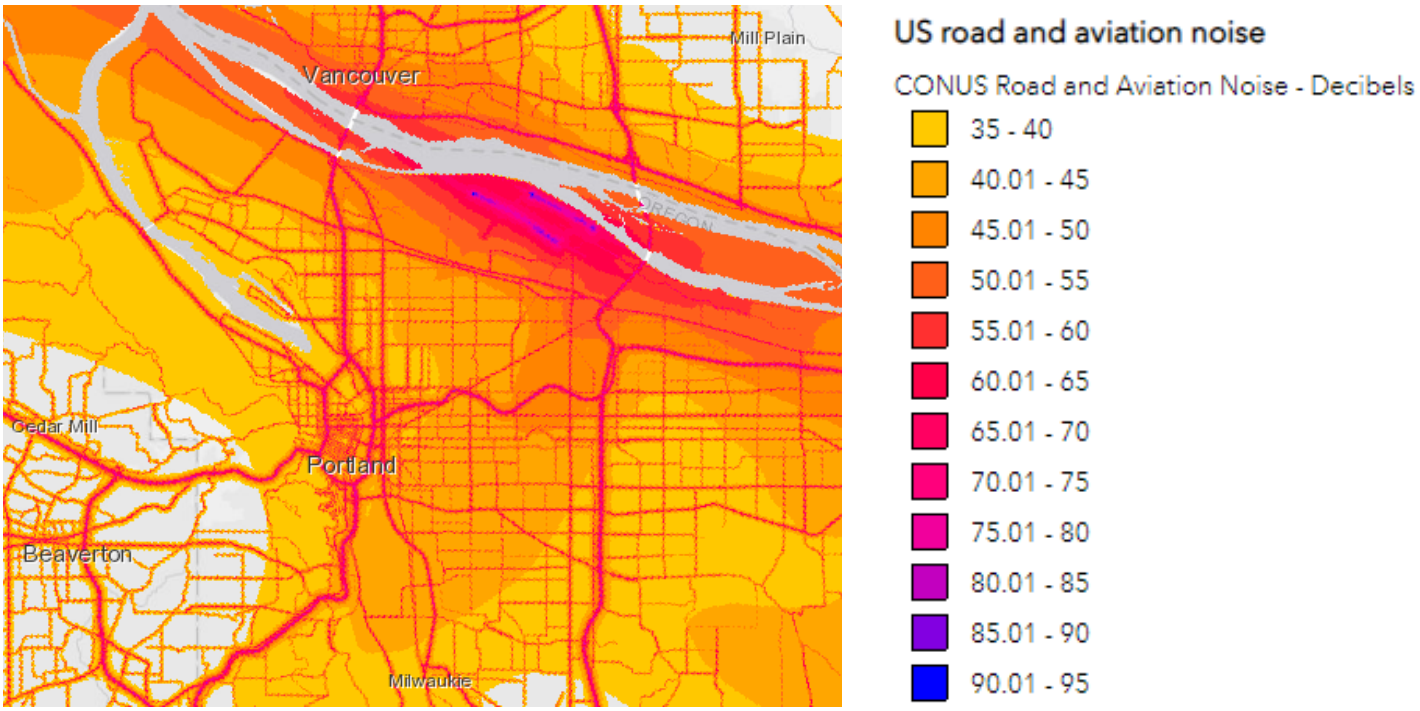
41 Seto, E. Y. W., Holt, A., Rivard, T., & R. Bhatia. 2007. "Spatial Distribution of Traffic Induced Noise Exposures in a US City: An Analytic Tool For Assessing The Health Impacts Of Urban Planning Decisions." International Journal of Health Geographics, 6(1), 24. https://pubmed.ncbi.nlm.nih.gov/17584947/.

42 Seto, E. Y. W., Holt, A., Rivard, T., & R. Bhatia. 2007. "Spatial Distribution of Traffic Induced Noise Exposures in a US City: An Analytic Tool For Assessing The Health Impacts Of Urban Planning Decisions." International Journal of Health Geographics, 6(1), 24. https://pubmed.ncbi.nlm.nih.gov/17584947/.

Exposure to prolonged noise pollution contributes to a variety of health issues. An extensive health impact study from noise pollution by The World Health Organization (WHO) finds noise from traffic is the second highest public health threat, after air pollution.[43] Children, elderly, and people experiencing chronic illness suffer the most from noise pollution. The WHO study reports that children are particularly vulnerable to cognitive impairment and other developmental issues from noise pollution. The study also notes different decibel levels and timing of exposure (night or day) being associated with different health impacts, finding any ambient noise over 40 decibels can trigger a variety of sleep-related issues, such as insomnia, daytime fatigue, and other health issues associated with lack of sleep. Conversely, continued exposure to over 60 decibels during the day increases the risk of several cardiovascular diseases and hypertension. On-road freight activity likely exacerbates areas with high noise exposure, and therefore may contribute to the variety of health complications associated with noise pollution.

43 World Health Organization. 2011. "Burden of Disease from Environmental Noise Quantification of Healthy Life Years Lost in Europe." https://www.who.int/quantifying_ehimpacts/publications/e94888.pdf?ua=1.

Figure 10. Noise Pollution from Roads & Aviation in Portland



https://maps.bts.dot.gov/arcgis/apps/webappviewer/index.html?id=a303ff5924c9474790464cc0e9d5c9fb

Health Impacts

Exposure to diesel engine exhaust is shown to increase the risk of heart attack, stroke, and cardiovascular disease, exacerbate asthma and other respiratory illnesses; can lead to low-weight and preterm births; and is linked to cancer, especially lung cancer.[44] There is also a growing body of evidence linking traffic-related air pollution, including diesel exhaust, to neurodevelopmental disorders like Autism Spectrum Disorder.[45] Further, noise pollution associated with freight activity on major roadways can lead to hearing impairment, insomnia, lack of sleep and associated health issues, and is associated with increased risk of cardiovascular disease and hypertension. There is consensus among many national and international agencies that diesel exhaust is a carcinogen that can be tied to increased risk of lung cancer.[46 47]

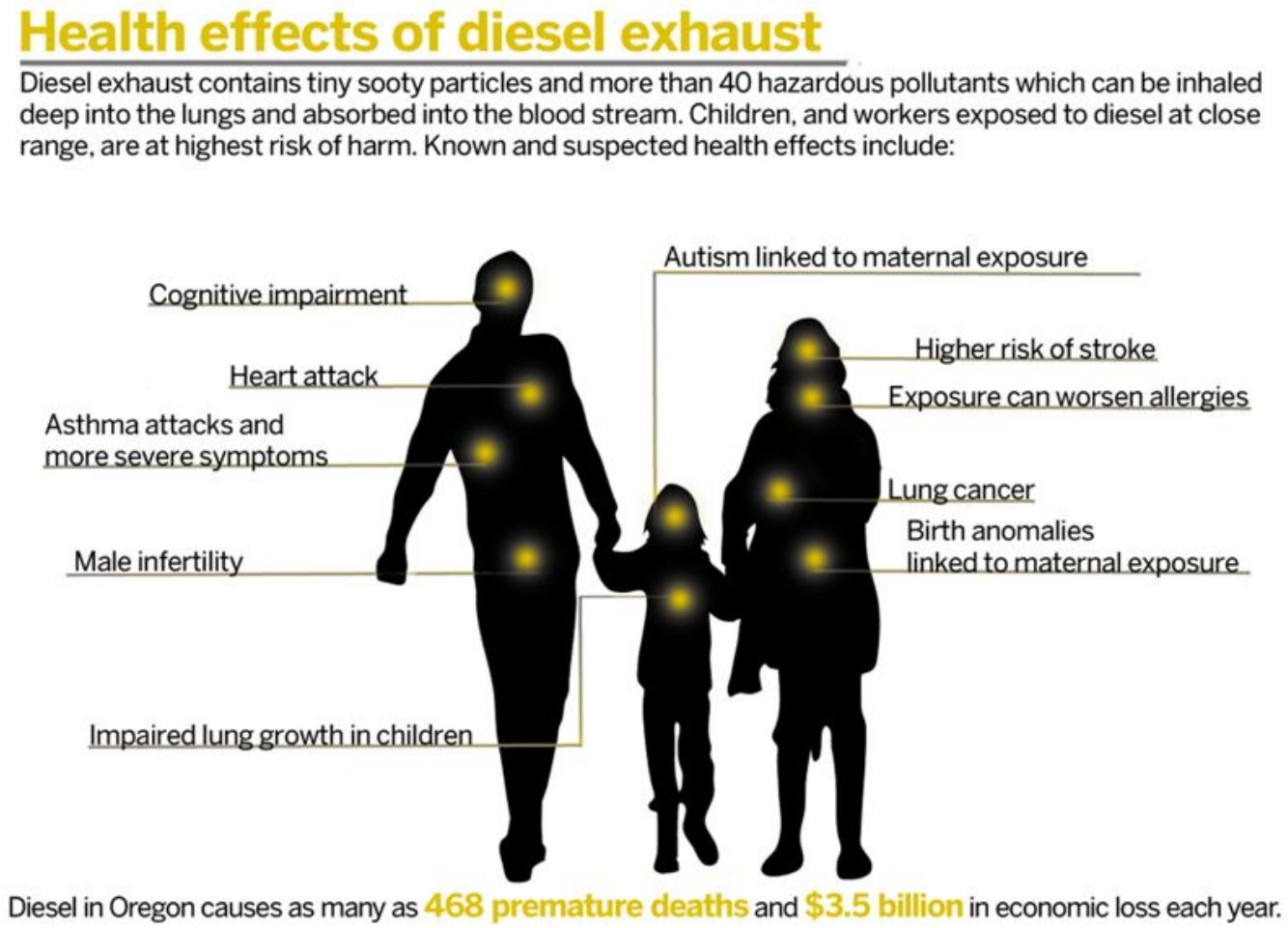
44 Multnomah County. "Diesel Pollution: Bad for Oregon's Health." https://www.portlandoregon.gov/brfs/article/733313

45 Multnomah County. "Diesel Pollution: Bad for Oregon's Health."

46 Agencies linking diesel exhaust to cancer include: The International Agency for Research on Cancer (IARC) that is part of the World Health Organization (WHO); The National Toxicology Program (NTP) that is formed from parts of several different US government agencies, including the National Institutes of Health (NIH), the Centers for Disease Control and Prevention (CDC), and the Food and Drug Administration (FDA); The US Environmental Protection Agency (EPA); and The National Institute for Occupational Safety and Health (NIOSH), which is part of the CDC that studies exposures in the workplace.

47 American Cancer Society. "Diesel Exhaust and Cancer." Accessed 28 July 2020. https://www.cancer.org/cancer/cancer-causes/diesel-exhaust-and-cancer.html.

Figure 11. Health Effects of Diesel Exhaust



Source: Multnomah County. "Diesel Pollution: Bad for Oregon's Health."

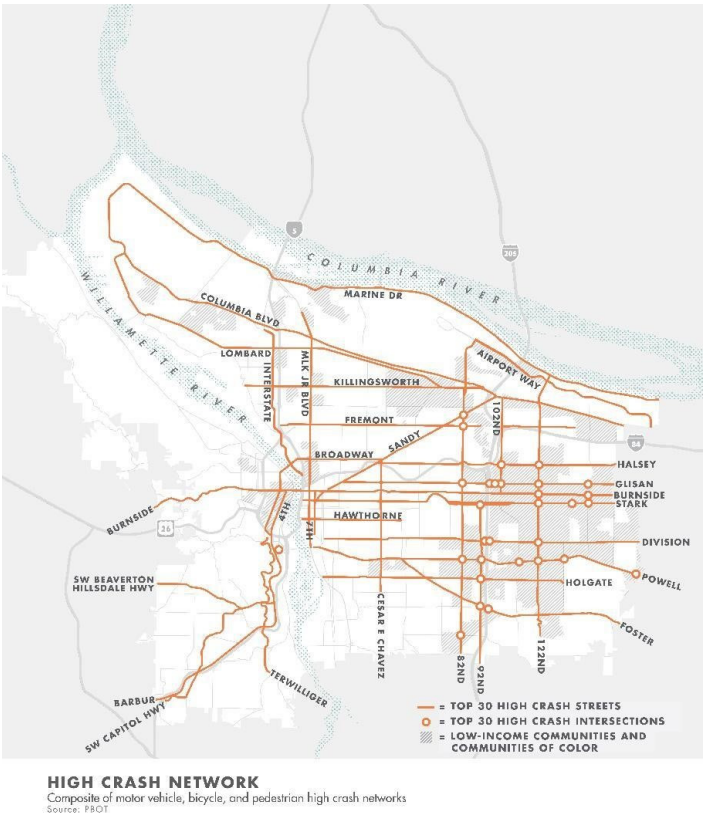
Vision Zero and Crash Injuries

Traffic crash injuries are a public health concern. In Multnomah County, unintentional injury, which includes injuries from traffic crashes, is the third leading cause of death, after cancer and heart disease[48].

In 2015, the Portland City Council unanimously adopted Vision Zero, the City of Portland's commitment to eliminating traffic deaths and serious injuries for all road users. The 2016 Vision Zero Action Plan identifies the three guiding principles of Vision Zero: equitable, data-driven, and accountable. The Action Plan also explains why Vision Zero identifies several major crash factors, and actions PBOT will take to address these crash factors. One of the leading factors in fatal and serious injury crashes is street design. Fifty-seven percent of fatal and serious injury crashes occurred on 8 percent of Portland streets, also called the High Crash Network (HCN). Many of these High Crash Corridors are also primary freight routes in the city, as shown in **Figure 12** where these two networks are shown side-by-side.

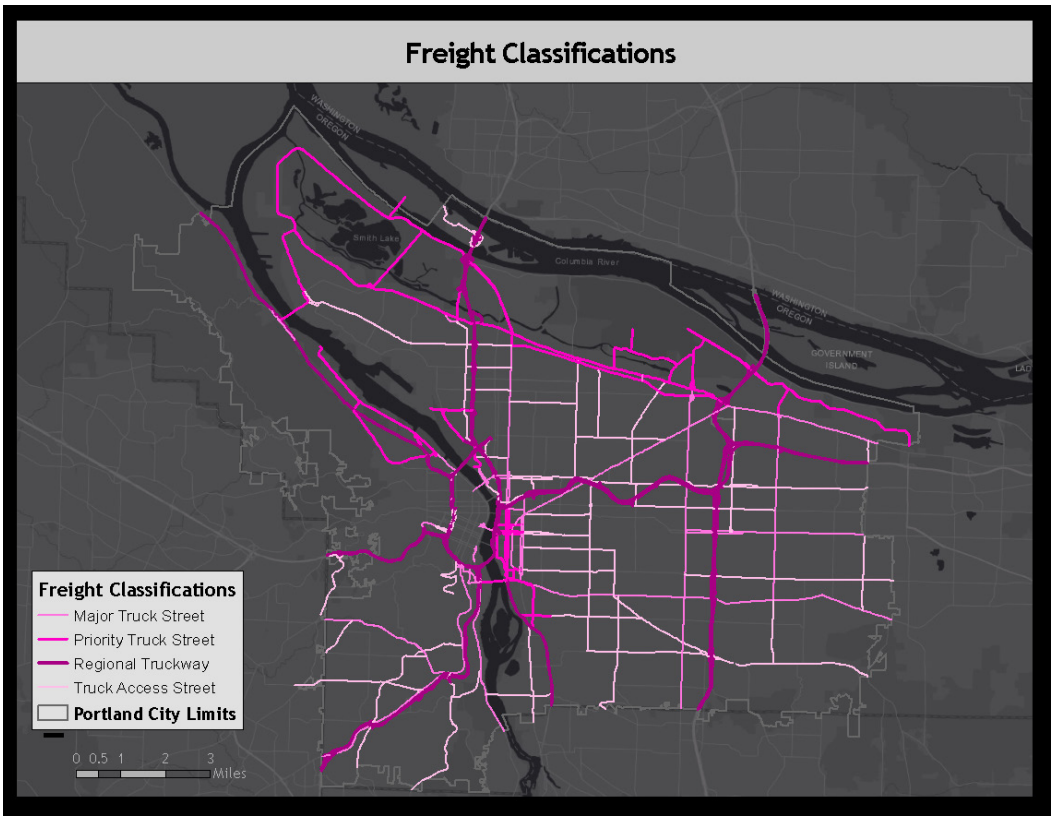
48 Centers for Disease Control and Prevention, National Center for Health Statistics. Underlying Cause of Death 1999-2019 on CDC WONDER Online Database, released in 2020

Figure 12. Portland Vision Zero High Crash Network and PBOT Transportation System Plan (TSP) Freight Route Classifications



Source: PBOT

Figure 12. Continued



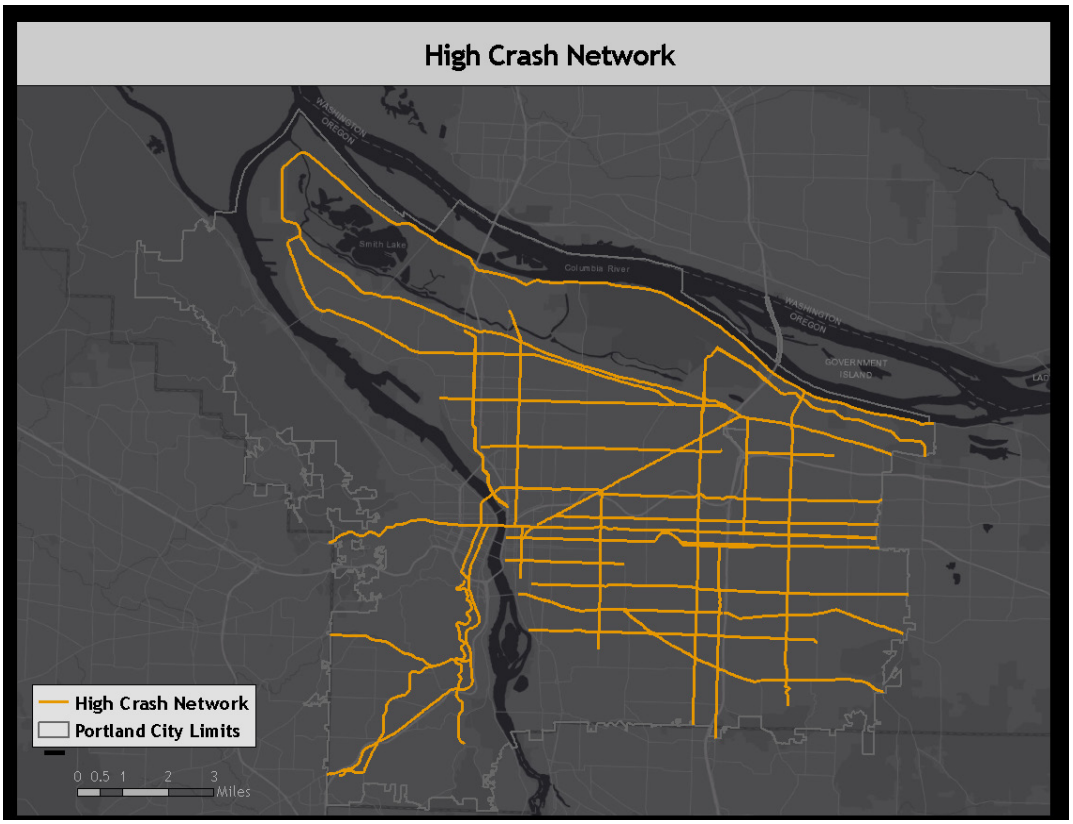
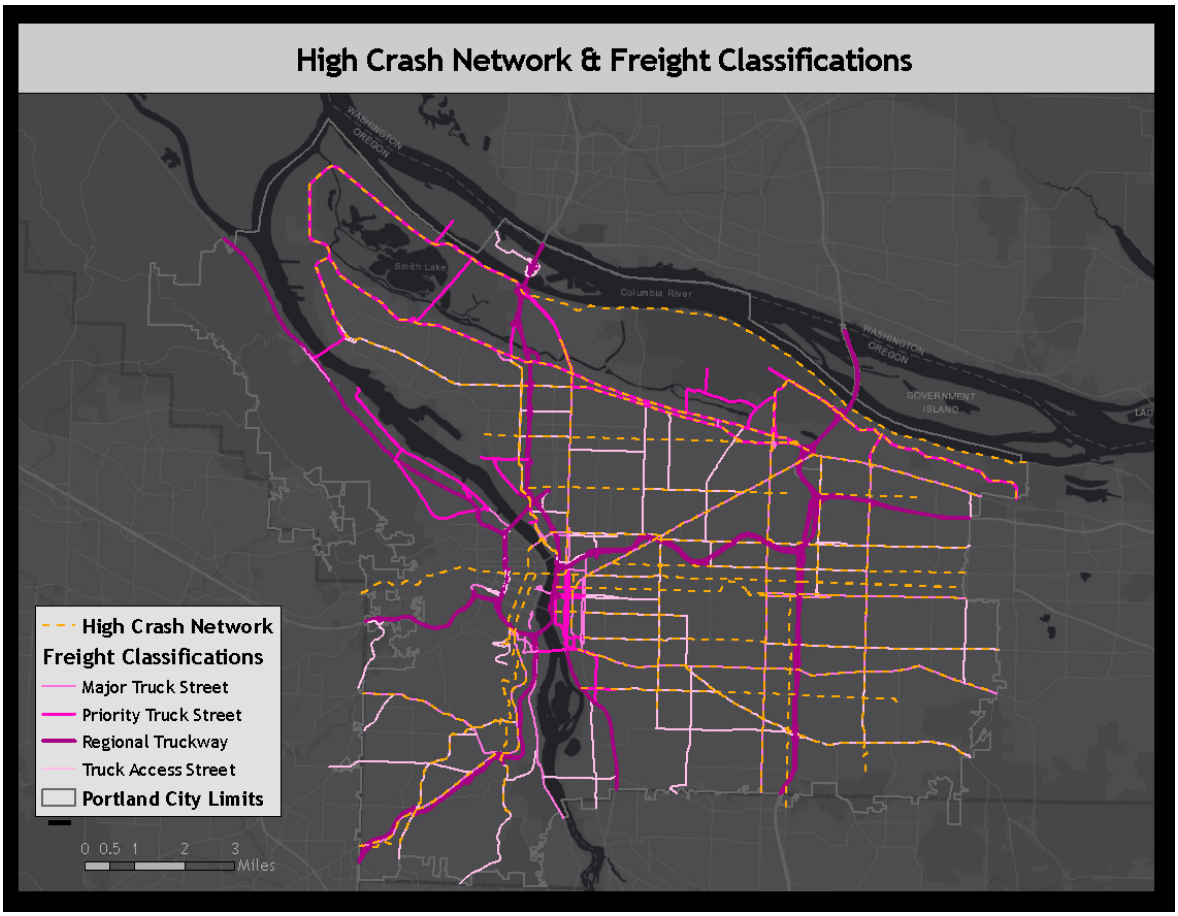


Figure 12. Continued



Source: PBOT

Street design is one of the most effective tools to support traffic safety. Multi-lane roadways with high speeds and insufficient street lighting create challenges for all road users to travel safely. These features combined with a significant volume of large and heavy freight trucks makes for dangerous conditions for the most vulnerable road users including pedestrians, people on bikes, and people on motorcycles. These vulnerable road users make up over 50 percent of traffic deaths every year but are a far smaller share of how people travel in Portland. This disproportionality is especially true in the area east of 82nd Avenue, also called East Portland, where pedestrians are twice as likely to die in a traffic crash than in other parts of the city. For these reasons, one of Vision Zero's highest priorities is protecting pedestrians. PBOT recognizes that as the city's population continues to grow, there will be more areas where vulnerable road users interact and travel in the same spaces as freight vehicles.

As e-commerce has grown in recent years, so have traffic crashes involving freight vehicles in Portland. Figure 10 shows the annual number of injury crashes involving freight trucks for the 20 most recent years of data available, 1999 to 2018. Crashes shown involve at least one injury sustained by any road user in the crash, including pedestrians, people on bikes, passengers and drivers in vehicles, including those traveling in freight trucks. Traffic crashes involving freight vehicles have increased over the past twenty years, and more sharply since 2010, as shown by the blue trendline in the below figure.

A deeper dive into examining truck-involved crashes in the City of Portland was executed as part of the 2040Freight planning effort and laid down in the 2040Freight Existing Condition Report[49]. This study found that from 2014 to 2018, 56,942 collisions were reported in Portland, and of these, 2,267 were truck-involved collisions (4% of total collisions), and 3.3.% of those were severe or fatal injury collisions. Additionally, two significant findings resulted from this analysis:

- most truck collisions were a result of drivers who did not yield right-of-way (20% of collisions), followed by improper turns (17% of collisions); and
- the most common collision type for truck collisions in the City of Portland is turning movement (38%), followed by rear-end (22%) and sideswipe-overtaking (18%).

This study suggests three main recommendations:

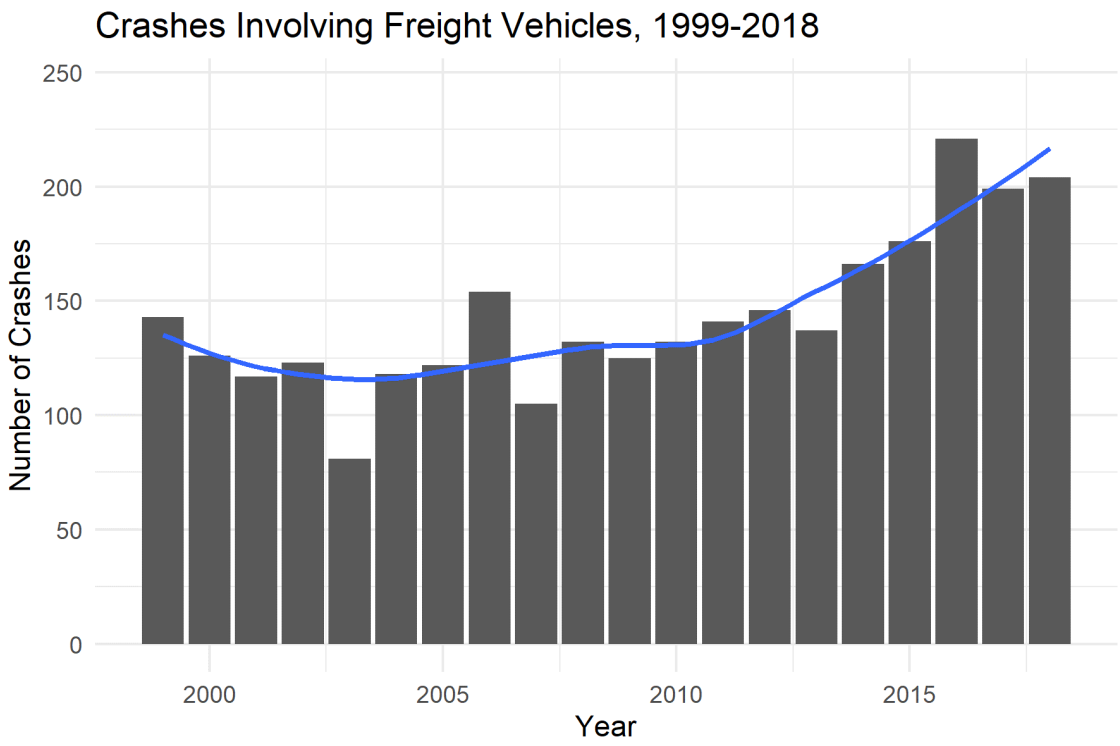
- improving visibility, especially at intersections, to allow vehicles to safely pass freight vehicles turning to access businesses could help reduce these types of collisions;
- focusing on improving safety for those vulnerable road users, who are primarily exposed in collisions with trucks due to the large nature of the vehicles involved.
- implementing safety countermeasures for vulnerable users, such as separated facilities, clear signage or providing for alternate parallel routes.

In addition to concerns about protecting vulnerable road users, the safety of heavy truck freight drivers is also important. Freight drivers are also injured and killed in traffic crashes in Portland. In April 2019, a freight truck driver was killed after pulling his truck out onto NE Columbia Boulevard and walking back to close the gate to his business. And in August 2019, a freight truck driver died on I-5 after losing control of his truck and crashing into a road sign structure. These deaths are tragic and Vision Zero is committed to eliminating traffic deaths for everyone traveling on Portland roadways.

49 WSP & Fehr and Peers (2021) 2040Freight Existing Conditions Report. Prepared for PBOT.

https://www.portland.gov/sites/default/files/2021/2040freight_existing_conditions_report_1_0.pdf

Figure 13. Annual Portland traffic crashes involving freight vehicles 1999-2018.



Source: Oregon Department of Transportation (ODOT) Crash Analysis and Reporting Unit.

Climate Impacts

Freight activity as it exists today cannot be separated from its environmental impact and its contribution to climate change. Diesel fuel consumption is a major contributor to anthropogenic climate change as one gallon of diesel fuel emits approximately 14% more carbon dioxide (CO2) than gasoline on a per gallon basis (22.4 pounds of CO2 per gallon of diesel, compared to 19.6 pounds of CO2 per gallon of gasoline.)[50] Additionally, the pollutants associated with diesel exhaust, such as particulate matter, nitrogen oxides, and black carbon have an even greater impact on climate change. For example, black carbon, which accounts for roughly 70% of diesel particulate matter, is a potent short-lived climate pollutant, meaning it does not exist in the atmosphere as long as CO2 (days to weeks rather than thousands of years), but it has a higher potential to warm the atmosphere (known as global warming potential (GWP)). Additionally, due to the effectiveness of black carbon PM at absorbing light and heating its surroundings, it absorbs solar radiation in the atmosphere and re emits that radiation as heat, which can influence cloud formation, regional circulation, and rainfall patterns. Further, when deposited on ice and snow, black carbon darkens these reflective surfaces and reduces their ability to reflect sunlight (albedo), accelerating surface melting.[51]

The Paris Agreement commits countries to limit global temperature rise to 1.5˚-2˚ Celsius (2.7-3.6˚ Fahrenheit) and the Intergovernmental Panel on Climate Change (IPCC) special report on global warming of 1.5˚ C stresses that deep reductions in emissions of carbon dioxide (CO2) and non-CO2 climate forcers, particularly the air pollutants of methane and black carbon, are also crucial. [52]Given the short-lived nature of black carbon, reducing diesel emissions can create substantial near-term climate benefits.

Ozone like nitrogen dioxide (NO2) is harmful to health and can cause inflammation in the lungs, chest pain, coughing, and reduce immunity to lung infections. These pollutants can also lead to or exacerbate chronic respiratory and cardiovascular impacts. Ground level ozone is a secondary pollutant formed by a reaction of two other groups of pollutants in the presence of sunlight. The pollutants that react to form ground level ozone are Volatile Organic Compounds (VOCs) and Nitrogen oxides (NOx). Motor vehicles are major sources for both NOx and VOCs. The 2014 National Emissions Inventory shows mobile on-road heavy duty diesel vehicles are the second largest sources of nitrogen oxides in Oregon. Ozone trends are on the rise across the Willamette Valley including Portland. As the number of hot sunny days keep increasing in Portland due to climate change, actions to reduce ozone and protect health need to be strengthened.[53]

50 US Energy Information Administration (EIA). 2016. "Carbon Dioxide Emissions Coefficients." https://www.eia.gov/environment/emissions/co2_vol_mass.php.

51 Climate & Clean Air Coalition. "Black Carbon." Accessed 28 July 2020. https://www.ccacoalition.org/en/slcps/black-carbon.

52 Intergovernmental Panel on Climate Change (IPCC). 2018. "Special Report on Global Warming of 1.5 ˚C. https://www.ipcc.ch/sr15/.

53 Oregon Department of Environmental Quality, "Oregon Annual Air Quality Report: 2018" (2019)

https://www.oregon.gov/deq/FilterDocs/2018AQAnnualReport.pdf

Picture 3.1: A large group of young elementary students accompanied by parents and teachers walking to school as part of a PBOT Safe Routes to School project. Three children are wearing constumes. [Source: PBOT]

CONCLUSION

Freight activity is integral to Portland's trade-based economy. Its impacts on humans, the environment, and economy of the region are far-reaching. The 2040Freight Plan must reckon with these impacts and be shaped in a way that mitigates current and future harm.

Freight activity is a significant contributor to diesel emissions, which can have numerous negative impacts on human and environmental health. Portland has some of the highest rates of diesel exposure in Oregon and noise and air pollution levels are highest near freight infrastructure. Due to the many planning decisions to site major transportation infrastructure, such as Interstate-5, through historically Black and low income communities in Portland, the legacy of these decisions remains today with many vulnerable areas affected by freight pollution. In addition to experiencing the direct negative effects of diesel pollution, many of these vulnerable areas will also bear the negative indirect effects of these pollutants, as diesel exhaust is a significant source of CO2 and black carbon, two potent greenhouse gasses that have short and long term effects on climate change.

Planning for freight in the Portland region in a way that mitigates human and environmental harm will require careful consideration of freight's benefits and burdens.

APPENDIX

A. Demographics

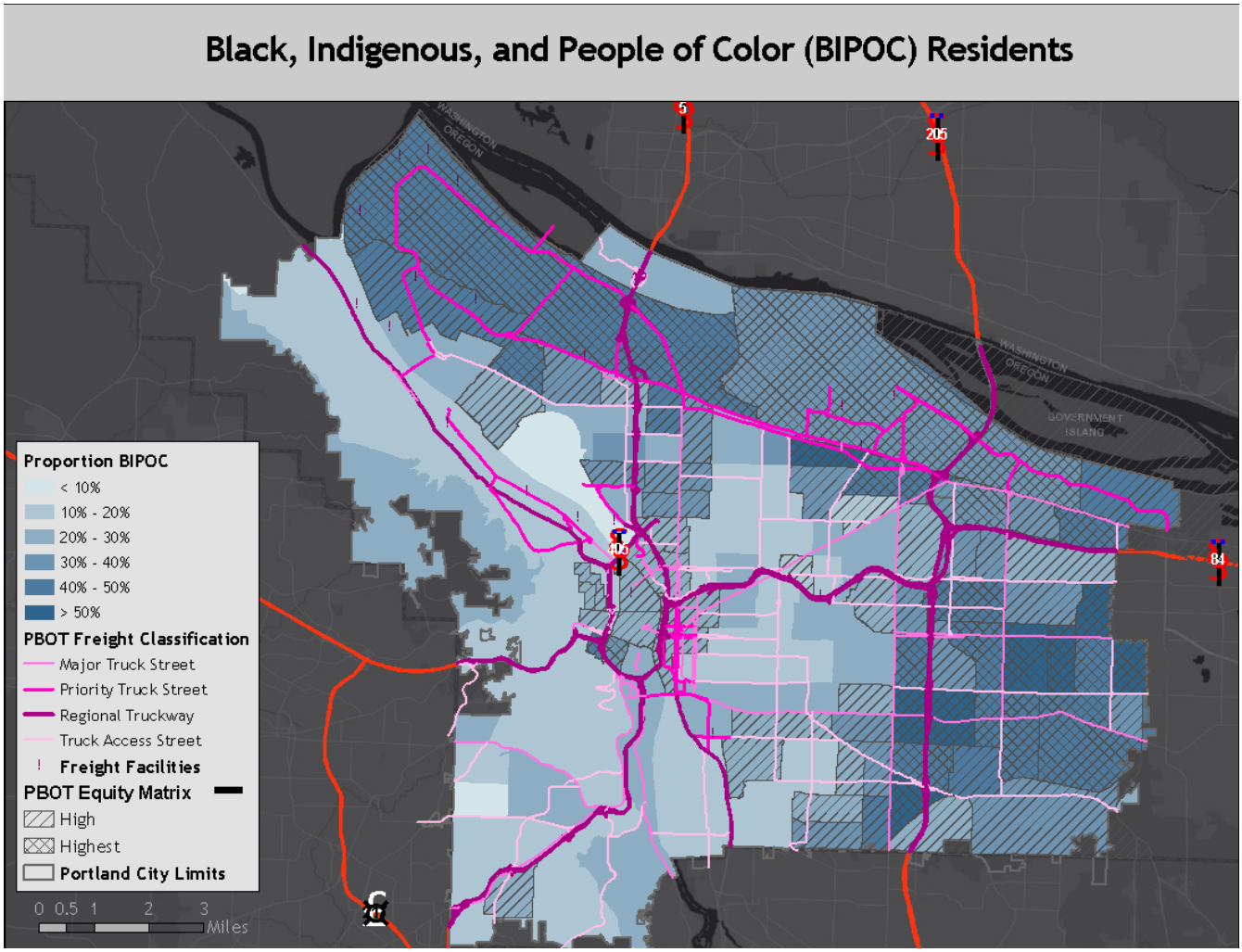



Figure A-1| Black, Indigenous, & People of Color Residents & Freight Classes, Portland (2015-2019)