Community Climate Choices

Health Impact Assessment

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ACRONYMS

BRFSS	Behavioral Risk Factor Surveillance System
CCC	Community Climate Choices
CSCS	Climate Smart Communities Scenarios
DALY	disability adjusted life years (sum of YLL and YLD)
DEQ	Oregon Department of Environmental Quality
GHG	greenhouse gas
GreenSTEP	Greenhouse Gas Strategic Transportation Energy Planning Model
HIA	Health Impact Assessment
ITHIM	Integrated Transport and Health Impact Model
LDV	light-duty vehicle (gasoline powered)
ODOT	Oregon Department of Transportation
PHD	Public Health Division of the Oregon Health Authority
PATS	Portland Air Toxics Solutions
VMT	vehicle miles traveled
WHO	World Health Organization
YLD	years of life with a disability
YLL	years of life lost

EXECUTIVE SUMMARY

Community Climate Choices Health Impact Assessment

Climate change may pose serious risks to public health. Significant shifts in the climate are already happening. The Third National Climate Assessment found that as the climate continues to change, Oregon will likely experience more frequent heat waves and wildfires, an increase in asthma and other respiratory diseases, changes in disease patterns, and diminishing water quality and quantity [1]. Curbing climate change is a critical public health issue and national public health officials support efforts across the nation to reduce greenhouse gas (GHG) emissions.

The recommendations offered in this Community Climate Choices Health Impact Assessment (CCC HIA) will be considered during Phase 3 of Metro's Climate Smart Communities Scenarios (CSCS) Project, underway in the Portland, Oregon metropolitan region. The focus of the project is to understand and choose the best way to reduce GHG emissions through transportation and land use strategies. The CSCS Project seeks to reduce GHG emissions by reducing per capita vehicle miles traveled (VMT) for light duty-vehicles and by investing in technologies that reduce emissions.

CCC HIA Scope

Geography: Portland, Oregon metropolitan region as defined by the Urban Growth Boundary

Timeline: 2010 (base year) to 2035 (horizon year)

Scenarios - adopted local and regional plans with:

- **A**: existing revenues
- **B**: increased revenues from existing sources
- **C:** new plans, policies and revenue sources

Exposure pathways: physical activity, traffic safety, air quality, land use

Quantitative tool: Integrated Transportation Health Impact Model (ITHIM)

Other considerations: magnitude of health costs associated with health pathways, vulnerable populations

Health Impact Assessment (HIA) is a way to consider how a policy or plan affects community health before the final decision is made. By providing objective, evidence-based information, HIA can increase positive health effects and mitigate unintended health impacts. The Public Health Division of Oregon Health Authority (PHD) conducted this assessment at Metro's request, with funds provided by the Center for Disease Control and Prevention's Healthy Community Design Initiative.

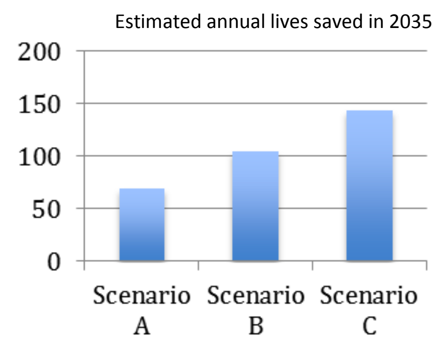
Investments in land use and transportation systems that reduce GHG emissions positively impact health by increasing physical activity, reducing traffic collisions and improving air quality. PHD and Metro agreed that the CCC HIA is necessary to better inform Metro and its partners in the selection of a final scenario by December 2014.

Key findings

This analysis found that the strategies under consideration to reduce GHG emissions also result in important health benefits in all exposure pathways, including increased physical activity, fewer traffic injuries and less exposure to air pollutants. These changes are likely to reduce illness and death in the region.

Through a literature review including 348 peer-reviewed articles and government reports linking the built environment to health, PHD found most of the land use strategies under consideration for the CSCS Project promote health. Evidence shows that elements such as level of residential density, land use mix, the number of nearby community destinations and ease of street connectivity are effective at promoting active transportation. Scenario B and C subsections labeled 'Complete Streets and Active Transportations Investments' support healthy behaviors the most. These strategies include better street connections, safer street crossings, wider sidewalks, safer street crossings, improved bus stops, more bikeways, trails and on-street bicycle facilities, and more efficient operation of transit signals.

The literature also aligns with advisory members' equity concerns. Low-income households in search of affordable housing options may locate in neighborhoods that are not well-served by affordable transportation options and have fewer health-supportive amenities. This underscores the need to create and preserve affordable housing options in areas that are well-served by transit.



Integrated Transport and Health Impact Model (ITHIM)

In addition to literature reviews for all pathways, PHD also used a quantitative model, ITHIM, to help understand the relative impact of each of three exposure pathways — physical activity, traffic safety and air pollution as measured by particulate matter ($PM_{2.5}$) [2]. ITHIM uses relative risks and burden of disease to estimate avoided illnesses (as measured by disability adjusted life years) and deaths for nine conditions associated with physical activity, three conditions linked to $PM_{2.5}$ exposure, and current traffic fatality rates. A clear limitation of ITHIM is it underestimates all health benefits by restricting calculations to certain pathways and diseases.

Results from ITHIM predict that strategies for reducing GHG emissions will promote health; health benefits occur in all exposure pathways for all scenarios. Scenario A levels of investment are expected to contribute to 64 avoided premature deaths annually. Scenarios B and C would result in 98 and 133 avoided premature deaths respectively. Every 12% decrease in GHG — the difference between each successive scenario — results in an approximate 0.65% decrease in illness among diseases studied.

Physical activity

The most significant and attainable health benefit of active transportation is increased physical activity. Increased physical activity from active transportation could account for as much as 86–91% of avoided deaths and 69–84% of avoided illness resulting from implementing the CSCS project.

> The CDC recommends 150 minutes per week of moderate physical activity for adults. Meeting this goal can increase life expectancy and reduce expensive and debilitating diseases. Nearly half of all Oregonians do not meet this recommendation.

We can improve our region's health and reduce premature deaths by increasing the number of people who regularly walk or bike to the library, school, work, church or store. A safe and convenient transportation system provides individuals with the flexible and healthy options they need to routinely choose more active modes of transportation. Prioritizing non-automobile users in the design and maintenance of streets increases the safety of all users and will facilitate walking, bicycling and use of public transit.

Traffic safety

Reduced GHG emissions through lower per capita vehicle miles traveled (VMT) results in fewer overall traffic fatalities and injuries. Scenario A results in one avoided traffic fatality per year and decreases disabilities from serious injuries (measured by disability adjusted life years or DALYs) by 2.0%. Scenario C would help avoid 12 traffic fatalities and 12.5% of DALYs from serious injuries a year.

Due to the increase in miles covered in active transportation modes, ITHIM shows the absolute numbers of pedestrian and bicycle fatalities will rise even as the rate decreases due to population growth. While physical activity benefits outweigh the risks of active transportation, effort should be made to mitigate traffic hazards for pedestrians and cyclists through traffic calming, street design and mode separation. Efforts should also be made to capture the 53% of 'interested but concerned' individuals in the region who would like to bike, but are worried about safety issues.

Air quality

Improved air quality is an important benefit of addressing GHG. Metro is targeting aggressive GHG emission reductions of 12, 24 and 36% for Scenarios A, B and C respectively. However, Metro's scenarios result in only modest $PM_{2.5}$ reductions of 2.8, 3.2 and 3.6% due to population growth and reliance on fleet change and fuel technologies. ITHIM results predict a modest decrease in respiratory illness, heart disease cases associated with air pollution, and premature death of lung cancer patients from long-term $PM_{2.5}$ exposure.

> **Portland Air Toxics Solutions Project**
>
> DEQ created the Portland Air Toxics Solutions (PATS) project to develop air toxics reduction strategies for the Portland region.
>
> In the Portland area success has been achieved in reducing lead, carbon dioxide and ozone (smog) to meet federal clean air standards.
>
> Despite this progress, DEQ is concerned about air toxics, which are known or suspected to cause serious health problems including cancer, nerve damage and respiratory irritation.
>
> www.deq.state.or.us/aq/toxics/pats.htm

ITHIM only incorporates long-term exposure to $PM_{2.5}$ and may underestimate health benefits associated with improved air quality. As suggested by the Portland Air Toxics Solutions Project, additional benefits may accrue from lower ambient ozone and air toxic concentrations.

There is no safe level of $PM_{2.5}$ exposure and current average concentrations of ozone are above safe levels. Episodic $PM_{2.5}$ (winter) and ozone (summer) events require regional solutions such as leading public efforts to change travel behavior in order to minimize health risk. Poor air quality can be localized and many vulnerable populations live near transportation corridors. Care should be taken to influence increased physical activity while minimizing exposure when designing active transportation facilities and adjoining transportation corridors.

Recommendations

Climate change poses a risk to the future health of Oregonians. Proposed strategies to mitigate climate change will also increase health benefits associated with physical activity, traffic safety and improved air quality. Based upon the findings of this report and with the support of the CCC HIA Advisory Committee, PHD has developed a series of recommendations to preserve and promote healthy communities throughout the region.

By developing and implementing a preferred scenario that meets or surpasses the GHG emissions reduction target set by the Department of Land Conservation and Development, PHD anticipates an improvement in public health.

The majority of health benefits from the CSCS Project can be attributed to active transportation such as walking and biking to work, transit, school and community destinations. **Based on this evidence, this HIA recommends that Metro maximize opportunities for active transportation for all communities by:**

- Adopting and identifying stable funding for the design elements listed in the subsection 'Complete Streets and Active Transportation Investments' of Scenarios B and C: street connections, wider sidewalks, safer street crossings, improved bus stops, bikeways, transit signal priority, and on-street bicycle facilities and trails.
- Improving transit service miles to meet levels recommended in Scenario C.
- Using an equity analysis to plan and develop equal access to active transportation throughout the region.

While the benefits of physical activity far outweigh the risks, active modes of transportation can lead to increased exposure to traffic injury and air pollution. **In order to reduce the risk of increased exposure to traffic injury and air pollution for all road users, this HIA recommends that Metro prioritize the design and maintenance of non-automobile facilities** by:

- Including safety features for pedestrians and bicyclists, such as separation from motorized traffic, when possible. Prioritize non-automobile users in design and maintenance of streets.

- Providing a parallel bicycle route one block removed from high-volume roads where feasible to reduce exposure to localized pollution while still maintaining access to community destinations.

Per capita VMT reduction is expected to modestly improve air quality as measured by many pollutants including air toxics, but temporal and localized air quality concerns remain. **Due to temporal and spatial air quality concerns, this HIA recommends that Metro maximize overall improvements in air quality through actions such as:**

- Aligning the CSCS preferred alternative to PATS goals. In collaboration with DEQ, determine how the preferred alternative helps meet Oregon's adopted ambient benchmark concentrations.
- Reducing exposure by using zoning and incentives to improve indoor filtration systems in new buildings along transportation corridors.
- Convening a regional committee to further address episodic air quality events. Solutions should be season specific and could promote incentives for short-term, alternative commute arrangements.

Finally, to improve health equity, this HIA recommends Metro ensure social and health goals are considered when prioritizing investments by:

- Explicitly and transparently addressing how investment links low-income and other vulnerable households to health-promoting resources.

INTRODUCTION

Health can be defined as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”[3]. A health impact assessment (HIA) is a way to explicitly consider how a policy or plan facilitates a healthy community before a final decision is made. The objective, evidence-based information provided by the HIA can be used to inform public decisions to increase positive health effects and mitigate unintended health impacts. In this case, the HIA looks at how Metro’s Climate Smart Communities Scenarios (CSCS) Project may affect the health of people in the Portland metropolitan region.

The 2009 Oregon Legislature required the Portland metropolitan region to develop a plan to reduce per capita greenhouse gas emissions (GHG) from cars and small trucks by 20 percent below 2005 levels by 2035. The Public Health Division of the Oregon Health Authority (PHD) supports statewide efforts to reduce GHG because curbing climate change is a critical public health issue. There are many ways to reduce emissions while creating healthy, more equitable communities with a vibrant regional economy. The goal of this HIA is to help provide information on which strategies are most health protective and what potential solutions may be when strategies have unintended health consequences.

To meet reduced GHG benchmarks, Metro is targeting fewer per capita single-occupancy vehicle (SOV) trips and vehicle miles traveled (VMT) by increasing land use and transportation investments. The CSCS Project is focused on meeting the emission target by investing in communities and providing services and shopping near where people live, improving transit service, using technology to manage traffic flow, building a well-connected network of complete streets and providing safer routes for walking and biking.

Metro is also considering impacts on public health, the economy, the environment and equity as part of the planning effort. Transportation investments and land use affect health in important ways. Many of the planned investments and actions have been shown to increase walking, biking and use of transit and reduce how often and how far people drive to meet their everyday needs. This will likely add 20–30 minutes of additional daily physical activity for individuals who shift to more active modes, greatly reducing the physical inactivity disease burden.

The primary health benefit associated with reducing GHG through the CSCS Project is increased physical activity and associated positive health outcomes. The reliance on active transportation to decrease GHG provides the bulk of the health benefits; the final plan could maximize health returns by increasing access and reducing barriers to biking, walking, and transit. This HIA also found the proposed investments and action to reduce GHG could result in decreased cancer, cardiovascular and respiratory burden from cleaner air and decreased traffic injuries from managing congestion.

The final plan could maximize health returns by increasing access and reducing barriers to biking, walking, and transit.

PROJECT OVERVIEW

Metro's Climate Smart Communities Scenario Project

This HIA informs Phase 3 of Metro's Climate Smart Communities Scenario (CSCS) project which will help choose the best investments and policies to reduce GHG emissions in the Portland metropolitan region. The plan includes strategies that will result in fewer per capita vehicle miles traveled (VMT) by gasoline-powered, light-duty vehicles (LDV). The HIA analyzed expected health benefits associated with reductions in per capita VMT and accompanying improvements in air quality and traffic conditions.

Metro's planning efforts are directed by a series of Oregon legislative mandates and administrative rules. The 2007 Oregon Legislature passed HB 3543 establishing statewide goals to reduce GHG emissions, calling for a reduction of 10% under 1990 levels by 2020 and 75% by 2050. These goals apply to all sectors, including energy production, buildings, solid waste and transportation. In 2009, the Oregon Legislature enacted HB 2001, a broad-based transportation bill that directed Metro to develop a preferred scenario to reduce GHG emissions from LDV while accommodating planned population and job growth. HB2001 also requires Metro to adopt the preferred scenario following public review and for local governments to implement the preferred scenario through local transportation and land-use plans. As a result of these legislative mandates, the Oregon Land Conservation and Development Commission (LCDC) set LDV GHG emissions reduction targets for each of Oregon's six largest metropolitan planning areas in June 2011. The Portland metropolitan area target calls for a 20% reduction below 2005 levels. This reduction is in addition to those expected from cleaner fuels and more fuel-efficient vehicles. A second LCDC rule-making effort in November2012 required Metro to adopt a preferred scenario by December 31, 2014.

To meet the legislative mandates and administrative deadlines, Metro has developed a three-phase process to analyze transportation and land use strategies while engaging the broader community including both citizens and policy makers of local governments, state agencies, port commissions and transit providers. During 2011, Phase 1 tested 144 different scenarios with the help of stakeholder organizations. The results of PHD engagement in Phase 1 are found in the CSCS HIA, released in April 2013[4]. The CSCS HIA quantitatively analyzed six 'representative' scenarios for three health pathways: physical activity, air quality and traffic safety. This analysis showed proposed investments, policies and actions that reduce GHG emissions also reduce VMT, providing important health benefits in all three areas studied. Physical activity accounts for the majority of health benefits in all six scenarios due to the shift to more active modes of transportation.

In Phase 2, which began in 2012, Metro narrowed and refined the 144 different scenarios through extensive modeling, down to three alternative approaches. Scenario A assumes implementing adopted plans with existing revenues and essentially represents a low-investment scenario. Scenario B relies on increased revenues to fund priority investments, reflecting full implementation of the adopted Regional Transportation Plan. Scenario C assumes additional policy and infrastructure investment beyond current adopted plans and would require even more revenue and new funding sources. Scenario C includes significant improvements to transit service across the region. All three scenarios assume there will be advancements towards cleaner fuels and more fuel-efficient vehicles.

In 2013 Metro released the results of Phase 2 of the CSCS project and has transitioned into Phase 3 – Community Choices. In Phase 3, Metro is seeking input from community and business leaders, local governments, state agencies and the public to determine which investments and actions should be included in a preferred scenario. Metro anticipates defining the draft preferred scenario in late spring 2014, with opportunities for public input in the fall of 2014. The Metro Council is scheduled to consider adoption of the preferred scenario in December 2014.

PHD and Metro agreed that a follow-up HIA, the Community Climate Choices HIA (CCC HIA), was necessary to better inform Metro and its partners in the selection of a final scenario. The CCC HIA provides additional information for Phase 3 decisions through a health-based analysis of the three scenarios developed in Phase 2. The HIA integrates an extended literature search with an update of the quantitative modeling as recommended by the previous HIA.

Climate, transportation, and public health

Climate impacts our health in many ways. Climate change-related events that may adversely affect public health include drought and reduced water supply; extreme heat; wildfires; extreme precipitation and flooding; severe winter storms; worsening air quality due to ozone pollution; decreased frost that leads to changes in vegetation patterns and longer growing seasons; and increases in vector- or insect-borne diseases. To mitigate the effects of climate change, many communities are implementing plans and policies that will reduce GHG emissions [1].

Addressing changing climate through land use and transportation investments, policies and actions has long-term health implications. This approach includes designing communities and streets to make walking, biking, and expanded transit service more safe and convenient. Creating communities that reduce barriers to walking and biking will increase the proportion of Portland metropolitan residents who are able to meet physical activity will increase heart health, reduce body mass index (BMI) and decrease risk for many chronic diseases.

Table 1. Top 10 risk factors ranked by attributable burden of disease, U.S. and Canada in 2010

Rank (out of 43)	Risk factor
1	Tobacco smoking (including second-hand)
2	High BMI
3	High blood pressure
4	High fasting glucose
5	Physical inactivity and low physical activity
6	Diets low in fruits
7	Alcohol use
8	Diet low in nuts & seeds
9	High cholesterol
10	Drug use

Source: Global Burden of Disease Study, 2010[5]

Cancer and heart disease are currently the top two “underlying causes of death,” accounting for 48% of all deaths in Oregon[6]. This reflects a larger trends of chronic disease such as heart disease, Type II diabetes and cancer surpassing communicable and infectious disease as the primary cause of mortality (death) and morbidity (illness) in high-income countries such as the U.S.

Behaviors linked to these chronic diseases, such as tobacco use, physical inactivity, poor diet, and alcohol and drug use have been identified as top risk factors for illness and death in Canada and the United States[5] (Table 1).

Screening and scoping with the advisory committee

In 2011, PHD was awarded a three-year grant through the CDC's Healthy Community Design Initiative. As part of this grant, PHD agreed to perform three HIAs to explore how to best integrate health considerations into transportation and community planning decisions. The PHD program prioritizes performing HIAs on regional or state-wide transportation and community planning decisions and relies heavily on consultation from a diverse set of multi-disciplinary stakeholders in the form of an advisory committee.

Health Impact Assessment (HIA) begins with a process of scoping with the advisory committee; through scoping, the specific pathways and health conditions of concern are identified and prioritized. The scope of this HIA was influenced a great deal by the previous CSCS HIA addressing Phase 1, which identified increased physical activity, traffic safety and cleaner air as potential ways that the final plan could affect health. It was clear that GHG emission reductions achieved by walking and biking to work and transit would result in significant health benefits through increased physical activity. As people drive less, they are less likely to be involved in traffic collisions. Driving less will also result in cleaner ambient air. These three pathways were addressed in the CSCS HIA released in April 2013.

In the CSCS HIA, PHD used the ITHIM model to help understand the relative impact of the three exposure pathways: physical activity, traffic safety, and air pollution as measured by $PM_{2.5}$ [2]. The ITHIM modeling assumed six scenarios representative of the 144 scenarios under consideration in Phase 1. ITHIM used information about the relative risk of 13 diseases given exposure to two types of inputs provided by ODOT's GreenSTEP model: measures of miles traveled by mode and particulate matter ($PM_{2.5}$) as an indicator of air quality[1]. Results indicated that physical activity is the dominant pathway to health benefits. One of the recommendations of the CSCS HIA was to "carry out additional quantitative health impact assessment of the three scenarios that are identified for further evaluation in spring 2013 to further inform development and adoption of a final preferred scenario."

In early summer 2013, PHD and Metro followed that recommendation and began a second HIA – the Community Climate Choices HIA (CCC HIA) – to better inform Metro and its partners in the selection of a final scenario by December of 2014. To guide the CCC HIA, PHD reconvened 38 regional experts in land use and transportation planning, local governments and public health to help develop the CCC HIA in September 2013. See Appendix B for complete list. PHD held a series of small group and agency-specific

[1] ITHIM is limited to modeling pathways with known risk ratios: nine diseases linked to physical activity, traffic injuries and fatalities, and three diseases linked to $PM_{2.5}$ exposure. Please see Appendix E for more information about ITHIM methodology and limitations.

conversations in addition to full advisory committee meetings in order to maximize participation opportunities in the CCC HIA:

- June 19, 2013: Metro project review and HIA screening with Community Choices program staff.
- August 29, 2013: Meeting with DEQ Air Toxics program staff to discuss air quality questions and concerns raised during the CSCS HIA.
- September 19, 2013: First advisory committee small group conversation to discuss monetization options and finalize the HIA scope (12 participants).
- October 17, 2013: Second advisory committee small group conversation to review initial air quality findings and discuss equity implications (8 participants).
- October 31, 2013: Third advisory committee small group conversation to review initial land use findings and discuss equity implications (11 participants).
- November 12, 2013: Meeting with full advisory committee to review assessment findings, discuss framing considerations and develop draft recommendations (25 participants).

The advisory committee provided feedback on the areas and methodologies of the assessment, initial findings and draft recommendations. Advisory committee members who were unable to attend meetings were encouraged to provide input electronically throughout the process.

Parameters were determined by the scenarios defined by Metro: the analysis uses 2010 as the base year and 2035 as the horizon; geography[2] considered is the Portland metropolitan region within the Urban Growth Boundary, and the three scenarios match those of Phase 2 of Metro's project. Baseline for quantifying health effects applies 2010 prevalence of illness or death to projected 2035 population figures.

The scope of the CCC HIA also incorporates three additional areas of concern that surfaced during the CSCS HIA and CCC HIA processes. First, several advisory group members expressed an interest in expanding the air quality analysis beyond ITHIM's treatment of $PM_{2.5}$. In response, PHD undertook an additional literature review of transportation-

CCC HIA Scope

Geography: Portland, Oregon metropolitan region within the Urban Growth Boundary

Timeline: 2010 (base year) to 2035 (horizon year)

Metro Scenarios - adopted local and regional plans with:

A: existing revenues
B: increased revenues from existing sources
C: new plans, policies and revenue sources

Exposure pathways: physical activity, traffic safety, air quality, land use

Quantitative tool: Integrated Transportation Health Impact Model (ITHIM)

Other considerations: magnitude of health costs associated with health pathways, vulnerable populations

[2] Metro used ODOT's GreenSTEP model for air quality; this regional model does not account for changes in Vancouver, WA emissions. In some instances in the report, health data is reported in a different geography such as 3-county or MSA (7-county); when an alternative to the UGB is used, it is clearly indicated in the tables and text.

related air quality health science. This included exploring other criteria pollutants and air toxics for inclusion in ITHIM as well as understanding both long and short-term exposures to transportation-related air pollution. While data and methodological limitations did not allow for complete integration of these other air pollution concerns, the air quality literature in this HIA has been expanded to discuss these pathways.

Second, many advisory group members expressed an interest in directly analyzing land use strategies within the plan. After an extensive literature review, this HIA includes a section devoted to understanding how the specific land use and transportation strategies may affect health.

Finally, advisory group members and decision makers expressed an interest in understanding the magnitude of saved costs associated with health benefits. Methodological limitations make a global number impossible to compute, but this HIA contains information about the costs of diseases of interest throughout the report.

Methods

HIA is guided by practice standards established by the Society of Practitioners of Health Impact Assessment (SOPHIA). This HIA adheres to the HIA Minimum Elements established by the North American HIA Practice Standards Working Group (Appendix A).

HIA begins by assessing the state of the science for pathways of interest with in-depth literature reviews. PHD maintains a robust database of 348 journal articles, scientific reports, and government guidance linking the built environment to health. In order to address the specific nature of this planning exercise, this database was updated by performing GoogleScholar, Pubmed, and ScienceDirect searches for literature specific to the pathways since 2008: [health] AND [physical activity, safety, and air pollution, land use]. Particular weight was given to systematic reviews, government guidance, and/or articles addressing sub-populations with vulnerabilities such as children, elders, and racial-ethnic minorities.

An important objective of HIA is documenting current health conditions. PHD used state and federal databases to characterize current prevalence and incidence rates. Information about costs associated with health impacts come from a combination of reports from partner state agencies and CDC's Chronic Disease Calculator, v2.0. http://www.cdc.gov/chronicdisease/resources/calculator/

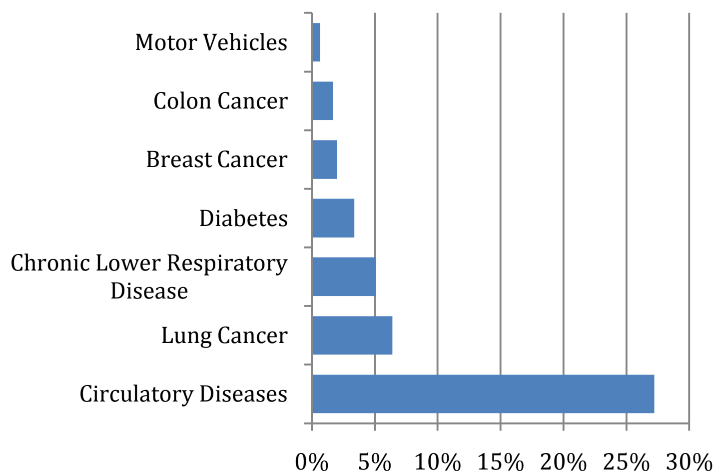
This HIA also quantitatively modeled health impacts using ITHIM for physical activity, traffic safety, and air quality as measured by $PM_{2.5}$. ITHIM uses current and local burden of disease estimates and applies relative risks or measures of expected changes in exposure to estimate changes in mortality (deaths) and illness (as measured by disability adjusted life years or DALYs). ITHIM calculates mortality and illness for both baseline and each scenario (A, B, and C as defined by Metro in Phase 2); outputs are generally reported in the difference between baseline and scenario. Conceptually, baseline in ITHIM is the expected number of deaths and illness given the current rate of exposure for the expected population in

2035. Estimated impact is thus the difference between the expected outcome at baseline and the scenario. More information is available about ITHIM methodology in Appendix E.

CURRENT HEALTH CONDITIONS, RISK FACTORS, AND COSTS

Approximately 11,050 people died in the three-county area (Clackamas, Multnomah and Washington counties) in 2010. Of those deaths, at least 42% were from causes that may be impacted by this plan. For example, primary cause of death statistics for the area indicate nearly one- quarter of deaths are from circulatory disease (heart and strokes), another 11% are from chronic respiratory diseases or lung cancer, and at least 3% of death certificates list diabetes as a primary cause[5]. All other causes, or 58% of deaths, are caused by conditions not directly tracked in the HIA but are likely to improve with implementation of the plan. Approximately one third of the 'other' category (and approximately 20% of the overall total) are cancers with less direct links to physical activity or air-pollution.

Selected causes of death, Three -County 2010[5]



Underlying conditions erode quality of life for many individuals. Table 2 on the following page provides Oregon and Portland MSA[3] prevalence rates for chronic conditions and associated risk factors as estimated from the CDC's *Behavioral Risk Factor Surveillance System Survey* (BRFSS) in 2011[8]. According to BRFSS, approximately 3% of adults in the region have survived a heart attack, a similar number suffer from chest pain or heart disease and 2.7% report having survived a stroke. These three cardiovascular conditions are highly associated with risk factors such as physical inactivity, high blood pressure, high cholesterol, and high BMI (weight). Recent BRFSS data also shows that approximately 28% of adults report high blood pressure and 36% have had a high cholesterol reading in the past 5 years. Nearly 40% of adults report not meeting the recommended 150 minutes of aerobic physical activity per week. Over 35% are overweight and nearly 24% are obese[8].

Respiratory illness significantly degrades quality of life. Poor air quality contributes to conditions such as asthma and chronic obstructive pulmonary disease (COPD). A little more than 5% of adults report having COPD. Over 9% of Portland region adults report a current asthma condition; the Oregon adult rate is the

[3] The Portland-Vancouver-Hillsboro OR-WA MSA is defined as the seven county region including Clackamas, Columbia, Multnomah, Washington, and Yamhill Counties in Oregon, and Clark and Skamania Counties in Washington

sixth highest rate in the country [8, 9]. At least 7–8% of children in Oregon have asthma according to parental response and when teens are directly surveyed, the prevalence increases to 10% [9].

Table 2. Adult prevalence rates for chronic disease and associated risk factors [8]

BRFSS 2011 category	U.S. state median	Percent of adults [95% Confidence Interval]	
		Oregon	Portland MSA[4]
Heart attack	4.4	3.6 [3.1-4.2]	3.2 [2.5-4.0]
Chest pain or coronary heart disease	4.1	3.6 [3.1-4.0]	3.1 [2.4-3.7]
Stroke	2.9	2.9 [2.5-3.4]	2.7 [2.1-3.3]
Any physical activity last month?	73.8	80.3 [78.7-81.3]	81.5 [79.5-83.6]
150 minutes of aerobic per week	57.7	61.1 [59.3-62.9]	60.3 [57.8-62.8]
High blood pressure	30.8	29.9 [28.5-31.3]	27.9 [26.0-29.9]
Cholesterol checked and high in past 5 years	38.4	38.5 [36.8-40.2]	36.1 [33.8-38.5]
Overweight	35.7	34.8 [33.31-36.4]	35.8 [33.4-38.1]
Obese	27.8	26.7 [25.2-28.3]	23.7 [21.7-25.7]
Diabetic	9.5	9.3 [8.4-10.2]	8.5 [7.3-9.8]
Depression (ever treated)	17.5	23.9 [27.5-25.3]	22.8 [20.8-24.7]
COPD (Chronic obstructive pulmonary disease)	6.1	5.9 [5.2-6.7]	5.2 [4.2-6.3]
Ever had asthma	13.6	16.7 [15.4-18.0]	16.2 [14.3-18.0]
Current asthma	9.1	10.5 [9.4-11.5]	9.6 [8.2-11.0]

Chronic conditions are a significant financial burden to households and taxpayers. While Oregon-specific cost data are sometimes difficult to calculate, the CDC provides a Chronic Disease Cost Calculator to estimate state-specific Medicaid (Oregon Health Plan), Medicare, and private insurance expenditures for the treated population in any given year. The tool estimates annual direct medical costs in 2010 dollars and does not include lost wages, reduced productivity or years lost to premature death. It does minimize double counting across categories by statistically controlling for deaths with more than one cause, also called comorbidity [10]. Additional information about assumptions, data sources and modeling techniques can be found in Appendix D.

[4] Data at this level of geography is age-adjusted and can be compared to other MSAs and the State.

Table 3 displays the estimated expenditures on chronic disease in Oregon, adjusting the costs for proportion of population living in the three-county area. More than $1.5 billion dollars is spent each year on cardiovascular disease in the region. Fifteen percent of Oregon's population are Medicaid recipients and 14%, including some that also qualify for Medicaid, are Medicare recipients [11]. Of the $1.5 billion spent each year on cardiovascular disease, $623 million of that cost is borne by the taxpayer in Medicaid and Medicare payments and at least $481 million is paid by private insurance. The cost incurred in 2010 by all payers for maintenance and complications from diabetes is estimated at $710 million, asthma cost $176 million and depression, which is helped by physical activity, cost $382 million [10].[5]

Table 3. Estimates of 2010 three-county annual expenditures (in 2010 $mil) for select chronic diseases

	Medicaid	Medicare	Private insurers	All payers[1]
Total cardiovascular disease[2]	$120	$503	$481	$1,551
Chronic heart failure	$12	$31	$10	$78
Coronary heart disease	$12	$167	$189	$470
Hypertension	$47	$149	$197	$592
Stroke	$48	$120	$63	$356
Other heart disease	$30	$106	$68	$258
Diabetes	$59	$199	$226	$710
Asthma	$34	$39	$66	$176
Depression	$22	$80	$157	$382

Source: CDC Chronic Disease Calculator, v2.0[10]

(1) All payers is estimated separately and may not equal the sum of Medicaid, Medicare, and private insurers.

(2) Total cardiovascular disease is a summation of the listed conditions, but only includes a portion of hypertension to avoid double counting. Similarly, diabetes complications can lead to cardiovascular disease; summing cardiovascular disease and diabetes would result in double counting. All other categories statistically control for listed conditions as well as common diseases not listed.

According to the CDC, more than $1.5 billion dollars is spent each year on cardiovascular disease in the region. Almost half of that cost is borne by taxpayers.

[5] The Chronic Disease Cost tool also provides projected costs; it estimates that expenditures for cardiovascular disease will increase by 79%, asthma by 66%, and diabetes by77 % by 2020 after accounting for inflation.

FINDINGS: ITHIM – Overview and results

ITHIM was identified in the CSCS HIA as a way to quantify morbidity (illness and injuries) and mortality (death) related to transportation changes. ITHIM was developed by public health researchers in the UK to assess potential health impacts of GHG reductions at a regional level by using population-based disease burden information for 13 different conditions in three potential pathways: physical activity, traffic safety (injuries and fatalities), and air quality [2].

Health outcomes in ITHIM include premature mortality (death) and morbidity (illness). Mortality data is based on burden of disease — specifically the relative risk of a disease given a change in exposure – associated with physical activity, traffic crashes, and air quality. The last time ITHIM results were released for the CSCS HIA, mortality data was based on U.S. risks. To improve accuracy of the model, mortality data for this HIA was based on Oregon-specific risks using 2010 vital statistics [12].

For morbidity, ITHIM calculates disability adjusted life years (DALYs) from the World Health Organization's (WHO) burden of disease database. DALYs are the sum of years of life lost (YLLs) and years living with a disability (YLDs). The YLL component of DALYs in ITHIM was revised using mortality rates from the Oregon Public Health Assessment Tool (OPHAT). Average mortality counts for 2008–2010 were extracted from OPHAT for the transportation related illnesses addressed in ITHIM and entered into the DALY Calculation Template from WHO (http://www.who.int/healthinfo/global_burden_disease/tools_national/en/) to revise YLL. YLD values were imputed from the United States burden of disease for the population of Oregon and entered into the ITHIM.

Table 4. ITHIM data inputs

Data Input	Baseline (2010)	**Scenario A** Adopted plans with existing revenue	**Scenario B** Adopted plans with increased revenue	**Scenario C** Scenario B plus additional policy/ infrastructure and new funding sources	Data source and notes
Reduction in GHG		↓12%	↓24%	↓36%	Modeled using ODOT's GreenSTEP. GreenSTEP inputs include Metro's Household Activity Survey, monitored PM2.5 emissions rates from DEQ.
Vehicle miles traveled (VMT) per person per week	134	125	117	102	
Distance by mode[1]	Walk=1.0% Bike=1.6% Bus=0.21% Car=97.2%	Walk=1.3% Bike=1.7% Bus=0.16% Car=96.7%	Walk=1.5% Bike=2.6% Bus=0.21% Car=95.6%	Walk=1.8% Bike=3.5% Bus=0.39% Car=94.2%	
$PM_{2.5}$ (µg/m3)	6.6317	↓2.8%	↓3.2%	↓3.6%	
UGB population	1,481,118	1,954,716 (2035 Estimate)			U.S. Census

(1) GreenSTEP breaks out VMT per person per week for the modes listed. The inputs reported here have been changed to percent.

ITHIM requires a number of inputs beyond health disease burden information. Metro provided vehicle miles traveled by mode and road type and $PM_{2.5}$ levels for each scenario. (Details are provided in Table 4.) PHD used 2010 census data for age distributions in the three-county area and outputs were increased by approximately 42% to adjust for the additional expected population by 2035.

ITHIM results are summarized in Table 5. (More detailed methodology descriptions, limitations and results are provided in Appendix E; pathway-specific results are discussed in later sections.) ITHIM shows that the current investment trajectory (Scenario A) will result in 64 avoided annual deaths in 2035 or a 0.9% drop in premature mortality given current death rates for conditions considered. ITHIM measures avoided illness through DALYs with current investment trajectories resulting in a 0.7% decrease in illness.

More aggressive investments clearly show greater reductions in disease and death. Scenario C would more than double the number of avoided annual deaths when compared to Scenario A. The 133 avoided annual deaths represent an approximate 2% reduction in current premature mortality rates with these pathways. Similarly, each additional 12% reduction in GHG from light-duty vehicles would garner the co-benefit of a 0.65% reduction in DALYs.

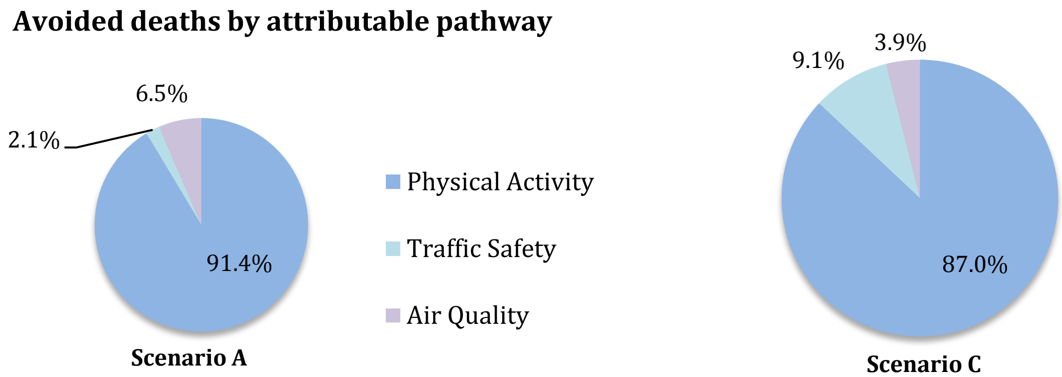
Table 5. Summary of ITHIM results

	Avoided	Scenario A		Scenario B		Scenario C	
		Count[1]	Percent reduction	Count[1]	Percent reduction	Count[1]	Percent reduction
Physical activity	Mortality	-58	1.4%	-89	2.1%	-116	2.9%
	DALY[2]	-793	1.3%	-1333	1.9%	-1786	2.8%
Traffic safety	Mortality	-1	1.2%	-4	3.5%	-12	10.5%
	DALY[2]	-72	2.0%	-173	4.9%	-443	12.5%
Air quality ($PM_{2.5}$)	Mortality	-4	0.2%	-5	0.2%	-5	0.3%
	DALY[2]	-37	0.2%	-42	0.2%	-47	0.2%
Total	Mortality	-64	0.9%	-98	1.4%	-133	2.0%
	DALY[2]	-903	0.7%	-1548	1.3%	-2276	1.9%

(1) This count has been adjusted for expected population of the UGB in 2035.
(2) Disability adjusted life years (DALY) is the summation of years of life lost (YLL) and years living with a disability (YLD) due to injury or disease. Note that YLD assumptions were not available some sub-categories and therefore significantly underestimate DALYs for physical activity and air quality.

ITHIM results show that the majority of health benefits associated with GHG emission reductions are from increased physical activity.

ITHIM results also show that the majority of health benefits associated with GHG emission reductions are from increased physical activity: between 87.0–91.4% of prevented deaths and between 78.5–87.9% of prevented illness as measured by DALYs. ITHIM underestimates health benefits of all pathways; the model is limited to nine disease associated with physical activity, reported rates of collisions, and three diseases associated with $PM_{2.5}$ as an indicator of air quality. (Please see Appendix E for expanded discussion of limitations.) Despite these limitations, these patterns are largely congruent with current patterns of disease burden and knowledge about active transportation addressing the large burden associated with physical inactivity.



Highlights of ITHIM

- Lowering GHG emissions results in health benefits in each scenario.
- Using the strategies proposed, current levels of investment (Scenario A) would result in 64 avoided deaths annually. Scenarios B and C would result in 98 and 133 avoided deaths, respectively.
- Every 12% decrease in GHG emissions (the difference between each scenario) results in approximately a 0.65% decrease in DALYS among diseases studied.
- The vast majority of avoided deaths and illness are attributable to increased physical activity. ITHIM underestimates all health benefits by restricting to certain pathways and diseases. For example, it does not account for health benefits of decreased air toxics. However, the large contribution of physical activity is consistent with current public health knowledge of the burden of disease from inactivity.

FINDINGS: Land use

Local land use regulations and community design shape the physical environment of our region. Land use impacts how we live, work and play, and can moderate or influence healthy environments and behaviors. Zoning has historically been used to protect human health by separating noxious, polluting uses from residential areas. Contemporary trends in land use research have shown a more nuanced if complex understanding of the intersection between land use and health. For example, land use mix and density may dictate the distance and ease in traveling to health-supportive resources such as employment, school, food, and recreation. Many of the CSCS Project strategies and actions focus on the interaction between land use and transportation; for the remainder of this section, "land use" refers to this interaction.

Another way to conceptualize the impact of land use and community design is to consider how physical activity, traffic safety, and air quality may change in different land use contexts and design decisions. The design of transportation facilities within mixed-use areas can impact health in multiple ways. The width, placement and striping of bicycle lanes and sidewalks can induce or prohibit active transportation modes due to perceived safety and desirability, serve as protection from auto collisions, and impact localized concentrations of air pollutants. When schools, shopping, services, residential and employment opportunities are in close proximity, people do not have to travel as far, making walking, bicycling and transit more convenient and viable travel options.

PHD performed a literature[6] review in order to understand the links between health and the specific land use strategies being considered. A summary of the literature for each land use strategy is provided in Table 6. The Magnitude of Health Impacts and Weight of Evidence columns provide a 1-5 scale (5 as the highest) to describe scientific knowledge for each pathway related to the strategy. The Magnitude of Health Impacts column reflect trends in overall burden of disease; strategies that are anticipated to have large effects on disease due to environmental and/or behavior changes were rated higher than those that will have more modest effects. The Weight of Evidence column addresses the quality and quantity of the research; '1's or '2's reflect conflicting or emerging research while a 5 rating reflect a robust literature drawn from meta-analyses, large epidemiological studies, and/or systematic reviews.

Although there is little literature directly linking health to the strategy, there is robust documentation of the health impacts of increased physical activity levels caused by more walking, bicycling and use of transit [13-16]. (See the Physical Activity section for more information.) Consequently, investments, policies and actions that make it more safe and convenient to walk and bike will benefit health. This is

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[6] *PHD maintains a robust database of 348 journal articles, scientific reports, and government guidance linking the built environment to health. In order to address the specific nature of this planning exercise, this database was updated by performing GoogleScholar, Pubmed, and ScienceDirect searches for the following since 2008: [health, physical activity, safety, and air pollution] AND [density or sprawl, mixed-use, transportation modes, parking, and transit service]. Particular weight was given to systematic reviews and/or articles addressing sub-populations with vulnerabilities such as children, elders, and racial-ethnic minorities.*

reflected in the Weight of Evidence column of Table 6 (page 22), which addresses the mode shift and health evidence separately for some strategies.

Many of the land use strategies under consideration are spatially interconnected and work synergistically. Residential density at or above levels associated with traditional single-family home urban neighborhoods is health supportive. However, the benefits of residential density require good connectivity to many diverse community destinations within walking and biking distance to encourage active transportation [17-21].

Complete streets may be the most health-promoting aspect of the investments and actions being considered.

Advisory group members repeatedly commented that land use strategies mattered a great deal. This is congruent with literature that stresses the cumulative effect of pedestrian and bicycle facilities, design, and nearby destinations in supporting active transportation options that result in increased physical activity [21-23]. These elements are addressed in the CSCS Project subsections ‘Complete Streets and Active Transportation’ in Scenarios B and C. Complete streets may be the most health-promoting aspect of the investments and actions being considered.

Transportation systems, and particularly public transit, play an important role in linking low-income households to health promoting resources such as fresh food, health providers and living wage jobs.

Low-income households are particularly reliant on the public transportation network to access job opportunities, shopping, services and other everyday needs [24]. Due to budget constraints, low-income households often live in neighborhoods with more affordable housing that lack supportive resources such as healthy food, parks, community centers and high quality medical care. Housing location has been found to amplify negative health associated with low socio-economic status [25, 26]. These neighborhoods often lack transit services and other amenities such as safe and convenient sidewalks, bike lanes and parks. These locations may have traffic safety risks such as high volume roads or poorly designed intersections that are difficult for vulnerable populations such as children and elders to navigate [26-30]. Community design and land use strategies listed in Table 6 place health supportive resources near affordable housing options. Transportation systems, and particularly public transit, play an important role in linking low-income households to health promoting resources such as fresh food, health providers and living wage jobs [24, 26].

Highlights of land use

- Elements of residential density, land-use mix, number of nearby community destinations and street connectivity are particularly effective at encouraging active transportation. These elements also work synergistically to influence walking, biking and use of transit.
- Most of the land use strategies listed in Table 6 and included in the scenarios promote health across multiple pathways.
- Investments and actions in Scenario B and C's subsections 'Complete Streets and Active Transportation' are the most important elements in encouraging healthy behavior. These elements include street connections, wider sidewalks, safer street crossings, improved bus stops, bikeways, transit signal priority, on-street bicycle facilities and trails.
- Low-income households, in search of affordable housing, may locate in neighborhoods that lack suitable transportation options. These neighborhoods also have fewer health supportive amenities. Low-income households may need access to health supportive resources more than any other group. It is important to create and preserve affordable housing options in areas that are well served by transit.

Table 6. Summary of literature review for land use strategies in Climate Smart Community Choices, Phase 2.

Land use policy	Current levels	Scenario A/B/C	Health pathway	Magnitude of health impact (5 '+' =largest)	Weight of evidence (5 '+' =most)	Additional considerations
Households in mixed use areas	26%	36% 37% 37%	Mixed use in the presence of reasonably high residential density and a short distance from many diverse community destinations is most likely to shift transportation mode and increase physical activity [17, 19].	+++	+++++	Mixed land use should be designed for all incomes including low-income families. Design matters. For example, multi-unit apartment complexes are often a land use buffer and qualify as mixed-use. These apartment complexes need to be fully integrated for connectivity to benefit from mixed-use. Housing/workplaces along major arterials are exposed to higher concentrations of air and noise pollution.
Urban Growth Boundary Expansion	2010 UGB	+28,000 +12,000 +12,000 (acres)	UGB literature is limited; however, limiting UGB expansion increases the likelihood of community destinations near residences by encouraging a compact, urban form. There is robust support for controlling sprawl. Urban development intensity is generally health supportive because nearby available resources increase. (See mixed-use above.) Residential density leads to increased physical activity as individuals shift to active transportation modes for daily activities [31, 32].	+++	++++	Development intensity without connectivity may not result in increased physical activity. Minimizing the expansion of the UGB may put upward pressure on housing prices, potentially exacerbating patterns of low-income households located in areas with limited resources. Controlling the UGB without addressing congestion (see delay reduced by traffic management policy below) can increase commute times which negatively impacts an individual's time for health-promoting activities.

Land use policy	Current levels	Scenario A/B/C	Health pathway	Magnitude of health impact (5 '+' =largest)	Weight of evidence (5 '+' =most)	Additional considerations
Bike travel	9%	10% 15% 20%	Aggressive mode shifts to bicycles will increase physical activity and health.	++++	+++ (mode shift evidence) ++++ (health evidence)	The access, placement, and design of bike facilities must maintain perceived and real safety [33]. Placement should also be designed to minimize air pollution exposure when possible [34].
Transit service (Daily revenue miles)	73,000	80,000 87,000 159,000	Increased transit service increases physical activity [35-38] (walking to/from stops), decreases air pollution, and increases traffic safety.	+++	+++++ (mode shift evidence) +++ (health evidence)	Low-income households are more likely to depend on transit and may have less access to transit. Transportation costs may be inelastic for this group but are a larger share of the household budget, so increases in transit costs may have inequitable impacts. Similarly, these households may choose a longer commute time to find affordable housing, which erodes time available for other health promoting activities. Expansions of service should consider and prioritize reaching low-income neighborhoods.
Work/non-work trips in areas with parking management	13%/ 8%	No change 30%/30% 50%/50%	Parking management influences active transportation and associated physical activity [39, 40].	+++	+++++ (mode shift evidence) + (health evidence)	The potential burden of parking costs and access to alternative transportation modes for low-income households should be considered.

Land use policy	Current levels	Scenario A/B/C	Health pathway	Magnitude of health impact (5 '+' =largest)	Weight of evidence (5 '+' =most)	Additional considerations
Miles of freeway/arterials added	N/A	+9 miles +81 miles +105 miles	Addressing congestion leads to decreased traffic injuries and fatalities, increased time for healthy activities and decreased air pollution [41, 42]. Adding road/lane miles could potentially increase connectivity by completing the system. Major roads are a significant barrier to active transportation, physical activity and social cohesion [26].	+ ++ --	++ ++ ++++	Induced demand may erode the congestion related pathways over time. Health impacts of additional lanes are extremely localized and vary by project. Each project should carefully assess the impact on nearby residents and mitigate air quality, noise and physical barriers during both construction and end-use. Care should be taken in designing multi-mode improvements to maximize health when adding arterial lane miles. The literature describes mixed results from reducing congestion with additional lane-miles. Reducing congestion should reduce the number of crashes, but the crashes may be more severe due to higher speeds associated with good traffic flow.
Delay reduced by traffic management strategies	10%	No change 20% 35%	Addressing congestion leads to decreased traffic injuries and fatalities, increased time for healthy activities and decreased air pollution [41, 42].	++	+++	Addressing congestion through traffic management is a more direct route to controlling commute times versus adding arterials or freeways.) PHD recommends this strategy over additional lane miles.

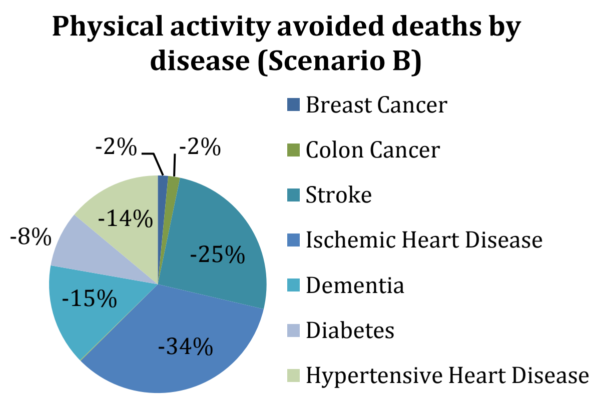
FINDINGS: Physical activity

ITHIM results for physical activity clearly indicate that reductions in GHG through increased walking and biking to transit and destinations produce significant health benefits. Physical activity prompted by investments in Scenario A can be expected to help avoid 58 deaths annually by 2035. Scenario C could help avoid 116 deaths and help reduce disease burden by up to 2.8%.

Table 7. ITHIM results attributable to physical activity

Avoided	Scenario A		Scenario B		Scenario C	
	Count[1]	Percent	Count[1]	Percent	Count[1]	Percent
Mortality	-58	1.4%	-89	2.1%	-116	2.9%
YLL	-468	1.5%	-747	2.3%	-988	3.1%
YLD	-325	1.0%	-586	1.6%	-799	2.3%
DALY[2]	-793	1.3%	-1333	1.9%	-1786	2.8%

(1) This count has been adjusted for expected population in 2035.
(2) Disability adjusted life years (DALY) is the summation of years of life lost (YLL) and years living with a disability (YLD) due to injury or disease. Note that YLD assumptions were not available for some sub-categories and therefore significantly underestimate DALYs for physical activity and air quality.



Physical inactivity is the fifth largest contributor to the current disease burden in the U.S.[5]. A large portion of expected health benefits from the CSCS Project are attributable to physical activity: over 87% of avoided premature deaths and 78.5% of avoided years living with a disability (DALYs) in Scenario C. Activity alleviates disease and death through preventative mechanisms such as reaching and maintaining a healthy weight or body mass index, decreasing blood pressure and cholesterol, and lowering blood glucose levels to prevent diabetes [43-45]. Increasingly, studies are showing that moderate physical activity regimens address cardiovascular disease (heart attack, chest pain, and stroke) and diabetes in a more prescriptive fashion, often performing as well as common pharmaceuticals [46].

Further analysis shows that avoided deaths and illness are largely from cardiovascular disease. In Scenario B, 73 percent of avoided deaths and 55 percent of avoided DALYs in the physical activity category are from heart disease or stroke.

Walking or biking to work, school, transit and other community destinations helps people reach the Surgeon General's physical activity recommendation of 150 minutes per week for adults and 300 minutes per week for children.

Well-functioning Transportation Systems Facilitate Choice and Physical Activity

Consider the transportation choices of an individual who lives in Troutdale and works in downtown Gresham.

Monday: Rides an 8-mile round-trip to workplace along safe and marked bike lanes.

Tuesday: Telecommutes but walks 1.5 miles by walking children to and from school and taking a break at a nearby coffee shop.

Wednesday: A child's extracurricular activity requires taking the family car. However he walks 0.75 miles to get lunch from a great sandwich shop.

Thursday: An important business meeting in downtown Portland is facilitated by taking the MAX into downtown and back to the office. After taking the bus home, he walks 1.25 miles over the course of the day to and from transit.

On Friday: Bike day! Repeat of the 8-mile round-trip bike ride.

Saturday: 3-mile round-trip family bike ride to a park for a soccer game.

Sunday: 3-mile round-trip family bike ride to church.

Assuming the commuter travels at 3-miles per hour when walking and 12 miles per hour when biking, this person has accumulated 150 minutes of physical activity for the week from travel alone.

Active forms of transportation such as walking or biking to work, school, transit and other community destinations are remarkably effective at helping individuals reach the Surgeon General's physical activity recommendation of 150 minutes per week for adults and 300 minutes per week for children [47]. New mass transit options may change daily physical activity levels, and could add 10 minutes of physical activity each day for one group of new transit users [48]. Only 60% of adults in the region currently meet the recommendation[8], suggesting active transportation investments could help a large proportion of the population begin to meet physical activity goals. Failure to meet the recommended 150 minutes of physical activity a week is estimated to reduce life expectancy by 3.4 years [16].

Transportation choices allow individuals to routinely and flexibly integrate physical activity into everyday lives. These choices are dependent upon a well-functioning and safe transportation system for all types of users. It also requires the support of a built environment that encourages active transportation through relatively high residential density featuring mixed use with many diverse, nearby community destinations anchored by high connectivity throughout the system.

An aggressive mode split change clearly drives the ITHIM physical activity results. Increasing the bike-mode split from 9% of 10-mile single-occupancy vehicle (SOV) trips in 2010 to 10, 15 and 20% in Scenarios A, B and C accounts for the majority of anticipated physical activity gains. The significant increase in transit service miles between Scenarios B and C amplifies the walking mode shift through walk trips to transit. Both strategies are critical in creating the health benefits.

Adults and children are more likely to choose active forms of transportation when they perceive they will be able to do so safely [49]. Design details and investments to make streets more complete and comfortable for potential pedestrians and cyclists are not accounted for explicitly in the ITHIM model. Complete streets and active transportation investments will be critical in implementing aggressive mode shifts needed to reach GHG reduction targets. (See Traffic Safety section for more information about perceived safety.)

Complete streets are needed in all communities. Low-income households are more likely to live in neighborhoods with fewer amenities including pedestrian and bicycling facilities [25, 27]. Suburban communities generally have lower levels of connectivity and less dense transit service. Both low-income and suburban communities will require significant pedestrian, bicycle, and transit investments to accrue health benefits at rates similar to wealthier and more urban parts of the region.

Highlights of physical activity

- The majority of health benefits (87–91% of avoided deaths, 79–88% of avoided illness depending on scenario) are attributable to increased physical activity such as walking and biking to work, transit, school and other destinations.
- A transportation system with many safe and convenient options provides individuals with flexible and healthy choices needed to routinely shift modes from single occupancy vehicles to more active modes of transportation. Prioritizing non-automobile users in design and maintenance of streets increases the safety of all users and will facilitate transportation mode shift to walking, bicycling and using transit.

FINDINGS: Traffic safety

Reduced reliance on single-occupancy vehicles will help control congestion as the metro population continues to grow. ITHIM estimates that current levels of investment will help avoid one traffic fatality (1.2% reduction) and a 2.0% reduction in DALYs due to fewer serious traffic accidents. Scenario C results in far more aggressive traffic safety benefits with 12 lives saved and 12.5% fewer years of disability due to injuries.

Table 8. ITHIM results attributable to traffic safety

	Scenario A		Scenario B		Scenario C	
Avoided	**Count[1]**	**Percent reduction**	**Count[1]**	**Percent reduction**	**Count[1]**	**Percent reduction**
Mortality	-1	-1.2%	-4	-3.5%	-12	-10.5%
YLL	-28	-1.2%	-84	-3.5%	-251	-10.5%
YLD	-44	-3.8%	-89	-7.6%	-192	-16.4%
DALY	-72	-2.0%	-173	-4.9%	-443	-12.5%

(1) This count has been adjusted for expected population in 2035.
(2) Disability adjusted life years (DALY) is the summation of years of life lost (YLL) and years living with a disability (YLD) due to injury.

The U.S. Department of Transportation (DOT) provides guidance in valuing prevented traffic fatalities. The current default value of statistical life (VSL) – a measure that aggregates many individuals' willingness-to-pay for a small reduction in mortality risk – is $9.1 million (in 2012 dollars) with a range of $5.2–$12.9 million provided for sensitivity analyses [50]. DOT also provides guidance about valuing injuries through an Abbreviated Injury Scale (AIS). Developed in the 1970s, AIS uses a QALY-based system to divide all possible injuries from crashes into a six-category scale of severity with the top severity being death. Current levels range (in 2012 dollars) from $27K for a minor laceration injury to $5.4 million for a critical injury such as ruptured liver [50]. There are no clearly established methods to convert DALYs to QALYs in order to apply AIS to ITHIM results.

The modeling indicates a reduction of LDV VMT per person on all types of roads with an increase in bicycle and pedestrian miles on minor streets and arterials. Even though overall traffic safety will improve, the increase of bicyclists and pedestrians on minor streets and arterials results in an increase in the absolute number of accidents for these two modes. The model predicts 2.5 more pedestrian deaths and 1.3 more bicyclist deaths in Scenario B in 2035. Since Scenario B also predicts 7.9 fewer automobile and motorcycle deaths, the overall fatality outcome is a net benefit of 4.0 avoided deaths. Patterns are similar for serious injuries and other Scenarios.

Table 9. ITHIM traffic safety results by mode for Scenario B

Mode	Annual fatalities			DALYs[1]		
	Baseline	Scenario B	Difference	Baseline	Scenario B	Difference
Walk	34.3	36.7	2.5	889.2	952.8	63.6
Cycle	10.4	11.7	1.3	316.7	356.7	40.0
Bus	0.0	0.0	0.0	0.0	0.0	0.0
Car	53.4	45.9	-7.5	1905.8	1639.5	-266.2
HGV	0.8	0.8	0.0	19.1	19.1	0.0
Motorbike	15.9	15.6	-0.4	424.5	413.9	-10.6
Total	114.8	110.7	-4.0	3555.4	3382.0	-173.3

(1) Disability Adjusted Life Years (DALYs)

This uneven distribution of benefits by mode may seem counterintuitive to studies that suggest a 'safety in numbers' effect. The safety in numbers effect is that as the proportion of pedestrians or bicyclists increases to a critical mass, motorized vehicle drivers become trained to 'look' and account for the non-motorist users, resulting in fewer collisions. The effect has been documented internationally and evidence is starting to appear in popular bicycling regions in the U.S. [33, 51-53]. While ITHIM allows for a safety in numbers adjustment, PHD did not exercise the safety in numbers option because it is unclear how to quantify the effect. The model also does not take into account infrastructure investments that may increase future bicyclist safety through increased visibility and separation from motorized traffic.

The physical activity benefits far outweigh the traffic risks associated with active modes of transportation [54-56]. One European study found that cycling instead of driving resulted in life-expectancy gain of 3–14 months over the course of a lifetime, far outweighing the potential risk of inhaled air pollution (0.8–40 days lost) and the risk of traffic accidents (5–9 days lost) [55].

The traffic safety results still indicate a need for safe strategies for pedestrians and bicyclists. The most effective way to increase safety for pedestrians and cyclists is through traffic calming measures and greater physical separation from motorized traffic [57-60]. Pedestrians, especially older adults, seem particularly sensitive to the location of sidewalks [61-63]. Bicyclists fare better on minor side roads than in unseparated bike lanes on major roads and benefit greatly from bicycle-specific facilities [53, 64].

The physical activity benefits of biking and walking far outweigh the traffic risks.

Perceived safety is a leading reason for individuals to avoid more active forms of transportation. Parental perceptions about perceived safety are predictive of children walking and biking to school [65, 66]. Bicyclists also respond to perceived safety. A recent study in the Portland region indicates 60% of Portlanders and 53% of the rest of the region are 'interested but concerned' about cycling. This potential 'market' of cyclists is far more worried about traffic safety than current cyclists; 84% are concerned about being hit by a car compared with 39–52% of 'enthused and confident' or 'strong and fearless' cyclists [67].

The cumulative effect of design strategies, investments and policies to address safety may serve as an indicator that streets are safe for all modes and thus help increase the number of pedestrians and bicyclists [40].

Highlights of traffic safety

- Traffic safety is an important co-benefit of reducing GHG emissions. Scenario A would result in one avoided traffic fatality per year and decrease serious injuries by 2.0%. Scenario C would help avoid 12 traffic fatalities and decrease serious injuries by 12.5% a year.

- The shift in transportation modes results in an increase in the absolute numbers of pedestrian and bicycle fatalities, even as the rate decreases. Even though the physical activity benefits far outweigh the risks of active transportation, this suggests extra effort should be made to mitigate traffic hazards for pedestrians and cyclists through traffic calming, street design and mode separation when possible.

- Fifty-three percent of individuals in the region are ‘interested but concerned’ about cycling. Addressing perceived safety for pedestrians and cyclists will help implement large mode shifts.

FINDINGS: Cleaner Air

Improving overall air quality is an important health benefit of GHG reduction. Reducing per capita VMT combined with clean fuel technologies are expected to decrease air pollutants attributable to light-duty vehicles. These pollutants include: $PM_{2.5}$, ozone precursors and air toxics such as benzene, 1, 3-butadiene, arsenic and chromium VI. Reductions of these pollutants would likely result in increased respiratory health, decreased cardiovascular events such as heart attacks, and decreased cases of cancers such as lung cancer and leukemia. Additionally, some populations are at greater risk from exposure to air pollution. For example, people with lung cancer have an increased risk of death when exposed to increased levels of $PM_{2.5}$.

To quantify the health impacts of cleaner air, ITHIM developers chose $PM_{2.5}$ as the pollutant indicator for mobile, onroad sources. PHD accepted this choice of pollutant based on the scientific consensus about the strength of and causal nature of the relationships between $PM_{2.5}$ and health. The periodic reviews of pollutants commissioned by the EPA [68-70] and a recent World Health Organization [71] scientific review all suggest that $PM_{2.5}$ is the best air pollution indicator for health-impact analyses. Using $PM_{2.5}$ as the exposure pollutant in ITHIM does underestimate some health effects including some cancer risks[7,8].

The $PM_{2.5}$ inputs for ITHIM were modeled by Metro in ODOT's GreenSTEP. Metro's scenario analyses showed a decrease in annual concentration of particulate matter as measured by $PM_{2.5}$ of 2.8% (Scenario A) to 3.6% (Scenario C). This is expected to result in modest decreases in deaths and illness (Table 10), primarily from fewer respiratory illnesses, reduced heart disease related to air pollution and reduced lung cancer mortality related to long-term $PM_{2.5}$ exposure.

Table 10. ITHIM results attributable to air quality ($PM_{2.5}$)

	Scenario A		Scenario B		Scenario C	
	Count	Percent reduction	Count	Percent reduction	Count	Percent reduction
Mortality	-4	0.2%	-5	0.2%	-5	0.3%
YLL	-37	0.2%	-42	0.2%	-47	0.3%
YLD	0	0.0%	0	0.0%	0	0.0%
DALY	-37	0.2%	-42	0.2%	-47	0.2%

(1) This count has been adjusted for expected population in 2035.
(2) Disability adjusted life years (DALY) is the summation of years of life lost (YLL) and years living with a disability (YLD) due to illness. YLD are unavailable for respiratory and air pollution-related cardiovascular disease as well as lung cancer at this time.

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[7] For more information on cancer risks associated with light-duty vehicles in the Portland region please see Portland Air Toxics efforts [74].

[8] Limitations are discussed in greater detail below and found in the discussion of ITHIM methodology in Appendix E. A more detailed discussion of potential air pollutants of interest and the current scientific understanding of health linkages is available in Appendix F.

The modest effect of the CSCS Project on air quality health benefits can be explained by the small reduction in $PM_{2.5}$ in the GreenSTEP model. One reason GreenSTEP is not showing a particularly large reduction in $PM_{2.5}$ is because heavy-duty diesel vehicles are a larger driver of $PM_{2.5}$ but are not under the purview of this project, which focuses on light-duty vehicles (LDV) only. A second reason for the modest decrease in $PM_{2.5}$ is that GHG emissions reduction is a function of both decreased VMT per capita *and* technological and fuel changes. Reductions in $PM_{2.5}$ from per capita VMT reduction are largely displaced with increasing population. Per capita VMT is decreasing, but VMT for the entire region will increase by 22.7% for Scenario A and 13.3% for Scenario B. Only Scenario C shows an overall reduction (2.2%) in regional VMT. The end result is that $PM_{2.5}$ hardly changes at all.

There are additional limitations with using $PM_{2.5}$ as the primary air quality pollutant in ITHIM. The model only accounts for long-term exposure to $PM_{2.5}$ even though there is good evidence that short-term, episodic exposure to $PM_{2.5}$ and other air pollutants results in health effects. ITHIM includes the effects of long-term exposure from $PM_{2.5}$ such as heart disease related to air pollution, lung cancer mortality and respiratory diseases. ITHIM does not address short-term $PM_{2.5}$ exposure including a one-day lag in hospitalizations and emergency department visits for ischemic heart disease and congestive heart failure (heart attacks) following a spike in $PM_{2.5}$ concentrations. A region of 5 million people can expect one premature cardiovascular death from a heart attack for every 10 $\mu g/m^3$ increase in $PM_{2.5}$ during the preceding day [72]. Causal respiratory outcomes are less certain for short-term $PM_{2.5}$ exposure but include emergency room visits and hospitalizations for COPD and respiratory infections [69].

Another limitation of ITHIM is that other important air pollutants highly attributable to LDV are not accounted for in the health model. The advisory group questioned the extent to which ITHIM was underestimating air quality benefits by limiting to $PM_{2.5}$ and suggested expanding the pollutant profile to include other criteria pollutants such as ozone and air toxics such as benzene. Ground-source ozone (smog) is another air-pollutant highly associated with transportation-related air pollution and is strongly correlated with significant long-term and short-term respiratory health effects. Exposure to ozone can result in decreased resistance to respiratory and lung infections. Over time, this exposure may restrict lung growth in children, alter the airway and put significant stress on the cardiovascular system [70]. Analysis of longitudinal cohorts documents a likely causal effect on mortality and morbidity from long-term exposure to ozone. Mortality is estimated at about a 4% increase in risk for every 10 ppb exposure [73]. Ozone and other criteria pollutants could not be quantified in ITHIM due to high multicollinearity between transportation-related pollutants and high correlation of health outcomes.

Also excluded from ITHIM but with significant carcinogenic effects are air toxics. A recent analysis of these pollutants and resulting recommendations are available in the Portland Air Toxics Solutions (PATS) report [74, 75]. Air toxics related to carbon emissions standards may show larger decreases in ambient concentrations than $PM_{2.5}$ in the scenarios. Although not included in ITHIM, decreased concentrations of air-toxics would also result in cancer and non-cancer health benefits. Recommendations from PATS include: use the ongoing regional transportation planning process to reduce vehicle use, target a 20% per person reduction in vehicle emissions by 2035, improve traffic signals to reduce congestion, support strong national standards for clean vehicles, adopt the latest California clean car standards, and promote electric vehicle charging stations [74, 75].

There is no level at which exposure to $PM_{2.5}$ is safe.

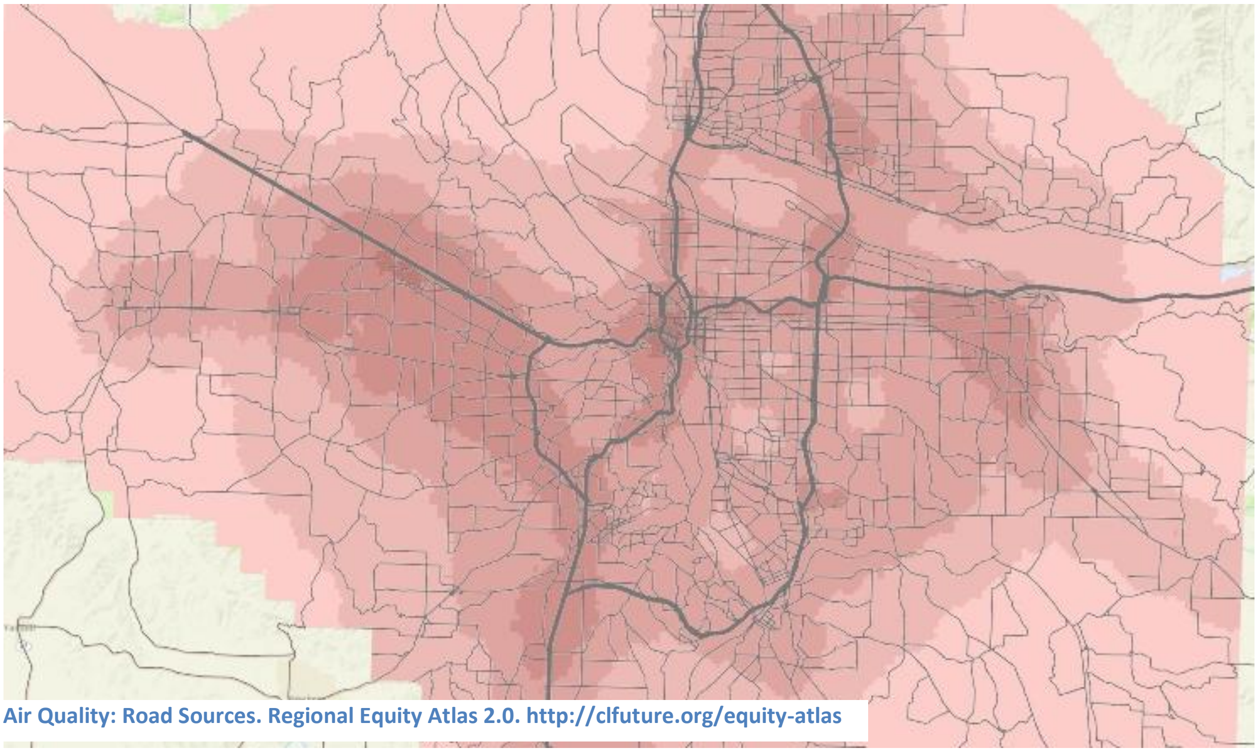
PHD continues to use $PM_{2.5}$ within ITHIM for several reasons. First, scientific understanding is well developed for $PM_{2.5}$, and it has the largest health impact at current ambient concentrations. (See appendix F for a broader discussion of $PM_{2.5}$ science.) Second, the correlation between variables is high. Pollutants associated with LDV emissions show a great deal of multicollinearity. Health outcomes such as respiratory and cardiovascular disease resulting from exposure are also highly correlated. One recent and highly cited dual-pollutant model of ozone and $PM_{2.5}$ showed ozone is primarily associated with respiratory outcomes and $PM_{2.5}$ with cardiovascular outcomes [73]. This suggests current relative risks for $PM_{2.5}$ may already account for some, but not all, of ozone respiratory effects and lung cancers from arsenic and chromium. Reductions in $PM_{2.5}$ would be expected to have similar rates of reduction in death and disease [71, 72].

The strategies and investments under consideration could protect health by reducing exposure to both $PM_{2.5}$ and ozone.

It is important to note the temporal and localized effects of air pollution. ITHIM is based on long-term exposure, but short-term exposure to $PM_{2.5}$, ozone and other air pollutants is also associated with negative health effects. There is no level at which exposure to $PM_{2.5}$ is safe [71, 72]. Any threshold for which ozone does not degrade health "is likely to lie below 0.045ppm" and may be lower than even 0.035ppm [71]. Climate change is also likely to result in warmer summers with even higher ground-source ozone levels.

Additional analysis of temporal patterns (see Appendix F) shows that there were five episodes of elevated $PM_{2.5}$ and one episode of elevated ozone in 2012. These spikes in short-term exposure are highly correlated and predictable from forecasted weather. Spikes in $PM_{2.5}$ during winter inversion layers and ozone on hot, summer days call for short-term interventions. Regional transportation strategies could help address episodic, short-term exposure to both $PM_{2.5}$ and ozone.

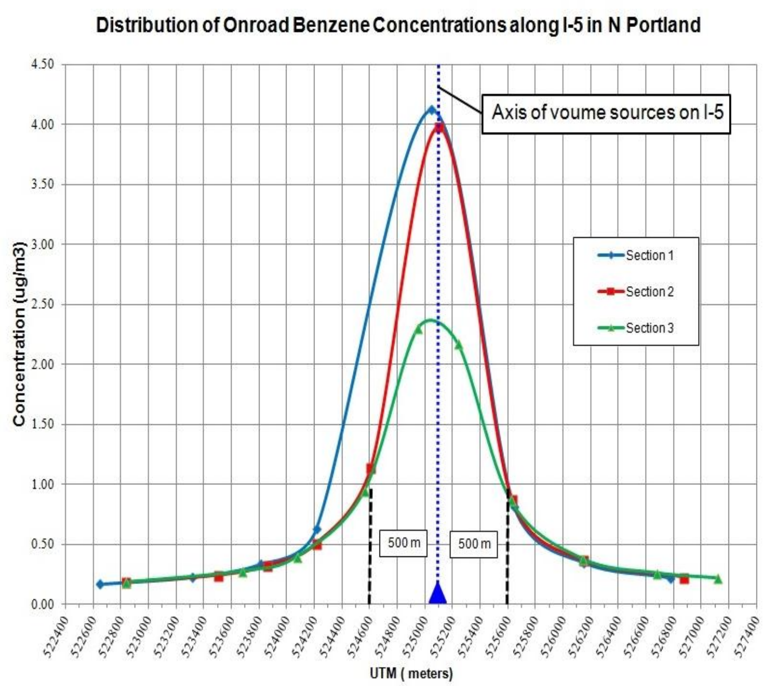
Air pollution is also highly localized[76]. Modest improvements in overall air quality should prompt modest gains in health benefits. These gains could be more significant in communities located near industry and transportation facilities due to the cumulative burden of exposure to air pollution from many sources [77, 78]. Models of air quality along road sources show higher concentrations of pollutants near interstates and on the windward side of the hills west of downtown Portland as seen in the map below.



Air Quality: Road Sources. Regional Equity Atlas 2.0. http://clfuture.org/equity-atlas

A recent DEQ analysis of ambient benzene concentrations along Interstate 5 near Killingsworth Street in North Portland shows that in-road concentration levels are up to ten times higher than urban background levels. While the concentrations drop quickly, concentrations are still 3–4 times higher than urban background levels 500 meters (or 5 blocks) removed from the freeway.

Given the localized nature of air pollution, elevated exposure during transport, particularly in active modes, is a growing concern. The benefits of physical activity outweigh the risks of exposure to air pollutants [54-56, 79]. The literature shows mixed results when measuring concentrations by mode (car, bike, or walking) [80-84]. On major streets, everyone is exposed to much higher levels of air pollution no matter the activity. However, because pedestrians and cyclists have elevated respiratory rates and may be in the roadway



longer, individuals taking these modes have higher personal exposures and uptakes of pollutants [84, 85]. Similarly, individuals working or living along major roads and freeways will also be at risk for higher personal exposure [86].

Highlights of air quality

- Improved air quality is an important benefit of addressing GHG. Metro's scenarios result in modest $PM_{2.5}$ reductions of 2.8, 3.2, and 3.6%. This translates into a relatively modest decrease in lung-cancer deaths, respiratory illness and heart disease related to long-term $PM_{2.5}$ exposure.

- ITHIM underestimates health benefits associated with improved air quality by only incorporating long-term exposure to $PM_{2.5}$. Although likely that additional benefits would accrue from lower ambient ground-source ozone and air toxic concentrations, understanding the extent of such benefits is beyond the scope of this HIA.

- PHD recommends that Metro aligns the CSCS project investments and actions to PATS goals. Metro's scenarios address many of the PATS recommendations such as using technology to manage congestion, more efficient fuel standards and expanded use of electric vehicles. This should lead to a reduction in ambient air toxic concentrations and increased health. It is beyond this analysis to determine if the scenarios meet State of Oregon adopted ambient benchmark concentrations for the suite of pollutants monitored under PATS.

- There is no safe level of $PM_{2.5}$ exposure and safe levels of exposure to ozone are much lower than current ground-source ozone averages. Short-term episodes of elevated $PM_{2.5}$ (winter inversion layers) and ozone (hot, summer days) are not accounted for in ITHIM, but can result in elevated rates of cardiovascular and respiratory death and illness.

- Air quality is localized and many vulnerable populations live near transportation corridors. Transportation corridors are documented to have much higher ambient concentrations of pollutants than other areas. Care should be taken in designing active transportation facilities and buildings adjoining transportation corridors to balance supporting increased physical activity while minimizing exposure.

SUMMARY OF KEY FINDINGS

GHG emission reductions using the proposed strategies will improve health through reducing the risk of climate change and through important health benefits associated physical activity, traffic safety, and improved air quality. Current levels of investment (Scenario A) are expected to contribute to 64 avoided deaths annually; Scenarios B and C would result in 98 and 133 avoided deaths respectively. Every 12 percent decrease in GHG emission – the difference between Metro scenarios - would result in approximately a 0.65 percent decrease in DALYS (illness) among diseases studied.

The majority of health benefits (87-91 percent of avoided deaths, 79-88 percent of avoided illness) from proposed strategies, regardless of scenario, are attributable to increased physical activity from active transportation such as walking and biking to work, transit, school, and other destinations. A transportation system with a broad range of safe and convenient options provides individuals with flexible and healthy choices needed to routinely shift from single occupancy vehicles to more active modes of transportation.

RECOMMENDATIONS

Climate change poses a risk to the future health of Oregonians. Proposed strategies to mitigate climate change will also increase health benefits associated with physical activity, traffic safety and improved air quality. Based upon the findings of this report and with the support of the CCC HIA Advisory Committee, PHD has developed a series of recommendations to preserve and promote healthy communities throughout the region.

By developing and implementing a preferred scenario that meets or surpasses the GHG emissions reduction target set by the Department of Land Conservation and Development, PHD anticipates an improvement in public health.

The majority of health benefits from the CSCS Project can be attributed to active transportation such as walking and biking to work, transit, school and community destinations. **Based on this evidence, PHD recommends that Metro maximize opportunities for active transportation for all communities by:**

- Adopting and identifying stable funding for the design elements listed in the subsection 'Complete Streets and Active Transportation' of Scenarios B and C: street connections, wider sidewalks, safer street crossings, improved bus stops, bikeways, transit signal priority, and on-street bicycle facilities and trails.
- Improving transit service miles to meet levels recommended in Scenario C.
- Using an equity analysis to plan and develop equal access to active transportation throughout the region.

While the benefits of physical activity far outweigh the risks, active modes of transportation can lead to increased exposure to traffic injury and air pollution. **In order to reduce the risk of increased exposure**

to traffic injury and air pollution for all road users, PHD recommends that Metro prioritize the design and maintenance of non-automobile facilities by:

- Including safety features for pedestrians and bicyclists such as separation from motorized traffic when possible. Prioritize non-automobile users in design and maintenance of streets.
- Providing a parallel bicycle route one block removed from high-volume roads when feasible to reduce exposure to localized pollution while still maintaining access to community destinations.

Per capita VMT reduction is expected to modestly improve air quality as measured by many pollutants including air toxics, but temporal and localized air quality concerns remain. **Due to temporal and spatial air quality concerns, PHD recommends that Metro maximize overall improvements in air quality through actions such as:**

- Aligning the CSCS preferred alternative to PATS goals. In collaboration with DEQ, determine how the preferred alternative helps meet State of Oregon adopted ambient benchmark concentrations.
- Reducing exposure by using zoning and incentives to improve indoor filtration systems in new buildings along transportation corridors.
- Convening a regional committee to further address episodic air quality events. Solutions should be season specific and could promote incentives for short-term, alternative commute arrangements.

Finally, to improve health equity, PHD recommends Metro ensure social and health goals are considered when prioritizing investments by:

- Explicitly and transparently addressing how investment links low-income and other vulnerable households to health-promoting resources.

APPENDICES

A. HIA Minimum Elements and Practice Standards

B. Advisory committee

C. Health conditions and prevalence rates by county (BRFSS)

D. CDC Chronic Disease Cost Calculator

E. ITHIM results

F. Air quality white paper

Appendix A. HIA Minimum Elements and Practice Standards

November 2010, Version 2
North American HIA Practice Standards Working Group, Society for the Practitioners of HIA

A health impact assessment (HIA) must include the following minimum elements, which together distinguish HIA from other processes. An HIA:

1. Is initiated to inform a decision-making process, and conducted in advance of a policy, plan, program, or project decision;
2. Utilizes a systematic analytic process with the following characteristics:
    a. Includes a scoping phase that comprehensively considers potential impacts on health outcomes as well as on social, environmental, and economic health determinants, and selects potentially significant issues for impact analysis;
    b. Solicits and utilizes input from stakeholders;
    c. Establishes baseline conditions for health, describing health outcomes, health determinants, affected populations, and vulnerable sub-populations;
    d. Uses the best available evidence to judge the magnitude, likelihood, distribution, and permanence of potential impacts on human health or health determinants;
    e. Rests conclusions and recommendations on a transparent and context-specific synthesis of evidence, acknowledging sources of data, methodological assumptions, strengths and limitations of evidence and uncertainties;
3. Identifies appropriate recommendations, mitigations and/or design alternatives to protect and promote health;
4. Proposes a monitoring plan for tracking the decision’s implementation on health impacts/determinants of concern;
5. Includes transparent, publicly accessible documentation of the process, methods, findings, sponsors, funding sources, participants and their respective roles.

Appendix B. List of CCC HIA Advisory Committee members

Tom Armstrong, City of Portland
Sarah Armitage, DEQ
Adam Barber, Multnomah County Planning
Aida Biberic, DEQ
Margi Bradway, ODOT
Aaron Breakstone, Metro
Ben Bryant, City of Tualatin
Karen Buehrig, Clackamas County
Steve Butler, City of Milwaukie
Betsy Clapp, Multnomah County Health Dept.
Lynda David, Regional Transportation Council
Erica Dejong, Office of Equity and Inclusion
Jennifer Donnelly, Dept. of Land Conservation & Development
Kim Ellis, Metro, Principal Transportation Planner
Leah Fisher, Health Promotion & Chronic Disease Prevention
Barbara Fryer, City of Beaverton
Jana Gastellum, Oregon Environmental council
Heather Gramp, PHD
Mara Gross, Coalition for Livable Future
Renee Hackenmiller-Paradis, OHA
Tia Henderson, Upstream Public Health
Eric Hesse, TriMet
Jon Holan, City of Forest Grove
Stacy Humphrey, City of Gresham, Urban Design & Planning Dept.
Katherine Kelley, City of Gresham
Mary Kyle McCurdy, 1000 Friends of Oregon
Nancy Kraushaar, City of Wilsonville
Michelle Kunec, City of Portland
John MacArthur, OTREC-PSU
Margaret Middleton, City of Beaverton
Thaya Patton, Metro
Barbara Pizacani, PDES
Mel Rader, Upstream Public Health
Dan Rutzick, City of Hillsboro
Vivek Shandas, PSU
Vivian Shatterfield, OPAL
Lainie Smith, ODOT
Emily Tritsch, City of Hillsboro
Dyami Valentine, Washington County
Steve White, Oregon Public Health Institute

Appendix C. County-level BRFSS

BRFSS 2011 category	U.S. state median	Percent of adults [95% confidence interval]				
		Oregon	Portland MSA[2]	Clackamas[1]	Multnomah[1]	Washington[1]
Heart attack	4.4	3.6 [3.1–4.2]	3.2 [2.5–4.0]	3.3 [1.7–5.0]	3.0 [1.5–4.5]	2.6 [1.5–3.8]
Chest pain or coronary heart disease	4.1	3.6 [3.1–4.0]	3.1 [2.4–3.7]	2.8 [1.4–4.2]	2.9 [1.7–4.2]	2.9 [1.6–4.2]
Stroke	2.9	2.9 [2.5–3.4]	2.7 [2.1–3.3]	2.8 [1.2–4.4]	2.7 [1.4–3.9]	3.0 [1.5–4.5]
Any physical activity last month?	73.8	80.3 [78.7–81.3]	81.5 [79.5–83.6]			
150 minutes of Aerobic per week	57.7	61.1 [59.3–62.9]	60.3 [57.8–62.8]	62.5 [56.7–68.2]	65.0 [60.9–69.2]	58.4 [53.0–63.8]
High blood pressure	30.8	29.9 [28.5–31.3]	27.9 [26.0–29.9]	30.6 [25.8–35.4]	26.8 [23.5–30.2]	27.1 [23.0–31.2]
Cholesterol checked and high in past 5 years	38.4	38.5 [36.8–40.2]	36.1 [33.8–38.5]	39.3 [33.5–45.1]	37.0 [32.8–41.2]	33.5 [28.7–38.3]
Overweight	35.7	34.8 [33.31–36.4]	35.8 [33.4–38.1]	35.6 [30.0–41.1]	35.9 [32.0–39.8]	34.3 [29.4–39.2]
Obese	27.8	26.7 [25.2–28.3]	23.7 [21.7–25.7]	25.4 [20.3–30.6]	19.5 [16.3–22.6]	25.5 [21.0–30.0]
Diabetic	9.5	9.3 [8.4–10.2]	8.5 [7.3–9.8]	8.6 [5.7–11.5]	8.8 [6.7–10.9]	6.0 [4.2–7.8]
Depression (ever treated)	17.5	23.9 [27.5–25.3]	22.8 [20.8–24.7]	21.7 [17.2–26.1]	25.5 [21.9–29.1]	22.3 [18.2–26.3]
COPD (Chronic obstructive pulmonary disease)	6.1	5.9 [5.2–6.7]	5.2 [4.2–6.3]	5.2 [3.1–7.3]	5.1 [2.9–7.4]	5.2 [3.2–7.2]
Ever had asthma	13.6	16.7 [15.4–18.0]	16.2 [14.3–18.0]	13.9 [10.2–17.5]	15.4 [12.3–18.5]	20.8 [16.1–25.6]
Current asthma	9.1	10.5 [9.4–11.5]	9.6 [8.2–11.0]	8.3 [5.5–11.0]	9.0 [6.5–11.4]	10.9 [7.7–14.2]

(1) These are not age-adjusted prevalence rates; caution should be used when comparing counties.

(2) The Portland-Vancouver-Hillsboro OR-WA MSA is defined as the seven–county region including Clackamas, Columbia, Multnomah, Washington and Yamhill Counties in Oregon, and Clark and Skamania Counties in Washington

Appendix D. CDC Chronic Disease Cost Calculator

The costs of chronic disease reported are from a recent version (November 2013) of the CDC's Chronic Disease Cost Calculator that can be found at www.cdc.gov/chronicdisease/resources/calculator/index.htm. The Cost Calculator uses a regression-based approach to estimate costs for chronic disease by state and payer type for the treated population. Below is a table of the Oregon (not three-county) results with accompanying notes as provided by the calculator, descriptions of datasets from the technical guide found at www.cdc.gov/chronicdisease/pdf/cdcc_tech_appendix.pdf, and the FAQs found at www.cdc.gov/chronicdisease/resources/calculator/faq.htm.

Overall summary for all diseases for Oregon

	All payers	Medicaid	Medicare	Private insurers	Absenteeism	All payers+ absenteeism
Arthritis	$1,553	$69	$445	$610		
Asthma	$411	$79	$92	$153		
Cancer	$1,888	$43	$620	$878	$202	$1,754
Congestive heart failure	$182	$27	$72	$23	$40	$451
Coronary heart disease	$1,098	$29	$390	$442	$106	$1,994
Hypertension	$1,382	$109	$349	$460	$3	$185
Stroke	$832	$112	$281	$147	$45	$1,143
Other heart disease	$603	$69	$248	$158	$63	$1,445
Depression	$892	$51	$187	$367	$53	$885
Diabetes	$1,658	$137	$464	$528	$9	$612
Diseases of the Heart	$1,883	$125	$710	$624	$94	$986
Total cardiovascular disease	$3,620	$281	$1,174	$1,123	$62	$1,721

*Costs reported in millions.

*Includes costs only for diseases that are selected and have cost values available.

Notes:

Annual expenditures inflated to 2010 $ following recommendations from the Agency for Healthcare Research and Quality. Costs include expenditures for office based visits, hospital outpatient visits, emergency room visits, inpatient hospital stays, dental visits, home health care, vision aids, other medical supplies and equipment, prescription medicines, and nursing homes. Payer populations are not mutually exclusive. Costs for all payers are calculated independently of costs for Medicaid, Medicare, and private insurers. Sums of the total costs across subpopulations may not equal the overall total costs due to rounding. Treated population is defined as the number of people receiving care for the disease in the previous year. The treated population in the Medical Expenditure Panel Survey and the National Nursing Home Survey was likely more resource-intensive than those included in alternative prevalence definitions based on a history of the disease who have not sought treatment recently. All results generated from the tool are estimates. Actual costs may be larger or smaller than those reported. [Continued below.]

The estimates for hypertension and diabetes include a portion of the costs of complications including congestive heart failure (CHF), coronary heart disease (CHD), stroke and other heart diseases. The sum of costs over selected diseases that include hypertension and diabetes could overestimate the costs associated with all the selected diseases. The costs for diseases of the heart include CHD, CHF, and other heart disease. The costs for total cardiovascular disease include diseases of the heart, stroke, and an estimate of hypertension costs that avoids double-counting of costs with other diseases. Excluding the costs of complications lowers the estimates for hypertension and diabetes by approximately 34% and 39%, respectively.

CDC Cost Calculator, default source data sets,

- (See: http://www.cdc.gov/chronicdisease/pdf/cdcc_tech_appendix.pdf for more information)*U.S. Census Bureau:* Total state population and breakdowns by sex and age for 2008 and state population projections by sex and age for 2010 through 2020 came from the U.S. Census Bureau.
- *Kaiser Family Foundation*: Medicare beneficiary data came from the Kaiser Family Foundation 2008 Medicare Health and Prescription Drug Plan Tracker.
- *Medicaid Statistical Information System (MSIS):* Medicaid enrollment data came from the Medicaid Statistical Information System (MSIS) State Summary Fiscal Year 2008. MSIS data are used by CMS to produce Medicaid program characteristics and utilization information for the states. The purpose of MSIS is to collect, manage, analyze and disseminate information on eligibles, beneficiaries, utilization and payment for services covered by State Medicaid programs.
- *Current Population Survey (CPS):* Private insurance enrollment data and breakdowns of enrollment by sex and age by payer (private insurance, Medicaid, and Medicare) came from the Current Population Survey (CPS). Private insurance data came from the 2008 CPS and Medicaid and Medicare data came from the 2007 through 2009 CPS. The Current Population Survey (CPS) is a monthly survey of about 50,000 households conducted by the Bureau of the Census for the Bureau of Labor Statistics. The sample is scientifically selected to represent the civilian noninstitutional population. The sample provides estimates for the nation as a whole and serves as part of model-based estimates for individual states and other geographic areas.

Treated Population, per-person costs, and absenteeism *(Treated population is defined as the number of people receiving care for the disease in the previous year.)*

- *Medical Expenditure Panel Survey (MEPS)* Data were pooled from the 2004 through 2008 Medical Expenditure Panel Survey (MEPS) Consolidated Data Files, a nationally representative survey of the civilian non-institutionalized population that provides data on annual medical expenditures, sources of payment, insurance coverage, and days missed from work due to illness or injury for each participant. The combined five-year MEPS sample included 153,012 persons of all ages living in the U.S. Estimates for both the treated population and costs have been adjusted to be nationally representative using MEPS sampling weights for years 2004 through 2008. The default data include years prior to the implementation of Medicare Part D, which took effect in 2006. All expenditure data were inflated to 2010 dollars using the gross domestic product general price index as recommended by Agency for Healthcare Research and Quality to reflect more current dollar values.

- *National Nursing Home Survey (NNHS)* Estimates for the institutionalized population, which are not available in other data sources, were derived from the 2004 National Nursing Home Survey (NNHS). The NNHS is a nationally representative sample of United States nursing homes, their services, their staff, and their residents. The NNHS provides information on nursing homes from two perspectives-that of the provider of services and that of the recipient of care. For recipients, data were obtained on demographic characteristics, health status, and sources of payment. Diseases were defined using International Classification of Disease (ICD-9) codes based on any diagnosis of the condition, either at admission or time of the survey and primary or secondary diagnosis.

Appendix E. ITHIM methodology and detailed results

The Integrated Transport and Health Impact Model (ITHIM) was developed by public health researchers in the United Kingdom to assess the potential health impacts of GHG emission reduction scenarios for London, U.K. and Delhi, India [4]. The model was later adapted for use in the San Francisco Bay area and applied to transportation scenarios created to comply with California's GHG emissions reduction goals. PHD further adapted the tool for use in the Portland metropolitan region for the CSCS HIA by using census data for the geography that makes up the Portland metropolitan region. In the CSCS HIA, PHD used ITHIM to assess six sample scenarios representative of a range of options associated with the 144 Phase 1 scenarios Metro was currently investigating. One of the recommendations of the CSCS HIA was to rerun ITHIM when the alternative scenarios had been narrowed by Metro to a manageable number. The CCC HIA contains the ITHIM analysis of the three scenarios (A, B, and C) defined in Metro's Phase 2 of the CSCS Project.

METHODOLOGY

For each disease considered, ITHIM applies measures of changes in exposure to estimate changes in mortality (deaths) and illness (as measured by disability adjusted life years or DALYs). ITHIM calculates mortality and illness for both baseline and each scenario and outputs are generally reported in the difference between baseline and scenario. Conceptually, baseline in ITHIM is the expected number of deaths and illness given the current rate of exposure for the expected population in 2035. Estimated impact is the difference between the expected outcome at baseline and the scenario.

ITHIM's methodology is grounded in applying relative risks to appropriate demographics. Relative risk is a statistical construct used by epidemiologists to understand the ratio of the probability of an event (developing a disease or dying) for those exposed compared to the probability of developing the disease without the exposure. In practice, relative risks are developed from large, longitudinal studies. For example, the probability of developing diabetes between two different groups — those who met the Surgeon General's exercise recommendations and those who did not — can be calculated from national, longitudinal survey data. Applying relative risks calculated from large cohort studies or in some cases, meta-analyses of multiple studies, allows ITHIM to estimate the number of new deaths or incidence of disease given current prevalence (or burden of disease) rates and the expected change in exposure from each scenario. By doing so, ITHIM is able to quantify the difference between baseline and scenario and allows for comparisons across scenarios.

One advantage of ITHIM is the ability to compare across various pathways. This is especially true when the tool can be refined to include local data. ITHIM was initially developed using global burden of disease data. This was updated with U.S. prevalence data for the San Francisco and CSCS HIA work. For the CCC HIA, PHD further refined ITHIM by using Oregon-specific prevalence data for mortalities; local demographic data was used to extrapolate WHO models to local populations for DALYs.

This burden of disease approach allows for a comparison in impacts from each disease included and, by summing diseases by exposure type, from exposure pathways. For instance, it allows PHD to state that Scenario B will prevent six times as many stroke deaths (through increased exercise) as traffic fatalities.

ITHIM uses the relative risks for 13 separate diseases assigned to three exposure pathways: physical activity, traffic safety, and particulate air pollution as indicated by $PM_{2.5}$. The burden of disease approach is helpful in understanding which exposure pathway and/or disease is driving health benefits (or burdens). In turn, this allows specific recommendations and mitigation measures to maximize health given the constraints of the scenarios.

ITHIM depends on modeled and survey data such as burden of disease estimates, relative risk ratios, air pollution estimates and outputs from ODOT's GreenSTEP model. ITHIM does not account for statistical uncertainty of modeled and survey data, which likely increases the uncertainty of ITHIM estimates.

The primary limitation of ITHIM is that it underestimates health benefits due to data availability and the specific exposures and diseases represented in each pathway. Although such an assessment is outside of the scope of this HIA, additional analyses on the reduction of toxic air pollutants and ozone from transportation and transportation-specific policies (such as fleet turnover and advances in fuel technology) would likely show additional health benefits.

Table E-1 Exposure pathway, variable, and included illness for ITHIM

	Exposure pathway		
	Physical activity	**Traffic safety**	**Air quality**
Exposure variable	Per capita miles traveled by mode as modeled by GreenSTEP	Miles traveled by person by mode by type of street (non-arterial, arterial, freeway) as modeled by GreenSTEP	$PM_{2.5}$ as modeled by GreenSTEP
Included illness	• Breast cancer • Colon cancer • Stroke[2] • Ischemic heart disease[2] • Depression[3] • Dementia • Diabetes • Hypertensive heart disease[2]	Serious traffic injuries	• Lung cancer[1] • Inflammatory heart disease[1,3] • Respiratory disease[1]

(1) Illness is measured by disability adjusted life years (DALYs) which is the summation of Years of Life Lost (YLL) and Years of Life with Disability (YLD). These illnesses do not have YLD rates available.
(2) While primarily affected by changes in exposure to physical activity, ITHIM also applies an air quality factor to these illnesses.
(3) Relative risks of death were not available for these illnesses.

ITHIM is limited in its ability to quantify and compare health pathways by the specific diseases included in each pathway. Inclusion of disease is based upon the availability of data for the relative risk, the relative importance of the disease for that particular exposure, and the ability to control the relative risk for other diseases of interest. Table E-1 lists the specific diseases by exposure category in this version of ITHIM. Because ITHIM is limited to the 13 diseases, it likely underestimates the health benefits from reducing GHG emissions in all of the major exposure routes. Contemporary trends in medical science are increasingly linking physical activity to many other diseases, conditions, and cancers. Similarly, traffic safety in ITHIM is limited to prevalence rates of *reported* collisions; ITHIM thus underestimates the number of prevented collisions to the extent that collisions are under-reported – particularly for bicyclists. Air quality is limited in ITHIM to $PM_{2.5}$ exposure only and thus underestimates health benefits from lower concentrations of a variety of ambient pollutants including ozone and air toxics.

Air quality affects a broad range of health outcomes and can be described through dozens of exposure variables. Advisory committee members suggested that ITHIM's treatment of the air pollution pathway was particularly weak due to its reliance on $PM_{2.5}$ as the *only* exposure variable for light-duty vehicle (LDV) emissions. PHD feels confident in $PM_{2.5}$ as the indicator due to the state of the science surrounding $PM_{2.5}$ as transportation-related air pollutant. However, PHD acknowledges that $PM_{2.5}$ does not capture the entire LDV emission profile including those of ozone precursors and air toxics. (Please see Appendix F for further discussion.) It is also important to note that $PM_{2.5}$ is considered a good transportation indicator because of the vast amount attributable to heavy-duty diesel emissions; however diesel emissions are beyond the scope of Metro's planning project.

PHD investigated adding additional pollutant profiles into ITHIM but ran into several issues. First, there is a high occurrence of multicollinearity between transportation-related emission pollutants and correlation between health outcomes. For example, in most of the country, long-term ozone and $PM_{2.5}$ measurements are highly correlated. Relative risks constructed with multi-pollutant models are relatively rare. Thus, even though $PM_{2.5}$ appears biologically linked to cardiovascular disease and ozone to respiratory disease, either pollutant can be used to predict both diseases. Summing $PM_{2.5}$ and ozone impacts would certainly double-count to some degree. This also suggests that some of the $PM_{2.5}$ health effects captured in the relative risks for lung cancer, respiratory disease, and cardiovascular disease may be picking up effects from other transportation related pollutants that are highly correlated with $PM_{2.5}$ emissions. For example, reduced time to death for lung cancer patients from $PM_{2.5}$ exposure may also include some lung cancers deaths from benzene exposure given the current science supporting the relative risk estimates. Complicating matters further, the cardiovascular and respiratory systems are biologically linked, making any separation of health outcomes difficult, particularly across a suite of pollutants.

Second, knowledge about the health risks of many air pollutants is based on toxicology studies for cancer. For example, most air toxics tracked by Oregon DEQ are known carcinogens. However, the risk of air toxics is generally stated in the *lifetime* risk of disease based on at least a multi-year exposure, such as working for many years at an industrial plant with high levels of toxic exposure. *Relative* risk ratios have an interpretation of yearly incidence or prevalence of disease based upon a shorter-term exposure such as a year; and is difficult to convert *lifetime* risk.

DETAILED RESULTS

Table E-2 provides detailed ITHIM results by exposure pathway for all three scenarios. Results include avoided mortality (deaths) and illness. Illness is measured by disability adjusted life years (DALY) which is the summation of years of life lost (YLL) and years living with a disability (YLD) due to illness. Results are presented in counts (or cases) avoided as well as percent reduction from current disease prevalence levels. Also note that ITHIM's raw count output assumes a stable (in this case 2010) population. All results in the report have been adjusted approximately 32% upward to account for population growth within the UGB. For example, there should be 58 fewer deaths from increased physical activity in 2035 if Scenario A is implemented. This is 1.4% decrease in current deaths attributable to physical inactivity.

Table E-2 Avoided mortality and illness (DALY) by exposure pathway and scenario

	Avoided	Scenario A			Scenario B			Scenario C		
		Count	Percent	Count w/ population factor[1]	Count	Percent	Count w/ population factor[1]	Count	Percent	Count w/ population factor[1]
Physical activity	Mortality	-44	-1.4%	-58	-68	-2.1%	-89	-88	-2.9%	-116
	YLL	-355	-1.5%	-468	-566	-2.3%	-747	-748	-3.1%	-988
	YLD	-247	-1.0%	-325	-444	-1.6%	-586	-605	-2.3%	-799
	DALY	-601	-1.3%	-793	-1,010	-1.9%	-1333	-1,354	-2.8%	-1786
Traffic safety	Mortality	-1	-1.2%	-1	-3	-3.5%	-4	-9	-10.5%	-12
	YLL	-21	-1.2%	-28	-64	-3.5%	-84	-190	-10.5%	-251
	YLD	-33	-3.8%	-44	-68	-7.6%	-89	-145	-16.4%	-192
	DALY	-55	-2.0%	-72	-131	-4.9%	-173	-336	-12.5%	-443
Air quality ($PM_{2.5}$)	Mortality	-3	-0.2%	-4	-4	0.2%	-5	-4	-0.3%	-5
	YLL	-28	-0.2%	-37	-32	0.2%	-42	-36	-0.3%	-47
	YLD	-0	-0.0%	0	-0	0.0%	0	-0	-0.0%	0
	DALY	-28	-0.2%	-37	-32	0.2%	-42	-36	-0.2%	-47
Total	Mortality	-48	-0.9%	-64	-74	1.4%	-98	-101	-2.0%	-133
	YLL	-404	-0.9%	-533	-662	1.4%	-874	-974	-2.1%	-1286
	YLD	-280	-0.6%	-370	-511	1.1%	-675	-750	-1.6%	-990
	DALY	-684	-0.7%	-903	-1,173	1.3%	-1548	-1,725	-1.9%	-2276

(1) ITHIM estimates disease reduction based on stable (2010) population figures. Assuming disease burden rates remain the same in 2035, counts are adjusted upward by addressing the 32.0% increase in population expected within the Urban Growth Boundary from 2010 to 2035.
(2) Disability adjusted life years (DALY) is the summation of years of life lost (YLL) and years living with a disability (YLD) due to illness. YLD are unavailable for respiratory and inflammatory cardiovascular disease (all cardiovascular disease associated with air pollution exposure) as well as lung cancer at this time.

To compare exposure pathways, the percent reduction attributable to each was calculated for deaths and illnesses. Table E-3 provides detailed results and shows that the majority of health benefits are from reducing physical inactivity burden.

Table E-3 Percent of health benefits attributable to exposure pathway by scenario

		Percent reduction attributable to exposure pathway		
		A	**B**	**C**
Physical activity	Mortality	91.4%	91.1%	87.0%
	YLL	87.8%	85.6%	76.8%
	YLD	88.0%	86.8%	80.6%
	DALY	87.9%	86.1%	78.5%
Traffic safety	Mortality	2.1%	4.1%	9.1%
	YLL	5.3%	9.6%	19.5%
	YLD	11.9%	13.2%	19.4%
	DALY	8.0%	11.2%	19.5%
Air quality	Mortality	6.5%	4.8%	3.9%
	YLL	7.0%	4.8%	3.7%
	YLD	0.0%	0.0%	0.0%
	DALY	4.1%	2.7%	2.1%

THIM provides outputs by disease for exposure pathways in which more than one disease is included. Tables E-4 present the population adjusted avoided illness (DALY) and mortality results for individual diseases in the physical activity and air quality ($PM_{2.5}$) exposure pathways.

Table E-4 Avoided mortality and illness (DALY) by illness and scenario for physical activity and air quality exposure pathways[1]

	Scenario A		Scenario B		Scenario C	
	DALY	Mortality	DALY	Mortality	DALY	Mortality
Breast cancer	-13	-1	-29	-1	-32	-1
Colon cancer	-11	-1	-21	-2	-24	-2
Stroke	-181	-15	-290	-23	-400	-29
Ischemic heart disease	-205	-20	-319	-30	-442	-42
Depression	-57		-125		-162	
Dementia	-117	-8	-220	-14	-241	-15
Diabetes	-129	-5	-209	-7	-324	-10
Hypertensive heart disease	-79	-9	-119	-12	-161	-16
Physical activity total	**-793**	**-58**	**-1,333**	**-89**	**-1,786**	**-116**
Lung cancer	-21	-2	-24	-2	-26	-3
Inflammatory heart disease (associated with PM2.5 exposure)	-2		-3		-3	
Respiratory disease	-14	-2	-16	-2	-17	-2
Air quality ($PM_{2.5}$) Total	**-37**	**-4**	**-42**	**-5**	**-47**	**-5**

(1) ITHIM estimates disease reduction based on stable (2010) population figures. Assuming disease burden rates remain the same in 2035, counts are adjusted upward by addressing the 32.0% increase in population expected within the Urban Growth Boundary from 2010 to 2035.

ITHIM addresses traffic safety by estimating the number of severe crashes and fatalities by mode and by type of road. The tool is able to account for increased crashes for active transportation users even as overall traffic crashes decrease as miles travel shift from car to other modes. Table E-5 and E-6 present estimates for traffic fatalities and injuries respectively in 2035. Note that all counts have been adjusted for 2035 population. Also note that injuries are serious injurious only. Injury information is further analyzed to develop DALY results presented above.

Table E-5 ITHIM estimates of expected DALYs from traffic injuries by mode in 2035

Mode	Baseline	Scenario A	Scenario B	Scenario C
Walk	889.2	958.3	952.8	898.1
Cycle	316.7	312.3	356.7	372.7
Bus	0.0	0.0	0.0	0.0
Car	1905.8	1773.9	1639.5	1418.1
Motorbike	424.5	419.4	413.9	404.4
Total [1]	3555.4	3483.0	3382.0	3112.5
Sum of difference between baseline and scenario		-72.4	-173.3	-442.9

(1) Note that the total is not the sum of the modes presented as it also adds in a small but fixed number of HGV crashes.

Table E-6 ITHIM Estimates of Expected Traffic Fatalities by Mode in 2035

Mode	Baseline	Scenario A	Scenario B	Scenario C
Walk	34.3	37.0	36.7	34.6
Cycle	10.4	10.2	11.7	12.4
Bus	0.0	0.0	0.0	0.0
Car	53.4	49.7	45.9	39.7
Motorbike	15.9	15.8	15.6	15.3
Total [1]	114.8	113.4	110.7	102.7
Sum of Difference between Baseline and Scenario		-1.4	-4.0	-12.1

(1) Note that the total is not the sum of the modes presented as it also adds in a small but fixed number of HGV crashes

Appendix F. Air Quality White Paper

ITHIM estimates air pollution mortality and morbidity using particulate matter ($PM_{2.5}$) as an indicator. The advisory group suggested exploring the expansion of the pollutant profile and expected health impacts beyond $PM_{2.5}$. Other commonly considered air pollutants include ground-level ozone (O_3) and NO_2 exposure. Ambient air is also monitored for known carcinogens or air toxics. All of these pollutants were investigated for potential inclusion in this HIA.

Air pollution is primarily regulated through the U.S. EPA and monitored by Oregon. The most prominent EPA regulations are for six 'criteria' pollutants. Three of these are particularly relevant to transportation: $PM_{2.5,}$ ozone and NO_2. The regulator context informs both the current conditions and the body of scientific evidence. Table 1 provides a summary of the most recent EPA science reviews for $PM_{2.5}$, ozone and NO_2 and includes known health outcomes and the relative weight of evidence. The health outcomes are cardiovascular ($PM_{2.5}$), respiratory (ozone) and central nervous system illness, and death. Because PM and ozone are further developed, the remainder of this section concentrates on these two pollutants when discussing criteria pollutants.

TABLE 1 Summary of U.S. EPA integrated science assessment weight of evidence for health effects associated with PM, ozone, and NO_2

Health outcome	**PM ($PM_{2.5}$)** 2009 ISA[69]	**O_3** 2013 ISA[70]	**NOx (NO_2)** 2008 ISA[68]
Short term exposure			
Respiratory morbidity	●●●●	●●●●●	●●●●
Cardiovascular morbidity	●●●●●	●●●●	●●
Central nervous system morbidity	Not reviewed	●●●	Not reviewed
Mortality	●●●●●	●●●●	●●●
Long term exposure			
Respiratory morbidity	●●●●	●●●●	●●●
Cardiovascular morbidity	●●●●●	●●●	●●
Reproductive/birth outcomes	●●●	●●●	●●
Central nervous system morbidity	Not reviewed	●●●	Not reviewed
Cancer	●●●	●●	●●
Mortality	●●●●●	●●●	●●

●●●●● **Causal** - Evidence is sufficient to conclude there is a causal relationship and has been shown to result in health effects in studies in which chance, bias, and confounding could be ruled out with reasonable confidence.
●●●● **Causal likely** - Evidence is sufficient to conclude that a causal relationship is likely to exist, but important uncertainties remain.
●●● **Suggestive of causal** - Evidence is suggestive of a causal relationship but is limited. (i.e. - relies only on toxicology, or high quality epidemiological study is inconsistent with past evidence)
●● **Inadequate to Infer** - Evidence is inadequate to determine that a causal relationship exists; available studies are of insufficient quantity, quality, consistency, or statistical power.
● **Not likely to be causal**

Scientific consensus about the strength of and causal nature of the relationships between $PM_{2.5}$ and health is clear from the EPA reviews [68-70]. A recent World Health Organization scientific review also concludes that $PM_{2.5}$ is the best air pollution indicator for health impact analyses [71]. Because the health pathways and risk ratios are most developed for $PM_{2.5}$, PHD feels confident in using $PM_{2.5}$ as the primary air pollution indicator within ITHIM.

Still, health evidence is mounting for ambient exposure from ozone and certain air toxics. Further, some pollutants affect certain health outcomes more than others. The following sub-sections provide analyses of criteria pollutants ($PM_{2.5}$ and ozone) and carcinogenic air toxics. Each section provides a brief literature review to understand the breadth and severity of health effects followed by presentation of local incidence of disease and pollution conditions. After the discussion of specific pollutants is a section that addresses the spatial distribution of air pollution and the health burden it places on specific vulnerable populations.

Criteria pollutants ($PM_{2.5}$ and ozone)

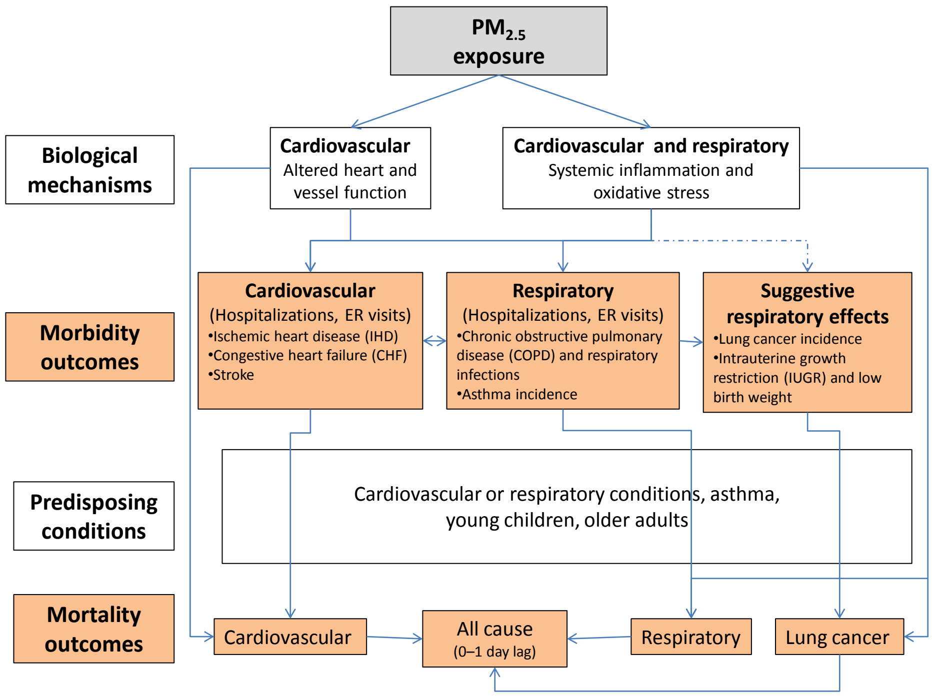
EPA regulates six criteria pollutants including $PM_{2.5}$ and ozone. $PM_{2.5}$ is ambient ultra-fine particles created during the combustion process and is primarily an issue during winter inversion layers. Ozone is created from reactions of precursor pollutants — largely emitted through combustion processes — in the presence of solar radiation. Elevated ground-source ozone concentrations typically occur in the afternoon and during summer months. The primary route of exposure for $PM_{2.5}$ and ozone is through inhalation.

Transportation emissions are a significant source of both pollutants. Nationally, road transportation accounts for 6.9% of $PM_{2.5}$ emission totals. Ozone is routinely reported in terms of precursor pollutants with 38.5% of NO_x and 1.2% of SO_x emission totals attributable to road transportation. Populations clustered near roads are much more likely to be exposed to road transportation sources. A recent study estimated that weighting concentrations by population would result in road transportation as the top contributor of human exposure. In this model, road transportation accounted for 26.3% of $PM_{2.5}$ and 54.3% of ozone exposure [87].

Health pathways for $PM_{2.5}$

Inhaling $PM_{2.5}$ harms the heart and lungs as the particles embed deep within the respiratory tract. Particulate matter degrades health through systemic inflammation, oxidative stress, and altered heart and blood vessel function. Short and long-term health outcomes of concern are primarily cardiovascular with secondary respiratory effects (see Figure E.1).

FIGURE E.1 Pathway diagram- Particulate matter exposure and health outcomes



The EPA states with the highest levels of confidence that short and long-term exposure to $PM_{2.5}$ causes cardiovascular morbidity (illness) and mortality (death), likely causes respiratory disease and death, is increasingly associated with poor birth outcomes such as low birth weight, and is increasingly believed to exacerbate lung cancer resulting in death.

Evidence of ***short-term*** exposure to $PM_{2.5}$ is best developed for cardiovascular mortality and non-fatal cardiovascular events [72]. Documented short-term morbidity outcomes associated with $PM_{2.5}$ include a one day lag in hospitalizations and emergency department visits for ischemic heart disease and congestive heart failure following a spike in $PM_{2.5}$ concentrations. A region of 5 million people can expect one premature cardiovascular death for every 10 $\mu g/m^3$ increase in $PM_{2.5}$ during the preceding day [72]. Causal respiratory outcomes are less certain but include emergency room visits and hospitalizations for COPD and respiratory infections [69].

Long-term exposure to $PM_{2.5}$ also increases the risk of cardiovascular and cardiopulmonary mortality [72]. A recent review suggests chronic exposure to $PM_{2.5}$ increases the nonaccidental risk of death by 6%, cardiovascular death by 12–14%, and lung cancer death by 15–21% for every increase in 10 $\mu g/m^3$ [88].

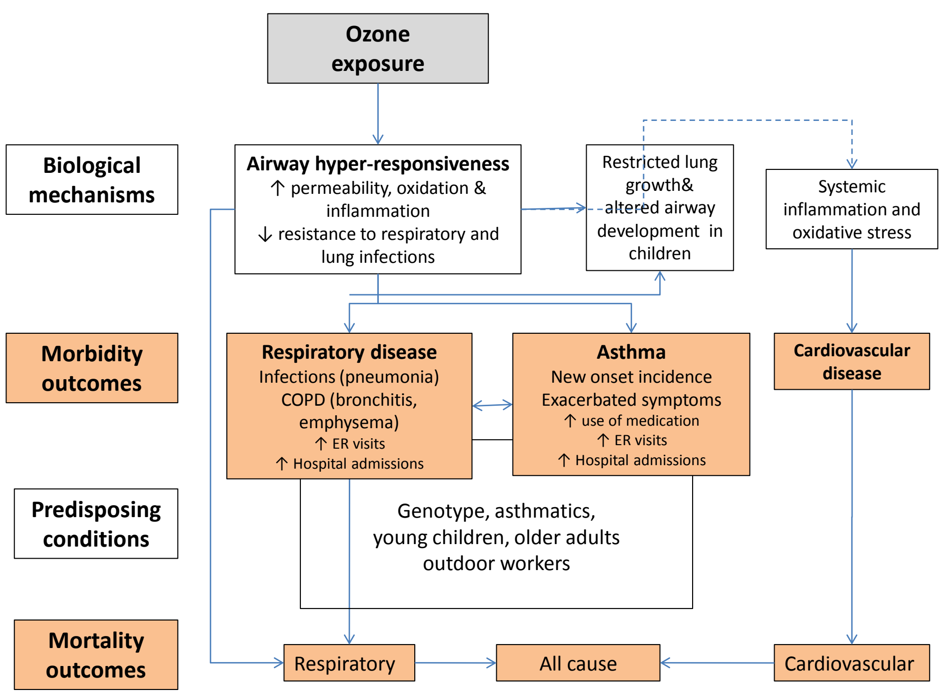
Morbidity outcomes associated with long-term exposure include: bronchitis in children, chronic bronchitis in adults over 30 years, asthma attacks, cardiovascular and respiratory hospital admissions, urgent care or emergency department visits due to asthma and cardiovascular disease, and restricted activity days for adults [71].

Emerging multi-pollutant models suggest pulmonary and respiratory responses associated with $PM_{2.5}$ may be due to highly correlated exposure to co-pollutants such as ozone [73]. Yet the linear relationship between $PM_{2.5}$ exposure and cardiovascular mortality hold at all levels for both short and long-term relationships [71, 72]. This implies **there is no level at which exposure to $PM_{2.5}$ is safe** and that **all reductions in $PM_{2.5}$ would be expected to have similar rates of reduction in death and disease**.

Health pathways for ozone

Ground-source ozone is documented to cause short-term airway hyper-responsiveness including increased permeability, oxidation and inflammation. (See Figure E.2.) Exposure to ozone can result in decreased resistance to respiratory and lung infections. Over time, this may restrict lung growth in children (an asthma risk), alter the airway, and stress the cardiovascular system [70].

FIGURE E.2 Pathway diagram- Ozone exposure and health outcomes



The relationship linking respiratory effects to ***short term*** exposure of ozone is well documented. Short-term health outcomes include respiratory mortality and morbidity as measured by respiratory and cardiovascular hospital admissions. Exposure to ozone has also been shown to increase new onset asthma, asthma symptoms, medication use, emergency room visits, and hospitalizations [70, 71].

Analysis of longitudinal cohorts also documents a likely causal effect on mortality and morbidity from ***long-term*** exposure to ozone. Research shows the strongest associations between long-term exposure and respiratory morbidity and mortality, with a 4% increase in risk for every 10 ppb exposure. Any secondary cardiovascular effects may be due to the correlation between ozone and $PM_{2.5}$ [73]. Other research suggests that mortality risk increases with ozone exposure in populations with predisposing conditions such as COPD, diabetes and congestive heart failure. Research also supports the conclusion that long-term ozone exposure exacerbates asthma incidence, severity and hospitalization [70, 71].

Analysis of local cardiovascular and respiratory conditions

Ozone and $PM_{2.5}$ have a significant effect on cardiovascular and respiratory conditions. While $PM_{2.5}$ may be more directly linked to cardiovascular outcomes and ozone to respiratory outcomes, the presence of either pollutant can cause and exacerbate both types of health effects.

Many people suffer from heart disease in the Portland region. According to BRFSS, approximately 3% of adults in the region have had a heart attack; a similar number suffer from chest pain or heart disease and 2.7% report having suffered a stroke. These three cardiovascular conditions are highly associated with risk factors such as physical inactivity, high blood pressure, high cholesterol and high BMI (weight). Recent BRFSS data also shows that approximately 28% of adults report high blood pressure and 36% have had a high cholesterol reading in the past five years. Nearly 40% of adults report not meeting the recommended 150 minutes of aerobic physical activity per week. More than 35% are overweight and nearly 24% are obese [8].

Prevalence(1) of adults who have suffered from heart attack, angina and stroke in Oregon and the three-county Portland region

	Heart attack	Angina (chest pain from heart disease)	Stroke
Oregon	3.6%	3.6%	2.9%
Clackamas	3.3%	2.8%	2.8%
Multnomah	3.0%	2.9%	2.7%
Washington	2.6%	2.9%	3.0%

(1) 2011 BRFSS

Cardiovascular disease is costly to treat. Oregon Hospital Discharge Index data in 2008 showed hospitalization charges for heart attacks averaged about $40,000 [89]. The CDC estimates from the Chronic Disease Cost Calculator put the annual direct medical costs at over $1.5 billion for the Portland metropolitan area. Approximately $620 million of the region’s cardiovascular costs are associated with Medicare and Medicaid patients which make up 14 and 15% of the Oregon population [10, 11].

Respiratory illness also significantly degrades quality of life. Conditions such as asthma and COPD are caused and/or exacerbated by poor air quality. A little more than 5% of adults report having COPD. More than 9% of Portland region adults report a current asthma condition making the Oregon adult rate the sixth highest in the country [8, 9]. At least 7–8% of children in Oregon have asthma according to parental response and when teens are directly surveyed, the prevalence increases to 10% [9].

Controlling asthma can be difficult and costly. Most asthma patients fill multiple prescriptions regularly. When medications are not adequately controlling symptoms, patients use the emergency department and hospital system. For every four asthma visits to the emergency department, at least one results in a hospitalization. The average cost of an asthma hospitalization is approximately $14,300. In 2011, this resulted in over $15 million in charges and taxpayers were asked to pay nearly $10 million for Medicaid and Medicare patients [9].

Costs (charges) of asthma hospitalization, 2011

		Clackamas	Multnomah	Washington	Three-county	Oregon(1)
Average cost of hospitalization						$14,300
Total costs	Medicaid/OHP	$677,661	$2,681,673	$999,123	$4,358,457	$8,000,000
	Medicare	$872,489	$3,452,655	$1,286,371	$5,611,514	$10,300,000
	All payment sources	$2,371,813	$9,385,857	$3,496,931	$15,254,601	$28,000,000

(1) Source: All-Payers, All Claims Database[9]

Analysis of local $PM_{2.5}$ and ozone conditions

The EPA sets National Ambient Air Quality Standards (NAAQS) Rules to regulate $PM_{2.5}$ and ozone.[9] These are provided below. Routinely exceeding the NAAQS will result in regulatory action including mandated completion of attainment plans.

Current U.S. EPA NAAQS for NOx, ozone and PM

Pollutant [final rule cite]	Primary/ secondary	Averaging time	Level	Form
Ozone [73 FR 16436, Mar 27, 2008]	Primary and secondary	8-hour	0.075 ppm (3)	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
Particle Pollution $PM_{2.5}$ Dec 14, 2012	Primary	Annual	12 μg/m^3	annual mean, averaged over 3 years
	Secondary	Annual	15 μg/m^3	annual mean, averaged over 3 years
	Primary and secondary	24-hour	35 μg/m^3	98th percentile, averaged over 3 years

Source: www.epa.gov/air/criteria.html 8/23/13

[9] It is important to consider that NAAQS are routinely revised and almost always become more stringent as scientific evidence builds. For instance, the Federal Clean Air Science Advisory Committee reviewing evidence before the 2008 EPA NAAQS rule of 0.075 ppm recommended a standard in the 0.060-0.070 ppm range. The court has upheld the 0.075 ppm rule, but most health experts would lower the standard to 0.060 ppm or below. The EU has a non-binding rule of no more than 25 days at or above 0.060 ppm; UK rules suggest levels below 0.050 ppm all but 10 days of the year.

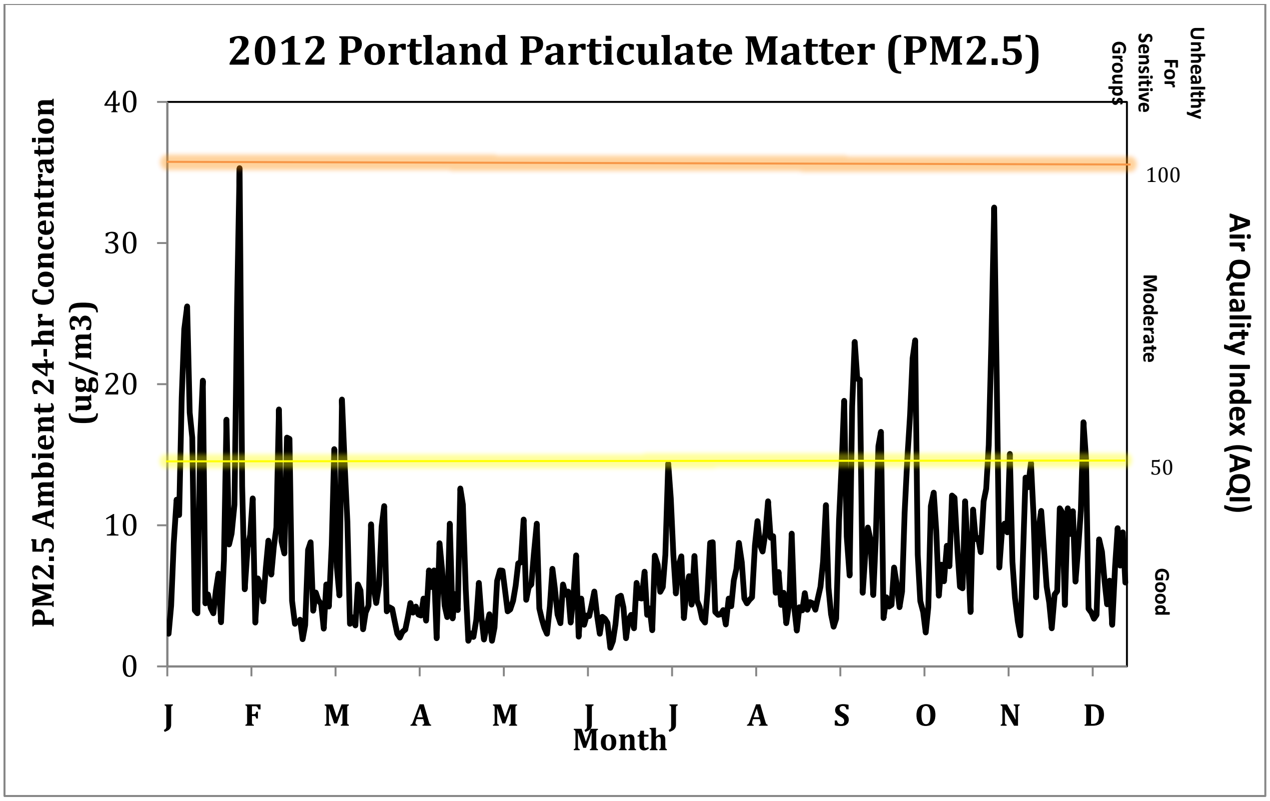
In general, the Portland metropolitan area is well within attainment. The yearly average of $PM_{2.5}$ has ranged between 6.3 and 9.8 µg/m^3 over the past decade. A yearly average of 2012 day-time ozone levels is approximately 0.033 ppm. While these levels are within attainment, this chronic exposure results in long-term illness and death.

The CDC's National Environmental Health Tracking [90] program provides county-specific estimates of mortality reduction in all-cause and coronary heart disease death associated with chronic exposure to $PM_{2.5}$. This tool estimates that a 10% reduction in $PM_{2.5}$ from 2009 levels (yearly mean = 7.8 µg/m^3) would result in a 0.5% decrease in all-cause mortality and a 2.2% decrease in cardiovascular mortality. This is the equivalent of 57 annual deaths, 31 of them from coronary heart disease, in the three-county Portland region [90]. Another highly influential and cited study found that every 10 ppb increase in ozone results in a 1.040 (1.013–1.067) relative risk of respiratory death even after controlling for $PM_{2.5}$ effects [73].

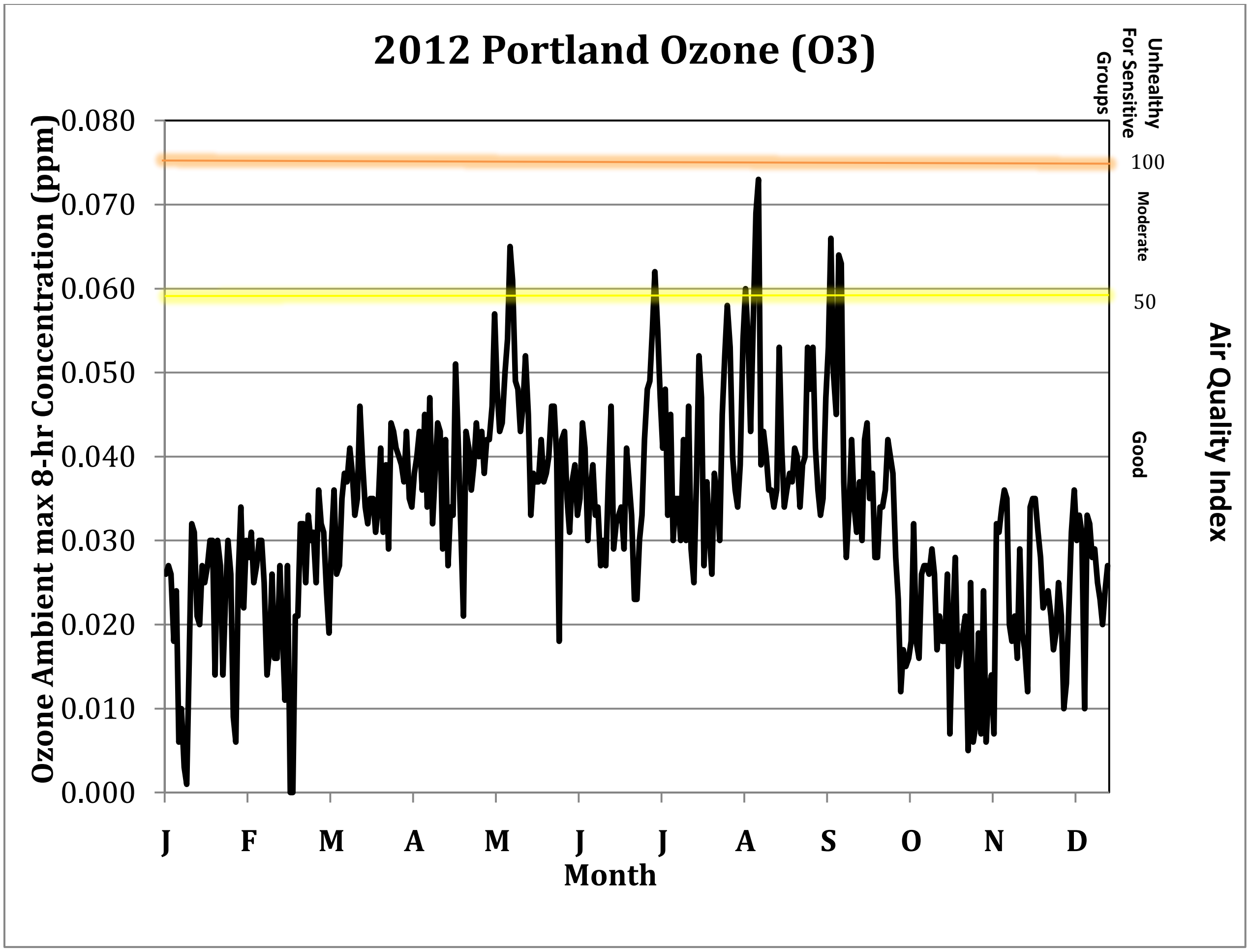
Another recent study used the epidemiological evidence to estimate sector-specific deaths attributed to long-term exposure to $PM_{2.5}$ and ozone. Oregon-specific mortality rates were estimated. According to this study, road transportation-related $PM_{2.5}$ — including both heavy duty diesel and light duty vehicles — causes more than 108 cardiovascular and lung cancer deaths and ozone causes more than 15 premature respiratory deaths within the UGB each year [87].

The NAAQS for $PM_{2.5}$ and ozone also help protect against acute health effects associated with high short-term exposure. The EPA has also developed an Air Quality Index (AQI) as a public communication tool to advise when air quality is poor enough to warrant behavior modification. AQIs are forecasted using meteorological data to predict when weather patterns will result in short term spikes in $PM_{2.5}$ (winter inversion layers) and ozone (hot summer days).

The graphs below provide daily maximum 24-hour $PM_{2.5}$ and 8-hour ozone averages and the associated AQI as recorded in the southeast Portland metropolitan region in 2012. The region is NAAQS compliant because there are few, if any, short-term spikes of $PM_{2.5}$ above 35 µg/m^3 or ozone above 0.075 ppm.



Source: Oregon DEQ, 2012



Source: Oregon DEQ, 2012

The AQI categories suggest that any value below 50 is 'good' for public health and values between 50 and 100 are only of 'moderate' concern. However, the public health literature increasingly suggests that all levels of $PM_{2.5}$ and ozone are of concern. There is no level at which $PM_{2.5}$ does not affect health. It is also widely recognized that any threshold for which ozone does not degrade health "is likely to lie below 0.045 ppm" and may be lower than even 0.035 ppm [71]. Warmer summers from weather events and climate change may result in even higher ozone levels.

Short-term AQI levels between 50 and 100 produce measurable impacts in cardiovascular and respiratory illness and death. These short-term air-quality 'episodes' may be weather-driven, but are still of great public health concern, particularly for vulnerable populations including those with high cardiovascular or respiratory risks and populations exposed to higher localized concentrations near busy roads and highways.

To understand the impact of short-term, acute exposure in the moderate AQI range, we considered the impact of $PM_{2.5}$ episodes[10] on one high-severity endpoint: death from a heart attack. A day or even hours of elevated $PM_{2.5}$ exposure can trigger a heart attack in populations with underlying heart disease risk factors. In 2012, the region recorded five $PM_{2.5}$ episodes where concentrations were well above 20 $\mu g/m^3$ for multiple days. For an area of 1.5 million people, every three-day $PM_{2.5}$ episode results in approximately one premature cardiovascular death triggered by a heart attack.[11] In the U.S., 15.2% of heart attacks result in death within 30 days [91]. In 2012, the Portland region likely experienced approximately 30 preventable heart attacks, five resulting in death, due to elevated exposure during $PM_{2.5}$ episodes.

A comparable exercise could be carried out for other cardiovascular endpoints for $PM_{2.5}$ episodes. Additional analysis would also tell a similar story for respiratory conditions such as asthma during ozone episodes. For example, a recent study of 1.2 million children under age six in New York State found the risk of respiratory and asthma hospitalization increased by 22% for every 0.001 ppm increase in mean ozone during the warm season and 68% on days with ozone was greater than 0.070 ppm even after controlling for 13 socio-economic, familial and weather variables [92].

Air toxics

Air toxics refer to the suite of pollutants in the air from a variety of sources, including industrial processes, transportation and wood burning stoves. This section briefly summarizes the 2012 Oregon Department of Environmental Quality (DEQ) Portland Air Toxics Solutions (PATS) report and effort and focuses on air toxics most associated with light-duty cars and trucks [75]. The table below lists the pollutants associated with light duty vehicles. It also lists possible health effects including EPA's cancer risk classification and the toxicological evidence.

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[10] Defined as multiple days with $PM_{2.5}$>15 µg/m3 with at least one of the days >20 $\mu g/m^3$.

[11] The American Heart Association (Brook et al, 2010) states that every day with a 10 $\mu g/m^3$ increase in $PM_{2.5}$ results in a one day lag of one premature cardiovascular death per 5 million people.

Onroad mobile air toxic pollutants and health effects

Pollutant	Health effects	Toxicological evidence - animal (A) or human (H)
Acrolein	General respiratory congestion; eye, nose, and throat irritation	A, H
Arsenic	Known (Class A) human carcinogen (lung); irritation of skin and mucous membranes	A, H
Benzene	Known (Class A) human carcinogen (leukemia); anemia, blood disorders, immune system damage	A, H
1,3-Butadiene	Probable human carcinogen (leukemia); cardiovascular disease	H
Chromium VI	Known (Class A) human carcinogen (lung); respiratory tract damage and disease	H
Ethyl benzene	Respiratory irritation, central nervous system	A
Formaldehyde	Probable (Class B1) human carcinogen (lung & nasal); respiratory irritation	H
Naphthalene	Possible (Class C) human carcinogen; eye and retina damage	A, H
Polycyclic aromatic hydrocarbons (PAH)	Varies depending on compound; 7 are probable (Class B2) carcinogens	

Inorganic arsenic, benzene, and chromium IV are all listed as Class A, known carcinogens. 1,3-Butadiene, a probable human carcinogen, is highly attributable to light-duty vehicle exposure. Epidemiological studies have shown arsenic and chromium increase the risk of lung cancer. Similar studies have shown that benzene increases the risk of blood disorders including leukemia. 1,3-Butadiene also increases the risk of leukemia and may increase cardiovascular effects. The EPA lifetime carcinogenic unit risks for each pollutant are shown below.

Lifetime carcinogenic risk for inhaled exposure

Pollutant	Primary cancer type	Unit risk
1, 3-Butadiene	Leukemia	3E-3 per µg/m^3 (0.08 per ppm)
Arsenic	Lung	4.3E-3 per 1 µg/m^3 (1)
Benzene	Leukemia, primarily acute myeloid	2.2E-6 to 7.8E-6 per 1 µg/m^3
Chromium VI	Lung	1.2E-2 per 1 µg/m^3

Source: www.epa.gov/iris/

(1) may increase in >2 µg/m^3 exposure settings

Current conditions

Oregon has adopted ambient benchmarks significantly lower than the lifetime carcinogenic risk in an effort to reduce health risks. (See www.deq.state.or.us/aq/toxics/docs/abcRuleFinal.pdf.) These benchmarks are meant to protect the public — including more sensitive groups such as the elderly and children — from health outcomes beyond cancer.

Oregon's Department of Environmental Quality (DEQ) monitors air toxics within the Metro region. DEQ recently modeled expected pollutant levels in 2017 for 19 pollutants and compared the results to benchmarks. Select results of this modeling exercise are provided in the table below.

Air toxics in the Portland metropolitan region

Pollutant	Current levels	Oregon benchmark		Modeled 2017 (1)	
	$\mu g/m^3$	$\mu g/m^3$	% Reduction	% Attributable to onroad mobile	% Attributable to light duty
Acrolein	0.131	0.02	84.7%	3	1.9
Arsenic	0.000558	0.0002	64.2%	28	10.1
Benzene	0.956	0.13	86.4%	13	12.4
1,3-Butadiene	0.249	0.03	88.0%	64	56.3
Chromium VI	0.000107	0.00008	25.2%	59	54.9
Diesel pm	1.117	0.1	91.0%	16	0
Ethyl benzene	0.631	0.4	36.6%	32	30.4
Formaldehyde	0.667	0.077	88.5%	8	5.0
Naphthalene	0.159	0.03	81.1%	10	6.2
Polycyclic aromatic hydrocarbons (PAH)	0.018	0.0009	95.0%	10	2.8-6.2

(1) Oregon DEQ (2011) Air Toxics Pollutant Summaries. 6/2/11.

Metro's Climate Smart Communities Scenarios Project is focused on light-duty vehicles. Significant reductions in vehicle miles traveled and gasoline fuel consumption are expected to help reduce air toxic pollutants with large portions attributed to light-duty, gasoline vehicles. These pollutants include a suite of 15 PAHs (2.8–6.2%), arsenic (10.1%), benzene (12.4%), ethyl benzene (30.4%), chromium VI (54.9%), and 1,3 butadiene (56.3%).

The scenarios under consideration are projected to reduce GHG emissions by 12, 24 and 36% respectively. The corresponding estimated decrease in $PM_{2.5}$ is 2.8, 3.2 and 3.5%. It is beyond the scope of this analysis to determine how individual air toxic pollutants will change under the scenarios given the limitations of ODOT's GreenSTEP model and the ITHIM methodology. Air toxics should decrease by at least the amount projected for $PM_{2.5}$ and may follow a trajectory closer to the GHG reduction targets depending on the pollutant. Further analysis would be needed to determine how the preferred alternative aligns with Oregon adopted ambient benchmark concentrations for the pollutants monitored under PATS.

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