HEALTH IMPACT ASSESSMENT ON POLICIES REDUCING VEHICLE MILES TRAVELED IN OREGON METROPOLITAN AREAS

A collaboration between Upstream Public Health, Oregon Health & Science University, Human Impact Partners, and a health and trasportation expert advisory committee.

May 2009

Mel Rader, Project Director
Upstream Public Health
240 N. Broadway St., Suite 201
Portland, OR 97227

503.284.6390
mel@upstreampublichealth.org

CONTRIBUTORS

This study was commissioned by Upstream Public Health.
Funding was generously provided by the Northwest Health Foundation.

Coordination:

- Mel Rader, Project Director, Upstream Public Health

Analysis:

- Yvonne Michael, Assistant Professor, Department of Public Health and Preventive Medicine, Oregon Health and Science University and Center for Health Research, Kaiser Permanente
- Leslie Perdue, Research Associate, Department of Public Health and Preventive Medicine, Oregon Health and Science University

Health and Transportation Expert Advisory Committee:

- Tom Armstrong, District Liaison, City of Portland, Bureau of Planning and Sustainability
- Cat Livingston, Family Physician, Oregon Health and Science University
- Noelle Dobson, Project Director, Healthy Eating Active Living, Community Health Partnership
- Nancy Goff, Program Coordinator, Health Impact Assessment, Oregon Department of Human Services
- Mary Kyle McCurdy, Senior Staff Attorney and Policy Director, 1000 Friends of Oregon
- Jenny Staab, Senior Research Analyst, Environmental Public Health Tracking Program, Oregon Department of Human Services
- Lidwien Rahman, Principal Planner, Oregon Department of Transportation Region 1; Board member, Willamette Pedestrian Coalition
- Greg Raisman, Traffic Safety Specialist, Portland Department of Transportation
- Tyler Deke, Manager, Bend Metropolitan Planning Organization
- Ali Bonakdar, Director, Corvallis Area Metropolitan Planning Organization
- Karl Rohde, Political Director, Bicycle Transportation Alliance

Advisors:

- Celia Harris, Human Impact Partners
- Jonathan Heller, Human Impact Partners

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Vehicle Miles Traveled and Oregon's Jobs and Transportation Act

Governor Kulongoski proposed setting specific targets for car use in order to meet established greenhouse gas emissions goals. Auto use is typically measured by vehicle miles traveled (VMT) –the number of miles that residential vehicles are driven within a given time period and geographic area. VMT vary widely from region to region because it is influenced by a number of factors including urban density, income levels, and accessibility of public transportation. The Governor's proposal would give funds to Oregon's six Metropolitan Planning Organizations (MPOs) to design and implement VMT reduction plans using a variety of policies, such as a VMT tax and investments in public transit.

Upstream Public Health identified the statewide VMT-reduction plan as a policy that could significantly affect Oregonians' health in ways that had not yet been fully examined. In January 2009, Upstream received funding from the Northwest Health Foundation to assess how VMT reduction strategies being considered by Oregon's six metropolitan regions would bring about changes in air quality, physical activity, and car accident rates—and what impact that would have on the public's health.

Methodology of the Study

The research used the steps of Health Impact Assessment (HIA) as recommended by the Centers for Disease Control and Prevention. HIAs are used to evaluate the effect proposed policies or projects will have on well-being and to promote decisions that are the most beneficial for health.

The project also used elements of community-based participatory research methodology to form an expert advisory committee, link research with advocacy, and to disseminate results to policy makers. The advisory committee included representatives from the public health and preventive medicine department at Oregon Health & Sciences University, the state public health division, metropolitan planning organizations, land use and planning community organizations, public health non-profits, and bicycle and pedestrian coalitions. The advisory committee identified the scope of the HIA including 11 specific policies to reduce VMT that were classified into three general categories: (1) changes to land use and the built environment, (2) increases to the cost of driving individual vehicles, and (3) investments in public transit. The report focused on the impact of each policy on three areas of health: physical activity, air pollution, and car collisions.

Recommended Policies for Health

The study demonstrated that reducing VMT would have significant health benefits overall. The research examined 11 different policies that could reduce VMT and recommended the five that would be the most beneficial in terms of the public's well-being.

Recommended policies for the built environment include maximizing the density of neighborhoods already within the urban growth boundary, requiring new developments be mixed-use and high-density with good connectivity, and improving the pedestrian infrastructure of neighborhoods. These kinds of changes to the built environment will make the metro areas more conducive to forms of transportation other than individual vehicles, which will have positive benefits for health by increasing physical activity, decreasing air pollution, and reducing car collision fatalities for drivers, pedestrians, and bicyclists.

It was also recommended that the coverage area for public transportation be increased across all the metropolitan regions and the use of these systems should be promoted. Public transit users are likely to meet recommended levels of physical activity.

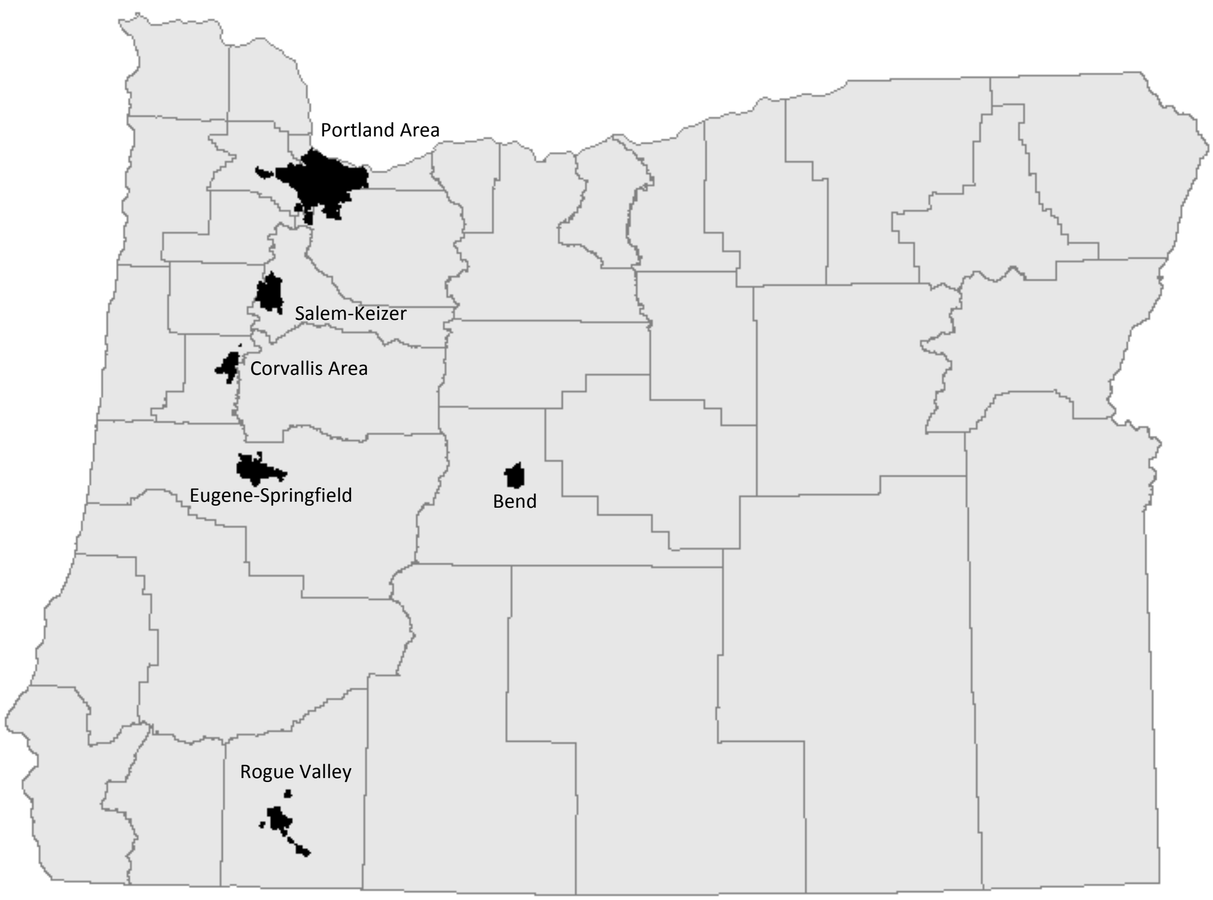
Requiring businesses in metropolitan areas to charge a fee for employee parking is the final recommended policy, since employees are less willing to pay for parking and will instead choose active forms of transportation, such as biking or public transit. Driving-related taxation systems were found to be less effective than parking fees at changing transportation patterns, and may adversely affect children and older adults, women, ethnic minorities, low-income and disabled people. If tax policies are implemented, it is recommended to enact strategies that can mitigate these negative consequences, such as making investments in access to public transit in low-income communities, developing affordable housing, and improving access to nutritious food in low-income neighborhoods.

The most effective way to decrease individual driving and lower VMT in Oregon is to employ a combination of these policies.

I. INTRODUCTION

Health impact assessments (HIAs) are utilized to inform policy decisions and promote decisions that are the most beneficial for health. The purpose of this health impact assessment (HIA) is to address the health impact of policies in the Jobs and Transportation Act (JTA) as it was introduced. The original JTA, among other objectives, aimed to lower vehicle miles traveled (VMT) in Oregon and consequently reduce greenhouse gas emissions from the transportation sector. VMT is the sum of distances traveled by all vehicles in certain areas for a specified period of time and is often presented as the vehicle miles traveled per person each day. These policies to reduce VMT would be most relevant for the six metropolitan planning districts in Oregon: Portland, Eugene-Springfield, Rogue Valley (Medford-Ashland area), Corvallis, Bend, and Salem-Keizer (Figure 1).

Figure 1. Urban growth boundaries of Oregon's metropolitan areas.



Seventy-eight percent of Oregon’s population resides in the ten counties containing the six metropolitan areas, and reducing their emissions from transportation choices will become increasingly important as the population increases in our urban areas. Policies to reduce the amount people drive can not only have positive benefits for our environment, but also for the health of Oregonians.

II. METHODS

A. Health Impact Assessments

Health impact assessments (HIAs) are used to evaluate the positive and negative impacts policies have on health (Centers for Disease Control and Prevention, 2004). HIAs typically include the following five steps:

1) *Screening* – Determining the need and value of a HIA.
2) *Scoping* – Determining which health impacts to evaluate, the methods for analysis, and the plan to complete the assessment.
3) *Assessment* – Using data, research, expertise, and experience to judge the magnitude and direction of potential health impacts.
4) *Reporting* – Communicating the results to stakeholders and decision-makers.
5) *Monitoring* – Tracking the effects of the HIA and the decision on health.

This report addresses the first four steps of the HIA (screening, scoping, assessment, and reporting). The final steps (the remainder of reporting and any monitoring) will occur after this report has been completed.

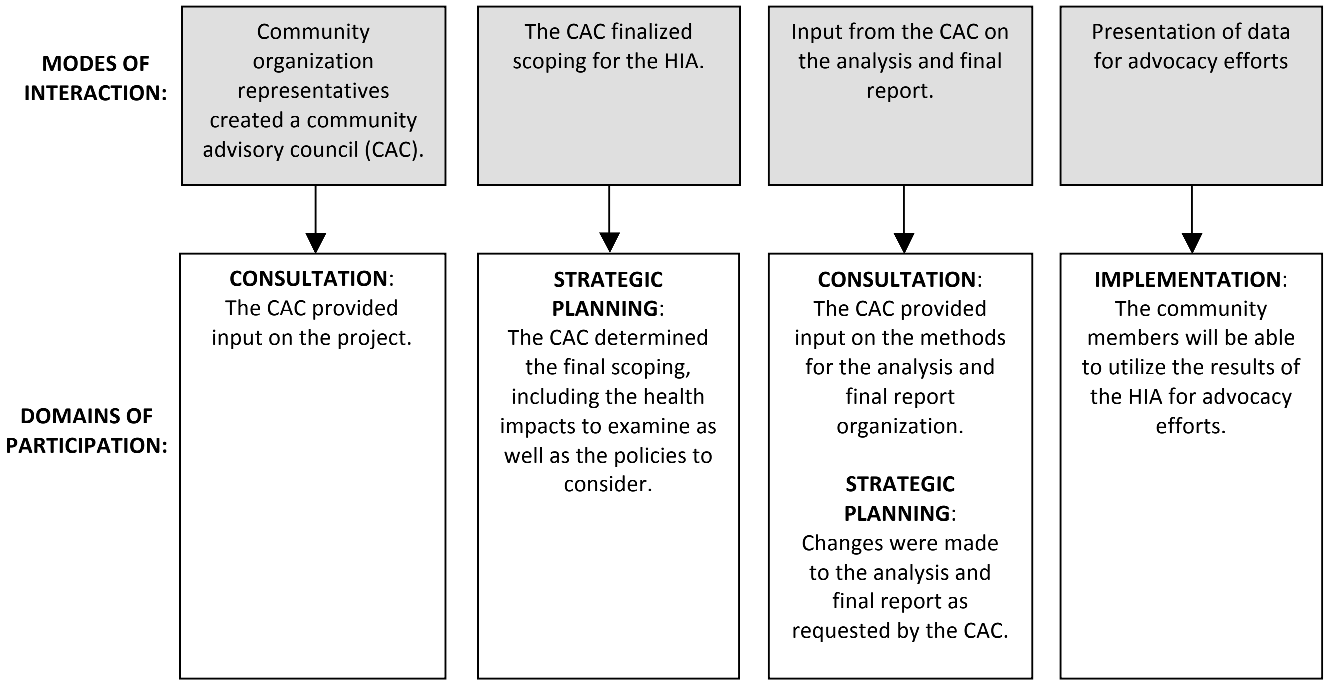
B. Community-Based Participatory Research

In order to utilize knowledge from a diverse group of experts as well as to incorporate the needs and views of community organizations that would be impacted by policies on reducing VMT, a community-based participatory research (CBPR) approach was utilized. CBPR is an orientation towards research that utilizes the unique strengths of the community and works with the community to conduct the research. CBPR also aims to move from research to action (Israel, Schulz, Parker, Becker, Allen, & Guzman, 2003), making it a valuable approach for this HIA that aims to ensure that the best policies for health are utilized.

There are 3 domains in which interaction can take place in a CBPR project: consultation, strategic planning, and implementation. Consultation involves engaging the community in discussions and questions about the project. Being involved in the strategic planning means that the community partakes in the creation of the project plan and makes changes along the way. Implementation includes involving community members as partners in conducting research (Arcury, Austin, Quandt, & Saavedra, 1999).

For this project, the community was represented by community organizations engaged and interested in land use and transportation policies and represent populations impacted by policies to reduce VMT. This CBPR project primarily involved community organizations in the consultation and strategic planning with minimal involvement in the implementation domain (Figure 2).

Figure 2. The modes of interaction and the domains of participation with the community organizations.



C. Screening

Since it was known that Oregon would be addressing climate change through policies to lower VMT in the 2009 legislative session, a crucial opportunity to address the health impacts of such policies was presented. A Health Impact Assessment Workgroup met for over a year to build skills in HIAs. The workgroup included Upstream Public Health, Community Health Partnership, Portland State University, the Oregon Public Health Division, Multnomah County Health Department, Clark County Health Department, Kaiser Permanente, Northwest Health Foundation, and The Coalition for a Livable Future. The Workgroup consulted with Brian Cole and Rajiv Bhatia, two national experts on HIAs. The screening of the project was carried out through discussions within the HIA Workgroup, and between Upstream Public Health and environmental organization partners. Preliminary scoping was also completed, but with the qualification that the community group would make the final scoping decision. The decision to conduct this HIA was based on: 1) the magnitude of the potential impact VMT related policies would have on health; 2) the interest of stakeholders in conducting the HIA; and 3) the availability of resources and data.

D. The Community Advisory Committee

In order to incorporate a CBPR approach, a community group was formed to direct the research and finalize decisions regarding the scope of the project. Community stakeholders were identified and contacted to ascertain their interest in forming a Community Advisory Committee (CAC) for this HIA. Community members were contacted at the state public health division, the metropolitan planning organizations, land use and planning community organizations, public health non-profits, and bicycle coalitions. An attempt was made to include representatives from minority community groups, but due to lack of time and resources the representatives could not participate in the process. The final CAC included 12 people. The CAC participated in 4 meetings: 1) a discussion of various policies to lower VMT; 2) finalizing the scope; 3) presentation of literature findings and discussion; and 4) discussing the final results of the HIA and this report. Feedback was also gathered from the CAC via email over the course of the assessment.

E. Scoping

The area of interest for this HIA included the six metropolitan areas of Oregon: Portland, Eugene-Springfield, Rogue Valley (Medford-Ashland area), Corvallis, Bend, and Salem-Keizer. Since the data used for this report was available primarily at the county level instead of by metropolitan area, the counties containing the aforementioned metropolitan areas were utilized: Multnomah, Washington, and Clackamas counties for Portland metropolitan; Lane County for Eugene-Springfield; Jackson County for Rogue Valley; Benton and Linn counties for Corvallis (although the city of Corvallis does not extend into Linn County, it lies close to the border and Linn County residents are likely affected by changes made to the Corvallis metropolitan area); Marion and Polk counties for Salem-Keizer; and Deschutes County for Bend. At the time of the 2000 Census, 86% of the population within those 10 counties was considered urban.

The CAC decided in the scoping meeting that the following general policies to lower VMT would be considered for this HIA:

1) Positive Changes to the Built Environment
2) Strengthening Public Transit
3) Increasing Costs for Driving Individual Vehicles

After the policies were selected, the proximal impacts were finalized by the CAC. Proximal impacts are those impacts that would be directly impacted in Oregon's population by the VMT-lowering policies (above). They include:

1) Physical Activity
2) Air Pollution
3) Car Collisions (with other cars, pedestrians, or bicyclists)

Proximal impacts that were not selected for this analysis due to time constraints or data uncertainty included the following:

1) Stress
2) Household Expenses
3) Access to Goods and Services
4) Water Pollution
5) Noise Pollution
6) Climate Change

Vulnerable populations were identified that could be affected by the policies. Characteristics identifying these populations include:

1) Age (children and older adults)
2) Gender (women)
3) Race/Ethnicity (racial/ethnic minorities)
4) Socioeconomic Status (low income persons)
5) Disability Status (disabled persons)

The CAC determined that any impact on vulnerable populations would be identified through the literature review described below.

F. Existing Conditions Data

To determine the state of health in Oregon with respect to potential VMT-lowering policies, data related to physical activity, collisions, and air pollution were identified and obtained from existing sources for the metropolitan counties. Existing conditions data are presented primarily in the appendix of this report.

Existing condition data for physical activity include the percentage of Oregonians meeting physical activity recommendations for 30 minutes or more of moderate physical activity five days per week or 20 minutes or more of vigorous activity three days per week and the percentage of adults overweight or obese. The aforementioned data was obtained from the Behavioral Risk Factor Surveillance System (BRFSS) compiled by the Oregon Department of Human Services (2007).

Data related to air pollution include the transportation mode Oregonians use to get to work and the average commute time, both obtained from the 2000 US Census. In addition, the vehicle miles traveled on state highways from 2002-2007 was obtained from the Oregon Department of Transportation (ODOT). The percentage of adults with asthma was obtained from BRFSS (Oregon Department of Human Services, 2007).

Collision data from 2003-2007 were obtained from the ODOT and includes injuries and fatalities from collisions involving cars only, pedestrians and cars, and bicyclists and cars.

G. Literature Review

To ensure that the HIA was unbiased in its presentation of the literature, systematic searches were undertaken for each of the following combinations:

1) Built Environment and Physical Activity
2) Built Environment and Driving/Air Pollution
3) Built Environment and Car Collisions
4) Public Transit and Physical Activity
5) Increased Costs and Driving

The Built Environment and Physical Activity

Ovid Medline was searched with the following terms: “exercise (exploded)” or “bicycling (exploded)” or “walking (exploded)” and “social planning (exploded)” or “environment design (exploded)” or “built environment (keyword).”

The results were restricted to English language articles and reviews, which was limited by the following: Review Articles, Reviews (Sensitivity), Topic Reviews (Cochrane), or Systematic Reviews, yielding 139 articles. Four reviews were included after abstract and full article reviews. The reference lists of the included articles were examined to obtain any additional pertinent reviews. An additional four reviews were added from reference lists.

Eight review articles compiled the final literature base for the built environment and physical activity.

The Built Environment and Air Pollution

An Ovid Medline search for reviews using the terms “air pollution (exploded)” or “air pollutants (exploded)” or “vehicle emissions (exploded)” and “motor vehicles (exploded)” or “transportation (exploded).” The results were restricted to English language articles and reviews, which was limited by the following: Review Articles, Reviews (Sensitivity), Topic Reviews (Cochrane), or Systematic Reviews, yielding 277 articles. After abstract and full article reviews, none of the potential review articles were included.

Two searches were conducted in Pubmed Medline with the keywords "built environment air pollution" and "air pollution road proximity," yielding 80 articles total. After an abstract and full article review, one article remained. Five additional articles were included from the reference lists.

Two searches were also performed in Transportation Research Information Services (TRIS) with the following keywords: "air pollution road proximity" and "air pollution and built environment," yielding a total of 53 articles. Five articles were included after abstract review, although four were only included for the use of their reference lists. An additional two articles were included from the reference lists, yielding a total of three articles.

Eight articles compiled the final literature base for the built environment and air pollution.

The Built Environment and Car Collisions

The search for reviews discussing the built environment and car collisions yielded no useful articles in Ovid Medline with the following search terms: "accidents, traffic" and "social planning" or "environment design" (all exploded) or "built environment" (keyword). Therefore, the search began with the Human Impact Partners (HIP) evidence base (http://www.humanimpact.org/EvidenceBase), which highlighted one report discussing the built environment and car collisions (Ewing & Kreutzer, 2006); this article was also only used for its reference list. This reference list was reviewed and an additional five articles were added, one of which was only used for the reference list. The reference lists of these articles were also reviewed and an additional four articles were added.

An additional Ovid Medline search with "accidents, traffic" (exploded) and "sprawl" (keyword) yielded two articles.

Ten articles compiled the final literature base for the built environment and car collisions.

Public Transit and Physical Activity

The reviews from the "Built Environment and Physical Activity" search were reviewed and any articles where public transportation was investigated were noted. Four articles were included from the reference lists of the reviews on the built environment and physical activity.

A search using Google was completed with search terms "public transit physical activity." The first 100 results were reviewed and two final articles were included.

One article from the Google Scholar search was particularly relevant (Besser & Dannenberg 2005), and this article was used in PubMed Medline to extract other articles that were related.

159 articles were related to the Besser article, and after abstract and full article review, six additional articles were included. The reference lists from the Pubmed search were reviewed and one additional article was included.

Thirteen articles compiled the final literature base for public transit and physical activity.

Increasing Costs and Driving Patterns

A search of Ovid Medline using the terms “Taxes (exploded)” and “Transportation (exploded)” yielded 17 articles. After excluding those that were not in English and completing abstract and full article reviews, only one article remained.

A search of TRIS using the keywords “vehicle and congestion and tax” resulted in 79 articles. After excluding those older than 1995 and reviewing abstracts and full articles, one article remained.

The first 100 results were reviewed from a Google Scholar search with the keywords “congestion pricing” and three were included. The first 100 articles were reviewed from an additional Google Scholar search with the keywords “fuel tax driving” and one article was included. No additional articles were included from the reference lists of the Google Scholar articles. One article in particular referred to fuel prices (Sipes & Mendelsohn, 2001) and it was used in Scopus to retrieve articles that cited it. One additional article was found and two references were pulled from that reference list.

Two additional articles were provided by Human Impact Partners. The reference lists were examined and one additional article was included.

One additional article known to the author on parking charges was added to the literature base (Hess, 2001) and it was used in Scopus to find other articles that cited it. Two additional articles were added from Scopus.

Eighteen articles compiled the final literature base for increasing costs and driving patterns.

III. RESULTS

A. The Built Environment

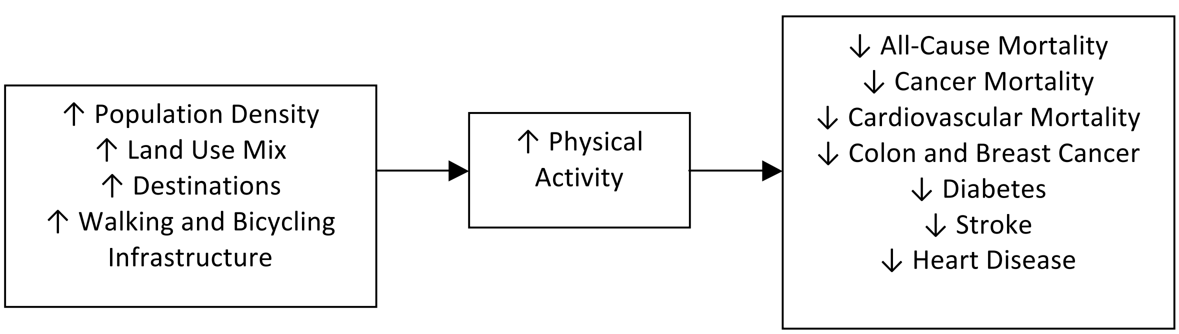
The built environment is defined as the part of our physical environment that is created through human activity. This includes such things as land use patterns, the transportation system, and urban design (Saelens & Handy, 2008). The built environment has the potential to positively influence transportation options, such as active transportation. In a series of focus groups conducted statewide, Oregonians consistently described a strong desire for communities where people of all ages can walk, bike, or use public transit to get where they need to go—as opposed to driving individual vehicles or being confined to their homes (1000 Friends of Oregon, 2008).

Physical Activity

The literature provides sufficient evidence that community-scale urban design and land use regulation is associated with higher levels of physical activity, although measures of the association are too heterogeneous to provide an estimate of the amount of change in physical activity (Heath, Brownson, Kruger et al., 2006; Humpel, Owen, & Leslie, 2002; Owen, Humpel, Leslie, Bauman, & Sallis, 2004; McCormack, Giles-Corti, Lange, Smith, Martin, & Pikora, 2004; Cunningham & Michael, 2004; Saelens, Sallis, & Frank, 2003; Lee & Vernez Moudon, 2004; Saelens & Handy, 2008). The most consistent characteristics positively associated with physical activity were population density, land use mix, and distance to nonresidential destinations.

Sufficient evidence was found in the literature that street-scale design and land use policies to support physical activity in small-scale geographic areas is effective in increasing physical activity, such as bicycle and pedestrian infrastructures (Heath, Brownson, Kruger et al., 2006; Saelens, Sallis, & Frank, 2003; Humpel, Owen, & Leslie, 2002; Davison & Lawson, 2006; Owen, Humpel, Leslie, Bauman, & Sallis, 2004; Cunningham & Michael, 2004).

Figure 4. Pathway between the built environment and increased physical activity and health.



Physical activity is associated with reduced all-cause mortality (Blair, Kohl, Paffenbarger, Clark, Cooper, & Gibbons, 1989; Gregg, Gerzoff, Caspersen, Williamson, & Narayan, 2003; Hu, Willett, Li, Stampfer, Colditz, & Manson, 2004) in an inverse dose-response fashion—increasing levels of physical activity being associated with decreasing levels of mortality (Myers, Kaykha, George et al., 2004). In addition, studies have found that physical activity is associated with reduced cause-specific mortality, including deaths from cardiovascular disease (Gregg, Gerzoff, Caspersen, Williamson, & Narayan, 2003) and cancer (Hu, Willett, Li, Stampfer, Colditz, & Manson, 2004). In addition, physical activity is associated with lowered risk of colon cancer and breast cancer in women (Lee, 2003), diabetes (Manson, Nathan, Krolewski, Stampfer, Willett, & Hennekens, 1992), heart disease, and stroke (Oguma & Shinoda-Tagawa, 2004).

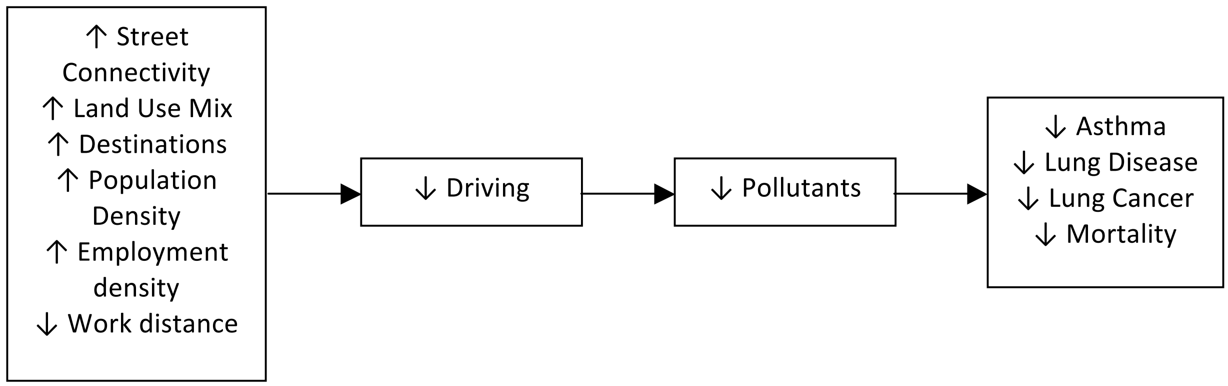
One major limitation of the built environment and physical activity literature is that the studies primarily report findings for one point in time; therefore, little can be said about whether the built environment actually encourages physical activity or whether people who want to be active choose to live in certain types of neighborhoods. Measurements of physical activity also vary widely between studies and it is difficult to determine which characteristic of the built environment is the most influential for physical activity.

Air Pollution

In neighborhoods with pedestrian-friendly built environment attributes, people are more likely to use active transportation to reach the services they need instead of driving. Spreading houses, jobs, and shops farther apart and limiting alternative modes of travel ultimately increases the need for cars to get to all of these locations, which in turn increases air pollution (Ewing & Kreutzer, 2006). Less driving means lower levels of pollution, especially because even short trips can pollute nearly as much as long trips when they involve cold starts (starting the engine after a cooling period of an hour or longer) (Frank, Stone, & Bachman, 2000).

Built environment characteristics, including street connectivity, land use mix, retail floor area, household density, employment density, census block density, and distance to work, have been found to be associated with fewer vehicle-related emissions (Frank, Sallis, Conway, Chapman, Saelens, & Bachman, 2006; Frank, Stone, & Bachman, 2000). The locations where we live, work, and play are also important since the proximity of these places to busy roads or roads with a high frequency of large truck traffic leads to higher exposure to pollutants (Kinney, Aggarwal, Northridge, Janssen, & Shepard, 2000; Lena, Ochieng, Carter, Holguin-Veras, & Kinney, 2002; Wu & Batterman, 2006; Zhu, Hinds, Kim, Shen, & Sioutas, 2002; Morawska, Thomas, Gilbert, Greenaway, Rijnders, 1999; Ilgen, Karfich, Levsen et al., 2001; Skov, Hansen, Lorenzen, Andersen, Lofstrom, & Christensen, 2001). Higher traffic density can lead to increased pollutant concentrations in both outdoor and indoor air (Ilgen, Karfich, Levsen et al., 2001; Skov, Hansen, Lorenzen, Andersen, Lofstrom, & Christensen, 2001).

Figure 5. Pathway between the built environment and air pollution and health.



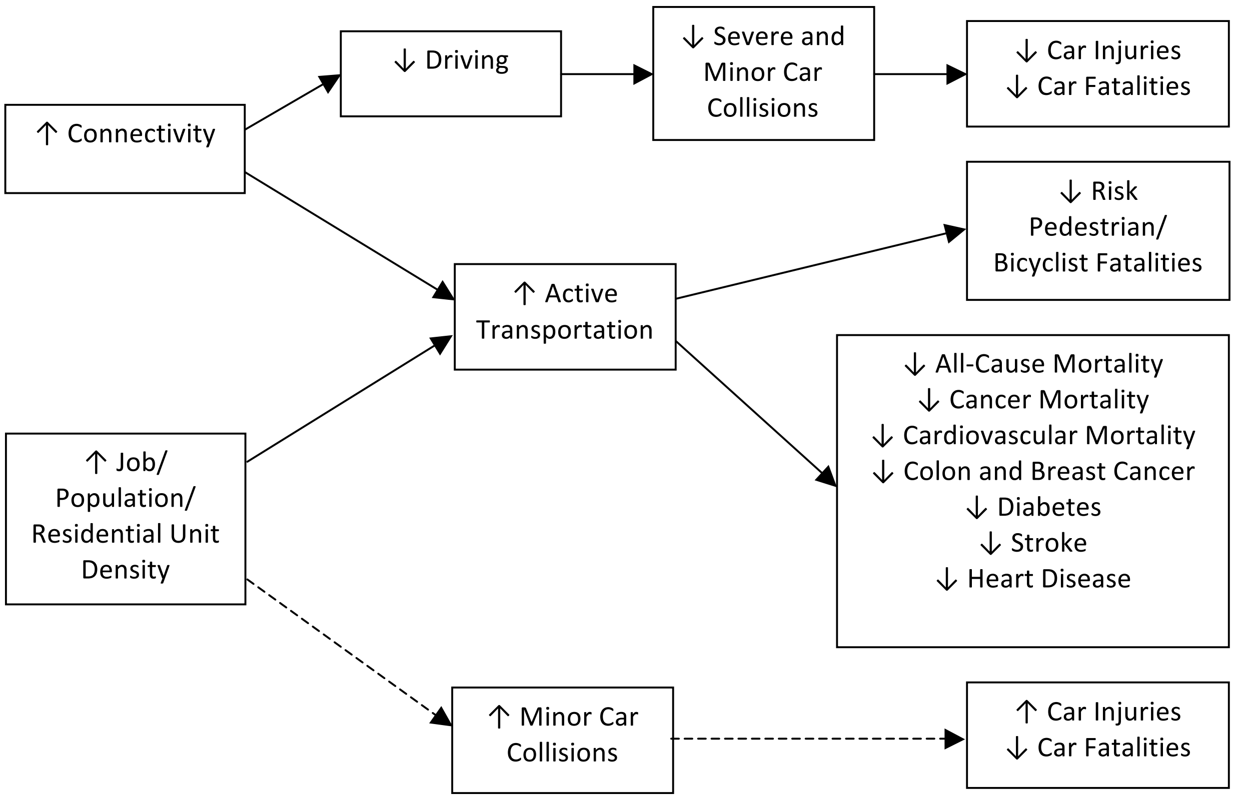
Any decrease in air pollution resulting from retrofitting neighborhoods or new construction that emphasizes positive built environments, such a high street connectivity and land use mix, will ultimately have positive effects on the health of Oregonians. Increases in pollutants such as nitrogen dioxide (NO_2) and fine particulate matter (PM) have been associated with cardiopulmonary mortality (Pope, Burnett, Thun et al., 2002; Filleul, Rondeau, Vandentorren et al., 2005). NO_2 has been linked to increased risk of lung cancer, and non-accidental mortality (Filleul et al., 2005) and fine PM has been linked to all-cause and lung cancer mortality (Pope, Burnett, Thun et al., 2002). Decreases in fine PM are associated with increased life expectancy (Pope, Ezzati, & Dockery, 2009) and decreases in chronic coughing and phlegm, wheezing, and dyspnea (Schindler, Keidel, Gerbase et al., 2009).

The primary limitation for this body of research includes varying measures of the built environment, which make it difficult to ascertain the specific component that is most influential for health.

Collisions

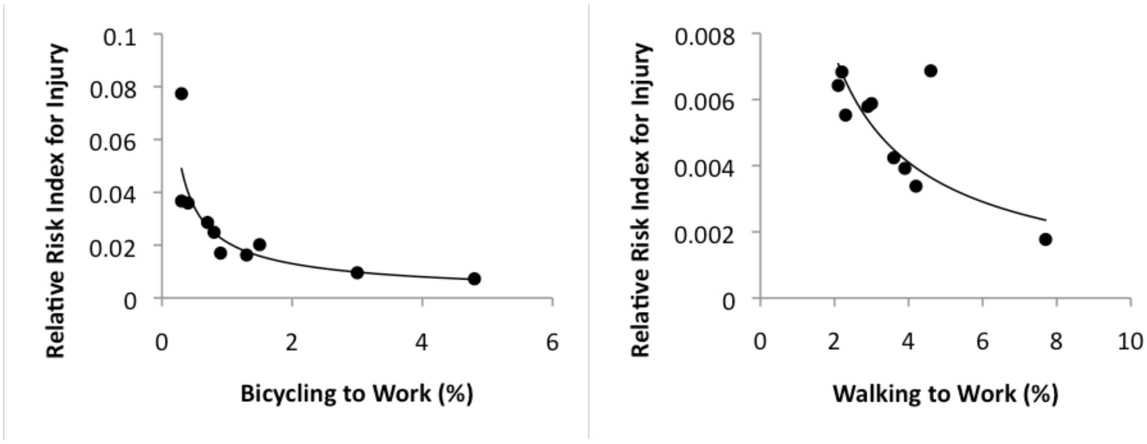
Typical suburban areas with low street connectivity, typified by cul-de-sac development and large roads that serve as primary access routes to many neighborhoods, have been found to have higher car collision fatality rates (Lucy, 2003; Ewing, Schieber, & Zegeer, 2003). Studies conducted in Atlanta and the Sunbelt states—areas with high growth after WWII, which typically indicates more sprawling, suburban development—found that pedestrian fatality rates were higher than other areas of the United States (Beck, Paulozzi, & Davidson, 2007; Paulozzi, 2006). However, one study did find that the number of collisions increased with higher population, job, and residential unit density (Lovegrove & Sayed, 2006). This may suggest that while collision related fatalities may decrease with positive built environment changes, the frequency of collisions may actually increase.

Figure 6. Pathway between the built environment and less driving and collisions.



Built environments that encourage alternate forms of transportation can lead to lower vehicle volume on roadways. Higher traffic volume has been found to be associated with higher risk of injury for pedestrians (Leden, 2002; Roberts, Norton, Jackson, Dunn, & Hassall, 1995; Lovegrove & Sayed, 2006). It has also been found that when alternate modes of transportation increase, such as walking and bicycling, the risks of accidents, injuries, and fatalities to pedestrians and bicyclists decrease (Jacobsen, 2003; Robinson, 2005; Leden, 2002). This has also been found for Oregon's metropolitan counties (see Figure 7 of Jacobsen's analysis repeated for Oregon's metropolitan counties; data used for this analysis can be found in the appendix). Conversely, an increase in the number of drivers has been found to increase the number of collisions (Shefer & Rietveld, 1997; Lovegrove & Sayed, 2006).

Figure 7. Risk of injury for walkers and bikers in Oregon's metropolitan counties.



A limitation is that only one study found an association between higher density and non-fatal collision frequency. Additional research is needed to more fully understand the complex relationship between built environments and collisions.

Overall Impact

Built environment changes, such as the creation of higher density, mixed-use, highly connected, and bicycle/pedestrian-friendly neighborhoods, can impact VMT by providing alternate choices of travel and shorter trips for Oregonians. Changes to the built environment that make it more conducive to forms of transportation other than individual vehicles will have positive benefits for health through increased physical activity, decreased air pollution, decreased car collision fatalities for car drivers, and decreased risk of fatalities for pedestrians and bicyclists.

Locating the places where Oregonians live, work, and play away from major roads will also have positive impacts on health through decreased pollution levels. If these places cannot be located away from major roads, buildings should compensate for any higher pollution levels with better air filtering systems to prevent exposure inside the building. This could be especially important for low-income populations, which generally live near areas with higher levels of pollution (Oregon DEQ, 2006). However, if Oregonians reduce the use of individual vehicles, it is possible that air pollution would become less problematic in busy areas.

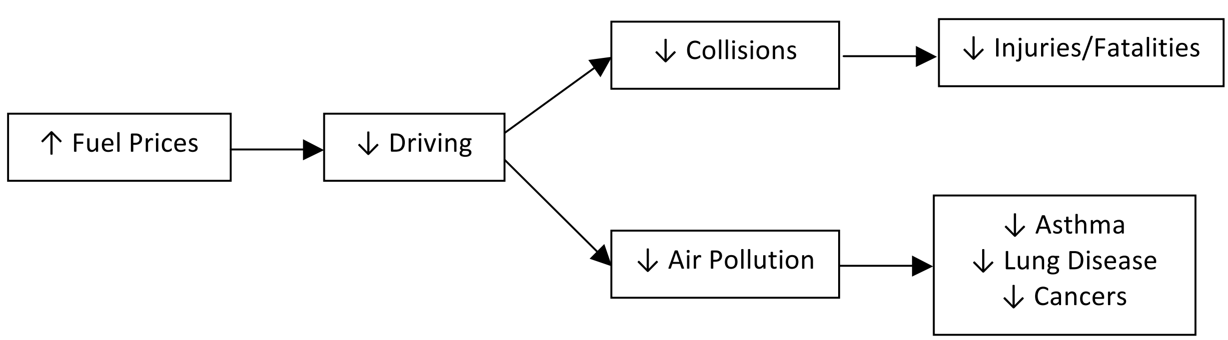
Additionally, while a higher density of pedestrians and bicyclists has been associated with lower fatality rates, safety measures should also be utilized in order to minimize any collisions between drivers and pedestrians or bicyclists; one meta-analysis found that traffic calming schemes can reduce the number of injury accidents by 15% (Elvik, 2001). Effective measures for pedestrian safety include roundabouts (single-lane), sidewalks, refuge islands in large intersections, exclusive pedestrian signal phasing, and good roadway lighting (Retting, Ferguson, & McCartt, 2003). However, changes to affect the safety of the built environment may have different effects on vulnerable populations and these vulnerable groups should be taken into account. For example, marked crosswalks without signals have been found to be associated with increased pedestrian-car collision risk for older pedestrians (Koepsell, McCloskey, Wolf et al., 2002). Altering the built environment to be more pedestrian- and bicyclist-friendly is a valuable strategy to reduce VMT, although making these changes to the existing built environment could be a lengthy process and the health benefits would not be realized immediately.

B. INCREASING COSTS

Fuel Tax

Increasing fuel prices have been found to be associated with decreases in fuel consumption and traffic volume. Elasticities from various studies show that a 10% increase in fuel price will decrease fuel use by 2-4% in the short run (about one year) and by 5-8% in the long run (about five years) (Sipes & Mendelsohn, 2001; Graham & Glaister, 2002; Goodwin, Dargay, & Hanly, 2004). Travel volume will decrease by 1-2% in the short run and 3% in the long run (Graham & Glaister, 2002; Goodwin, Dargay, & Hanly, 2004). The 2-cent increase in the fuel tax proposed in the JTA is less than a 1% increase and not sufficient to induce a shift in behavior. Thus, the proposed increase in price will have little effect on driving habits and health. An increase of at least 20% in price (about 45 cents based on April 2009 gas prices) would be needed to decrease traffic volume in Oregon by 6% in approximately five years (based on Graham & Glaister, 2002; Goodwin, Dargay, & Hanly, 2004).

Figure 8. Pathway between increasing fuel prices and health.



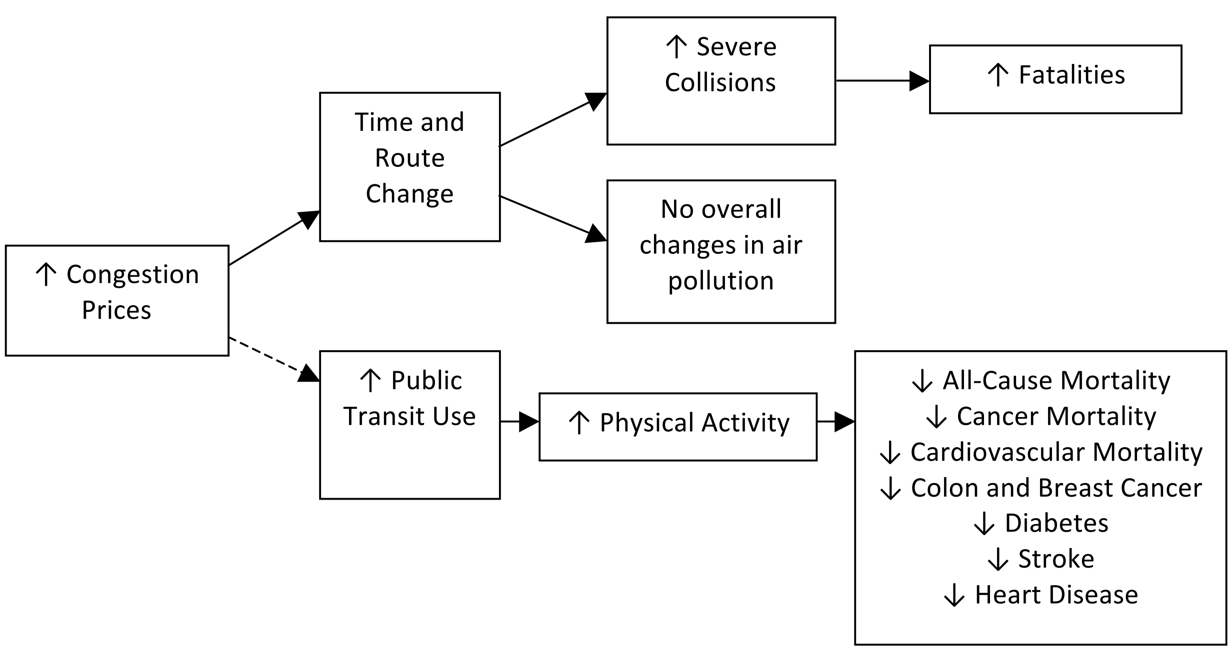
Research has found that increasing gas prices were associated with fewer accidents and deaths (Grabowski & Morrisey, 2006; Grabowski & Morrisey, 2004; Leigh & Geraghty, 2008). Also, air pollution will decrease by a small amount and have small positive changes with regard to diseases related to air pollution. Air pollution has been found to negatively affect health, as described previously. It was also found that a 20% fuel price increase sustained over one year would lead to a 2.5% decrease in deaths attributable to particulate matter (Leigh & Geraghty, 2008).

Congestion Pricing

Research has shown that congestion pricing leads to little change in individual driving frequency, but rather results in change in departure times or routes (Yamamoto, Fujii, Kitamura, & Yoshida, 2000; Chin, 1996; Arentze, Hofman, & Timmermans, 2004). Another study, in which variable higher tolls indicated more congestion, showed that drivers are willing to pay high tolls to continue to drive (Brownstone, Ghosh, Golob, Kazimi, & Van Amelsfort, 2003). In another area with congestion charges, morning traffic congestion was reduced but evening traffic remained congested (Chin, 1996). Only one study showed that when London implemented congestion pricing, there was a mode shift to public transit (Litman, 2004).

With respect to air pollution levels, prior research found no evidence that congestion pricing resulted in decreased overall air pollution (Beevers & Carslaw, 2005; Tonne, Beevers, Armstrong, Kelly, & Wilkinson, 2008; Namdeo & Mitchell, 2008). Therefore, there is no existing evidence in support of health benefits with regard to reductions in air pollution due to congestion pricing.

Figure 9. Pathway between congestion pricing and health.



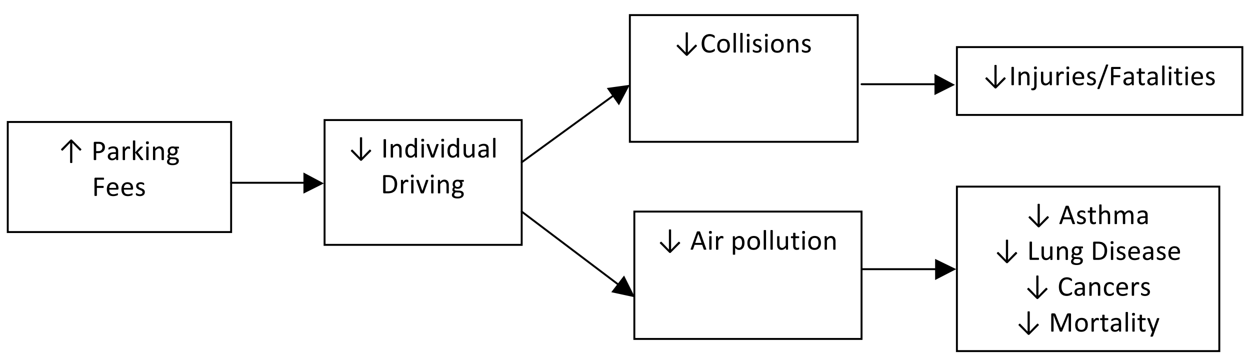
Overall, congestion pricing reduced congestion. However, congestion charges did not consistently result in change in mode of travel. The primary influence on congestion is mediated through changes in travel times and routes. As a result of these changes, prior research found that travel time is likely to increase and the addition of alternative routes on minor roads will likely not lead to any environmental benefits (May & Milne, 2000). Further, although congestion will likely decrease, traffic fatalities may increase with higher speed due to less congestion. Although the frequency of traffic collisions is related to the volume of cars on the road, fatalities tend to occur more commonly at higher speeds. Also, traffic congestion may push drivers to ride public transit instead of drive, meaning reducing congestion may cause individual driving to be more appealing and not reduce vehicle volume overall (Shefer & Rietvald, 1997).

One limitation from this body of literature is that a limited number of places have implemented a congestion charge, meaning the effects of congestion pricing in Oregon may be different from that in other areas.

Parking Fees

Increasing parking fees at work can lead to less individual driving (Hess, 2001; Farrell, O'Mahoney, & Caulfield, 2005; Watters, O'Mahoney, & Caulfield, 2006). However, a moderate proportion of workers indicated they would still drive to work despite the implementation of a parking fee (Hess, 2001; Farrell, O'Mahoney, & Caulfield, 2005; Watters, O'Mahoney, & Caulfield, 2006). Overall, the literature shows consistent evidence that parking fees would result in some employees changing the mode of transportation they use to commute to work, away from individual vehicles and towards public transit.

Figure 10. Pathway between parking fees and health.



The major limitation from this body of literature was that the studies were assessing employee reaction to a potential parking fee, not actual fees and observed behavior changes.

Vehicle Miles Traveled Tax

The literature had little evidence focusing on a vehicle miles traveled (VMT) tax. Only one study was found which indicated that a VMT tax reduced drivers' total mileage relative to a control group (Rufolo & Kimpel, 2008). However, there is not enough evidence to draw definitive conclusions on the impact of a VMT tax on driving and health.

The major limitation from this body of literature is the lack of evidence regarding the efficacy of a VMT tax with regards to transportation choices and ultimately health.

Overall Impact

Increasing the costs of individual driving is one proposed method of reducing VMT in Oregon. While increasing the costs of driving may be necessary to finance the existing transportation structures, the literature is not supportive of such charges doing much to change mode of transportation from individual driving.

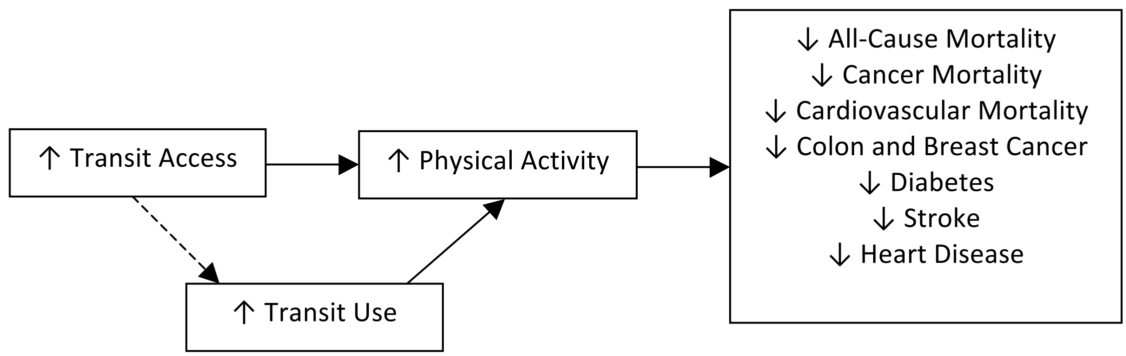
With respect to health, increasing the costs of driving will have only marginal benefits for health, with little evidence supporting transportation mode shifts away from individual vehicles. Only parking fees were consistently found to induce a potential mode shift from individual driving to public transit. However, increasing the cost of driving has the potential to increase the financial burden for low income populations.

Some literature has shown that a fuel tax is the least effective policy to produce welfare benefits (the effect of behavior changes from the proposed tax on total tax revenue less total externality cost) and a VMT tax achieves three to four times more welfare benefits of a gas tax (Parry, 2004; Parry & Small, 2005). Also, economic theory would hypothesize that a VMT tax would be more effective at reducing overall car trips rather than a fuel tax which might be more effective at reducing total vehicle emissions. Therefore a VMT tax may be more beneficial toward reducing obesity by encouraging people to get out of their cars and a fuel tax may be more effective at reducing the health impacts of air pollution by encouraging fuel-efficient cars (Bento, Goulder, Henry, Jacobsen, & von Haefen, 2005).

C. STRENGTHENING TRANSIT

Increased objective access to public transit is associated with more walking for transportation, meeting physical activity recommendations, and less motorized trips (Li, Peter, Harmer et al., 2008; Kitamura, Mokhtarian, & Laidet, 1997; Hoehner, Ramirez, Elliot, Handy, & Brownson, 2005; McCormack, Giles-Corti, & Bulsara, 2008). Additionally, transit use is associated with walking, often enough to meet public health recommendations for physical activity of 30 minutes or more of moderate activity 5 days per week (Edwards, 2008; Besser & Dannenberg, 2005; Villanueva, Giles-Corti, & McCormack, 2008; Wener & Evans, 2007; Vernez Moudon, Lee, Cheadle et al., 2007).

Figure 11. Pathway between transit access and health.



Increasing access to transit will increase physical activity in Oregon's population, although it is likely that the effect will be relatively small. It is strongly supported that transit users are more likely to meet physical activity recommendations compared to those that do not use transit.

Perception of transit access often does not correspond with objective access; simply increasing public transit access to Oregon communities will not increase physical activity if the perception of low access remains. If Oregonians believe that public transit is not an option because it is not "accessible," they will not utilize services that they actually have. It may be necessary to increase the perception of transit access since it has also been found to be directly associated with physical activity (Timperio, Crawford, Telford, & Salmon, 2004; De Bourdeaudhuij, Sallis, & Saelens, 2003; Evenson, Birnbaum, Bedimo-Rung, Sallis, Voorhees, Ring, & Elder, 2006; Hoehner, Ramirez, Elliot, Handy, & Brownson, 2005; Taylor, Leslie, Plotnikoff, Owen, & Spence, 2008).

Limitations of this literature include the low number of articles showing associations between physical activity and transportation access. However, research in this area has increased since a recent review that found little evidence to assess the association (Heath, Brownson, Kruger et al., 2006).

Overall Impact

Enhancing public transportation across Oregon's metropolitan counties is a viable option for reducing VMT. Overall, expectations are that increased transit access throughout Oregon's metropolitan areas will increase physical activity in a small portion of the population and will have a positive impact on health through reduced chronic diseases and mortality. However, only a small proportion of Oregon’s metropolitan counties have the population density that is required to support mass transit (12,500 people per square mile). Encouraging infill development along with public transit will increase the density and transit access for metropolitan dwellers.

While the impact of public transit on health is not large, creating alternative options for transit will be necessary in order to decrease individual driving in Oregon. This is especially important for low income populations that may currently have poor access to public transit and will feel the effects of increasing driving costs more acutely than middle and high income groups. Additionally, as a mode shift occurs from individual driving to increased transit use, it will also decrease the number of collisions and lower air pollution, as discussed earlier.

IV. VULNERABLE POPULATIONS

A. The Built Environment

Although some neighborhoods may have a positive built environment by conventional measures (e.g., land use mix and population density), residents of low income areas might still consider their neighborhoods unfavorable for walking. Safety and aesthetics are also important; low income neighborhoods have been found to have fewer street trees, landmarked buildings, clean streets, sidewalk cafes, and higher rates of felony complaints, narcotics arrests, and vehicular crashes compared to high income neighborhoods (Neckerman, Lovasi, Davies et al., 2009). Similar results have been found for schools with higher poverty or Hispanic student percentages. While the surroundings showed higher neighborhood-level walkability, shorter distances to school, and more sidewalks compared to the schools with the lowest poverty or Hispanic student percentages, these areas also had higher crash and crime rates and lower street-level walkability as captured by visual quality, physical amenities, maintenance, and perceived safety (Zhu, BArch, & Lee, 2008).

People with physical disabilities have been found to be more likely to participate in leisure time physical activity if they live in areas with active living buoys, including activity-friendliness (e.g., street connectivity, park benches, and walking paths), density of destinations, and safety (Spivock, Gauvin, Riva, & Brodeur, 2008). However, even when neighborhoods are accessible for the general population, there might still be barriers for people with visual or motor impairments. Problematic sidewalk pavement and puddles or poor drainage have been reported by disabled populations as barriers to physical activity in their otherwise accessible environment (Kirchner, Gerber, & Smith, 2008).

Creating positive built environments for vulnerable populations could require further changes than those necessary to have positive health impacts on the general population. However, it is possible that neighborhoods undergoing positive built environment changes could also result in changes in the neighborhood demographics. Improving the built environment may increase housing values and stimulate gentrification leading to displacement of low-income populations (The Coalition for a Livable Future and Portland State University, 2007).

Low income populations are also more likely to live and go to school in places with higher traffic exposure. Higher exposure to particulates has been found for lower-income neighborhoods compared to higher-income areas. Additionally, low income neighborhoods with high particulate exposure were associated with an increased risk of death from non-accidental causes compared to high income neighborhoods with low particulate exposure (Finkelstein, Jerrett, DeLuca, Finkelstein, Verma, Chapman, & Sears, 2003).

In California it was found that a substantial number of disadvantaged and nonwhite children attend schools near roads with heavy traffic (Green, Smorodinsky, Kim, McLaughlin, & Ostro, 2004). Low income as well as Black, Hispanic, and Asian children have been found to have higher exposure to vehicle emissions in their neighborhoods compared to high income and White children (Gunier, Hertz, Von Behren, & Reynolds, 2003). Those living in more deprived neighborhoods have also been found to have greater exposure to traffic and ambient particulate and gaseous pollutants (Finkelstein, Jerrett, & Sears, 2005).

Focus groups conducted in Portland, Oregon indicated that traffic and pedestrian infrastructure and neighborhood attractiveness influenced the physical activity of older adults (Michael, Green, & Farquhar, 2006). Slow traffic and good pedestrian infrastructure were important for older adults to feel walking was a safe activity in their neighborhoods. Participants also indicated they were more likely to walk in aesthetically pleasing neighborhoods, specifically neighborhoods with well-kept yards and gardens, interesting things to look at, and appealing designs of buildings and streets.

Changes to the built environment that lower collisions will have a positive impact on older adults since car collisions are more hazardous for older adults compared to other age groups. Drivers aged 70 years and older are more likely to die from car collision injuries than younger drivers due to increasing body fragility (Insurance Institute for Highway Safety, 2006). Additionally, older adults have a higher fatality rate for pedestrian-car collisions than all other age groups (National Highway Traffic Safety Administration, 2001).

B. Increasing Costs

The largest problem of increasing the costs of individual driving is that it will increase the burden on low income populations, who might not have access to alternate forms of transportation and will be forced to devote a higher percentage of their incomes to transportation. A disproportionate amount of people in racial and ethnic minority groups are low income; the 2000 Census reported that 24% of African Americans, 19% of American Indians or Alaska Natives, and 24% of Hispanics in Oregon's metropolitan counties had an income below the poverty level, compared with only 10% of Whites and 13% of Asian Americans.

Lower-income populations already have significantly worse health outcomes, and increasing transportation costs will further exacerbate the problems without any mitigation strategies. Even in developed counties, people who are low-income have increased risks for serious illness and shorter life expectancies. Increasing costs of transportation could increase the stress that these already burdened populations experience. Prolonged stressful circumstances are harmful for health and can lead to premature death (World Health Organization, 2003).

Negative effects could be mitigated by using tax revenues in ways that reduce health inequities. Investments in improved access to public transit, especially for low income neighborhoods could help reduce transportation inequalities. Another approach could be to reduce other taxes in exchange for an increasing transportation-related tax. It is recommended that higher energy costs should be offset for people in the bottom 40% of the income scale, since these people would be excessively burdened by increasing energy costs (Greenstein, Parrott, & Sherman, 2008).

C. Strengthening Transit

In a survey on neighborhood rebuilding preferences in New Orleans, it was found that low income populations rated affordable housing, a bus or streetcar line, and the presence of a corner store as being more important compared to the high income population (Hong & Farley, 2008). This indicates that low income populations prefer to live in areas where transit is available, likely due to their dependence on public transit to get around their community.

Without good public transit access, older adults and other people who cannot drive are isolated in their homes. Providing adequate transit access ensures that these populations will have the means to be active members of society. Public transit can also help older populations achieve the recommended levels of physical activity, which can help maintain the physical function and general health of older adults. Older adults have indicated that transit is essential to remain active and involved in their communities (Michael, Green, Farquhar, 2006). Beyond the physical benefits, active individuals have more social contact since they are less likely to withdraw from society (World Health Organization, 2002). Physical activity can also help reduce falls in older adults, a group that is particularly susceptible to fall-related injuries and mortalities (Oregon Department of Human Services & Oregon Health and Science University, 2009).

Increasing public transit will have a positive benefit for the vulnerable populations in Oregon, provided it becomes accessible for all Oregon residents, including low-income, minority, older, young, and disabled populations. Groups that cannot drive individual vehicles due to age, health, or financial concerns will find it easier to get around their community for necessary daily living tasks and social activities.

D. Other Impacts

While access to goods and services was not a proximal impact examined in this HIA, it was analyzed in limited depth because it is an area of particular relevance to vulnerable populations.

Access to goods and services in a neighborhood influences people's transportation decisions (Heath, Brownson, Kruger et al., 2006). Having retail outlets and public services in one's neighborhood provides convenient access to resources needed for daily life, such as full-service grocery stores, medical facilities, public transit stations, banks, senior centers, and childcare providers. Close proximity to these resources also increases physical activity (Ewing & Kreutzer, 2006; Handy, 1996) and is associated with a reduction in obesity (Frank, Andresen & Schmid, 2004). Increased physical activity is facilitated by the opportunity to walk, rather than drive, to nearby resources.

Low-income populations typically have less access to nutritious food compared to higher income populations. North and northeast neighborhoods in Portland, which are predominantly low-income, lack access to grocery stores. A study completed in 2003 found that nearly three in ten residents of these neighborhoods reported leaving their neighborhood often to shop in wholesale supermarkets in other areas of the city (The Coalition for a Livable Future & Portland State University, 2007).

In Portland, it has been found that older adults have less access to grocery stores. In one Portland neighborhood with a large population of adults 65 and older, not one resident lived within a half-mile of a full service grocery store or natural food store, and the average distance to the closest store was a mile and a half (The Coalition for a Livable Future & Portland State University, 2007).

Improving access to goods and services in Oregon neighborhoods that are currently underserved would reduce residents' need to drive far from home to shop for food. Improved public transit service in these areas would also help improve access to food and other essential resources for a healthy lifestyle.

V. CONCLUSION

The following tables summarize the strength of the evidence found from the literature reviews of the built environment (Table 10), increasing costs (Table 11), and transit (Table 12), based on professional judgment.

For the built environment, consistent evidence supports an association between density, destinations, and land use mix and walking for transportation. The evidence was also consistent in showing that areas with higher sprawl or suburban development had higher fatality rates from collisions. In addition, when pedestrian and bicyclist volume increases, the risk of injuries and fatalities for pedestrians and bicyclists decreases. Proximity to busy roads and heavy traffic was consistently associated with higher levels of air pollution nearby. Consistent associations were observed between population and workplace density, destinations, connectivity and decreased air pollution (Table 10).

Table 10. The quality of evidence on the built environment.

IMPACT	JUDGMENT OF MAGNITUDE OF IMPACT	QUALITY OF EVIDENCE
Active Transportation		
Destinations Population Density Land Use Mix	Moderate	Consistent positive relationships between walking for transportation and density, distance to nonresidential destinations, and land use mix.
Infrastructure for Pedestrians and Bicyclists	Moderate	Sufficient evidence that street-scale design and land use policies to support physical activity in small-scale geographic areas is effective in increasing physical activity.
Collisions		
Street Connectivity	Moderate	Consistent evidence that suburban areas or areas with higher "sprawl" have higher fatality rates (2 studies).
Population Density Employment Density Residential Unit Density	Insufficient	Increased collisions have been found to occur with higher population/job/residential unit density (1 study)
Pedestrian/Bicyclist Density	Moderate	Consistent evidence that when pedestrian and bicyclist flow increases, the risks of accidents/injuries/fatalities to pedestrians and bicyclists decrease (3 studies).
Air Pollution		
Busy Roads/Traffic	High	Consistent evidence that proximity to busy roads and higher traffic density is associated with higher levels of pollution outside and in nearby buildings (6 studies).
Street Connectivity Population Density Land Use Mix Destinations Employment Density Work Distance	Moderate	Consistent associations of population and workplace density, destinations, and connectivity with decreased air pollution (2 studies).

For increasing the costs of individual driving, consistent evidence was found that employer parking charges resulted in changing the mode of transportation employees used to get to work. The evidence for congestion pricing did not support an association with changes in transportation mode, but rather indicated that drivers changed routes and travel times to avoid charges. The literature did not indicate that congestion pricing would decrease air pollution. There was fair evidence that the gas tax would decrease fuel consumption, traffic volume, and the number of collision and deaths. There was insufficient evidence to examine the impact of a VMT tax (Table 11).

Table 11. The quality of evidence on increasing the costs of individual driving.

IMPACT	JUDGMENT OF MAGNITUDE OF IMPACT	QUALITY OF EVIDENCE
Driving Behavior/Mode		
VMT Taxes	Insufficient	Insufficient evidence to determine whether peak and flat rates resulted in less vehicle miles traveled (1 study).
Parking Fees	Moderate	Consistent evidence that employer parking charges would result in changes in modes of transport to work among employees (3 studies).
Gas Tax	Moderate	Consistent evidence that a gas tax was associated with reduced fuel consumption and traffic volume (3 studies).
Congestion Pricing	Low	Congestion pricing did not consistently result in change in mode of travel. The primary influence on congestion is mediated through changes in travel times and routes (5 studies).
Air Pollution		
Congestion Pricing	Negligible	There is no evidence that congestion pricing resulted in decreased overall air pollution (3 studies).
Car Collisions		
Gas Tax	Moderate	Fair evidence that increasing gas prices were associated with fewer accidents and deaths. Consistent results in the same direction (3 studies).

For public transit, the evidence consistently supported an association between access to transit and physical activity and that transit use contributes to users' meeting physical activity recommendations (Table 12).

Table 12. The strength of evidence on strengthening public transit.

IMPACT	JUDGMENT OF MAGNITUDE OF IMPACT	QUALITY OF EVIDENCE
Physical Activity		
Access to Transit	Moderate	The evidence was consistent in the direction of the association (4 studies), although the magnitude was relatively low and not all were significant (3/4 studies).
Transit Use	High	Consistent evidence that transit use is an active form of travel (5/5 studies) and that users tend to meet requirements for physical activity solely by transit use (4 studies).

Overall, the policies are compared in the summary table below (Table 13). Of the associations examined, the built environment has the most potential to benefit health through increased active transportation, reduced air pollution, and fewer fatalities from car collisions. Most of the policies to increase the costs of driving will not induce a mode shift away from individual vehicles and so will not increase active transportation or achieve a significant reduction in air pollution. However, increasing the costs of driving has been shown to decrease collisions and fatalities from collisions. Strengthening transit will lead to more active transportation and more Oregonians achieving recommended levels of physical activity. The relationship of public transit with air pollution and collisions was not examined and cannot be compared with the other policy types. However, ensuring access to transit other than individual vehicles is an important aspect of making a healthier built environment.

Table 13. Summary table.

	IMPROVED BUILT ENVIRONMENT	INCREASING COSTS	STRENGTHENING TRANSIT
Increased Active Transportation	+	–	+
Reduced Air Pollution	+	–	0
Collisions			
Fewer Collisions	~	+	0
Fewer Fatalities	+	+	0

Note: + = association, – = no association, ~ = equivocal, 0 = did not examine the association

VI. RECOMMENDED POLICIES TO BENEFIT HEALTH

All three policies to lower VMT work best together to reduce adverse health effects, although the built environment and strengthening public transit are more positive policies for vulnerable populations.

A. The Built Environment

Reducing or limiting "sprawl" in Oregon communities will have positive benefits for health through decreased obesity and chronic disease (McCann & Ewing, 2003). Built environment changes—such as creating neighborhoods with high population density, a mix of uses, and good street connectivity—can impact VMT by providing alternative choices of travel and shorter trips for Oregonians. Changes to the built environment that make it more conducive to forms of transportation other than individual vehicles will have positive benefits for health through increased physical activity, decreased air pollution, and decreased car collision fatalities for car drivers, pedestrians, and bicyclists. When increasing the population density of an area, safety measures should also be utilized in order to minimize all collisions between drivers and pedestrians or bicyclists. Safety modifications can separate pedestrians from vehicles by time or space, increase the visibility of pedestrians, or reduce vehicle speeds (Retting, Ferguson, & McCartt, 2003). A few example measures used by Germany and the Netherlands to improve the safety of bicycling include streets that give right-of-way priority to bicyclists, special traffic lights for bicyclists at intersections, and allowing bicyclists to turn on lights where cars are prohibited from turning (Pucher & Dijkstra, 2000). Depending on the area of interest, different approaches will be appropriate. For example, speeds cannot always be lowered on main roads, but pedestrian refuge islands would be appropriate.

Locating the places where Oregonians work, play, and live away from major roads when possible will also have positive impacts on health through decreased pollution exposure. If these places cannot be located away from major roads, buildings should compensate for the higher pollution levels with better air filtering systems to prevent exposure inside the building (Table 14).

Policies for the built environment that would have positive benefits for the health of Oregonians include requiring that new developments be mixed-use and high-density with good street connectivity, requiring infill development for the metropolitan areas instead of extending the urban growth boundaries, and creating bicycle- and pedestrian-friendly infrastructures (Table 14).

However, there are possible adverse effects from these policies as well (Table 14). Often new mixed-use and high-density neighborhoods may become too expensive for low income populations, therefore it is essential to require that developers include a mix of housing types for all income levels.

Table 14. Suggested policies for the built environment with associated health benefits, adverse effects, and possible mitigations.

Suggested Policies	Health Benefits	Adverse Effects	Mitigations
1. Require new developments be mixed-use and highly-dense with good connectivity. 2. Require infill development to maximize the density of neighborhoods already within the urban growth boundary. 3. Improve the existing pedestrian and bicycle infrastructure of neighborhoods	Increased physical activity, decreased air pollution, decreased car fatalities.	Neighborhoods might not be affordable for lower-income populations.	Include a mix of different housing types to ensure that all income levels can afford housing.
		Higher density neighborhoods could lead to an increase in the number of car collisions.	Implement traffic-calming measures and other pedestrian and vehicle safety measures.
		With increasing density, some people could be exposed to heavier traffic and pollution.	Install air filtration systems on buildings to prevent pollution exposure while indoors.

B. Increasing Costs

Increasing the costs of individual driving is one proposed method of reducing VMT in Oregon. While increasing the costs of driving may be necessary to maintain the existing transportation structures, the literature is not supportive that such changes reduce driving and benefit health. While congestion pricing has positive effects on traffic congestion, it has not been shown to alter the amount people drive, but rather encourages different departure times and routes. The gas tax has been shown to reduce deaths due to collisions and air pollution, although two studies have indicated a VMT tax has greater welfare benefits. The only policies that will be beneficial for health will be policies that induce mode shift away from individual vehicles. Studies examining the effect of employer parking fees indicated employees would shift from individual driving to public transit.

Thus, the policy that would have the most positive benefits for the health of Oregonians is having businesses in metropolitan areas charge a fee for employee parking (Table 15). However, if some businesses do not have good public transit service, it may be necessary to develop a plan for increasing transit service to that area or provide exceptions. If a tax is necessary, such as a gas or VMT tax, it is important to ensure that the portion of income that is spent by low income people in the state on transportation does not rise by providing tax refunds or different pricing schemes for different income levels. Since these populations already face health disparities, the added cost of such taxes would further decrease their health by making it harder for them to pay for healthy housing, food and for medical care.

Table 15. Suggested policies for increasing the costs of individual driving with associated health benefits, adverse effects, and possible mitigations.

<table>
<tr><th>Suggested Policies</th><th>Health Benefits</th><th>Adverse Effects</th><th>Mitigations</th></tr>
<tr><td rowspan="2">1. Require that businesses in metropolitan areas charge a fee for employee parking.

2. Utilize a VMT tax instead of a gas tax, if a tax is necessary.</td><td rowspan="2">Individual driving will decrease, leading to lower levels of pollution and car collisions.</td><td>If employees do not work in areas with good transit service, parking fees could be a burden.</td><td>Increase transit service or provide exceptions to businesses that do not have transit service in their area.</td></tr>
<tr><td>A parking fee or VMT tax could adversely affect low-income populations who do not live in areas with good transit service and will still need to use a vehicle to get to places they need to go.</td><td>Have varying fees and tax rates for different income brackets.</td></tr>
</table>

C. Strengthening Public Transit

Enhancing public transportation across Oregon's metropolitan counties is a viable option for reducing VMT. Overall expectations are that increased transit access throughout Oregon's metropolitan areas will increase physical activity in a small portion of the population and will have a positive impact on health through reduced chronic diseases and mortality. While the impact of public transit on health is not large, creating alternative options for transit will be necessary in order to decrease individual driving in Oregon and to increase the ability of vulnerable populations, such as older adults and low income populations without access to personal vehicles, to travel from place to place. In addition, in response to a VMT tax, people with nearby transit access reduce their miles driven more than those without close transit

(Rufolo & Kimpel, in press). Therefore, strengthening transit could help other policies be more effective.

A suggested policy that would positively benefit the health of Oregonians is to enhance transit access across metropolitan areas and promote this enhanced access through public health interventions (Table 16). However, some neighborhoods could be exposed to higher levels of pollution if they are located near a transit center due to the increased volume of buses. Therefore, it may be necessary to develop public transit that has lower levels of pollution for the immediate areas, such as light rail or better filtration of bus exhaust.

Table 16. Suggested policies for increasing transit access with associated health benefits, adverse effects, and possible mitigations.

Suggested Policy	Health Benefits	Adverse Effects	Mitigations
1. Increase transit coverage across metropolitan areas and promote the use of public transit.	Increased physical activity.	Some neighborhoods could be exposed to higher levels of pollution if located near transit centers.	Work to develop public transit that has lower levels of area-specific pollution (light rail, filter exhaust from buses).

D. Summary of Recommendations

While all these policies will affect health differently, together they can maximize the benefits to health, shift travel away from individual driving, and decrease VMT. Altering the built environment will encourage alternate forms of transportation and adding public transit access will further encourage different forms of travel. Increased costs will likely have little impact on driving behaviors, but it can provide an increased incentive for Oregonians to change their transportation mode, given they have access to public transit and a well-connected environment.

Future research should include longitudinal assessments of the built environment and physical activity; additional research on increasing costs and changes in driving behaviors; a focus on vulnerable populations, and statewide data to describe the built environment, transit access, driving behaviors and associated health conditions and behaviors.

VII. REFERENCES

1000 Friends of Oregon (2008). *Blueprint for Oregon's Future: Strategies and actions to help us meet Oregonians shared goals*. Retrieved April 15, 2009 from http://www.friends.org/sites/friends.org/files/Blueprint01.08_20web_version.pdf.

Arcury, T.A., Austin, C.K., Quandt, S.A., & Saavedra, R. (1999). Enhancing community participation in intervention research: Farmworkers and agricultural chemicals in North Carolina. *Health Education and Behavior*, 26(4), 563-578.

Arentze, T., Hofman, F., & Timmermans, H. (2004). Predicting multi-faceted activity-travel adjustment strategies in response to possible congestion pricing scenerios using an internet-based stated adaptation experiment. *Transport Policy*, 11(1), 31-41.

Beck, L.F., Paulozzi, L.J., & Davidson, S.C. (2007). Pedestrian fatalities, Atlanta metropolitan statistical area and United States, 2000-2004. *Journal of Safety Research*, 38, 613-616.

Beevers, S.D. & Carslaw, D.C. (2005). The impact of congestion charging on vehicle speed and its implications for assessing vehicle emissions. *Atmospheric Environment*, 39, 6875-6884.

Bento, A.M., Goulder, L.H., Henry, E., Jacobsen, M., & von Haefen, R. (2005). Distributional and efficiency impacts of gasoline taxes: An econometrically-based multi-market study. *American Economic Review*, 95(2), 282-287.

Besser, L.M. & Dannenberg, A.L. (2005). Walking to public transit: Steps to help meet physical activity recommendations. *American Journal of Preventive Medicine*, 29(4), 273-280.

Blair, S.N., Kohl, H.W., Paffenbarger, R.S., Clark, D.G., Cooper, K.H., & Gibbons, L.W. (1989). Physical fitness and all-cause mortality: A prospective study of healthy men and women. *Journal of the American Medical Association*, 262(17), 2395-2401.

Brownstone, D., Ghosh, A., Golob, T.F., Kazimi, C., & Van Amelsfort, D. (2003). Drivers' willingness-to-pay to reduce travel time: Evidence from the San Diego I-15 congestion pricing project. *Transportation Research Part A: Policy and Practice*, 37(4), 373-387.

Centers for Disease Control and Prevention (2004). *Health impact assessment*. Retrieved April 28, 2009 from http://www.cdc.gov/healthyplaces/publications/Health_Impact_Assessment2.pdf.

Chin, A.T.H. (1996). Containing air pollution and traffic congestion: Transport policy and the environment in Singapore. *Atmospheric Environment*, 30(5), 787-801.

Cunningham, G.O. & Michael, Y.M. (2004). Concepts guiding the study of the impact of the built environment on physical activity for older adults: A review of the literature. *American Journal of Public Health Promotion*, 18(6), 435-443.

De Bourdeaudhuij, I., Sallis, J.F., & Saelens, B.E. (2003). Environmental correlates of physical activity in a sample of Belgian adults. *American Journal of Health Promotion*, 18(1), 83-92.

Dill, J. (2004). Measuring network connectivity for bicycling and walking. *Transportation Research Board 2004 Annual Meeting*. Retrieved April 28 from http://www.enhancements.org/download/trb/trb2004/TRB2004-001550.pdf.

Edwards, R.D. (2008). Public transit, obesity, and medical costs: Assessing the magnitudes. *Preventive Medicine*, 46, 14-21.

Elvik, R. (2001). Area-wide urban traffic calming schemes: A meta-analysis of safety effects. *Accident Analysis and Prevention*, 33, 327-336.

Evenson, K.R., Birnbaum, A.S., Bedimo-Rung, A.L., Sallis, J.F., Voorhees, C.C., Ring, K., & Elder, J.P. (2006). Girls' perception of physical environmental factors and transportation: Reliability and association with physical activity and active transport to school. *International Journal of Behavioral Nutrition and Physical Activity*, 3(28).

Ewing, R. & Kreutzer, R. (2006). *Understanding the relationship between public health and the built environment: A report prepared for the LEED-ND Core Committee.* Retrieved April 15, 2009 from https://www.usgbc.org/ShowFile.aspx?DocumentID=1480.

Ewing, R., Schieber, R.A., & Zegeer, C.V. (2003). Urban sprawl as a risk factor in motor vehicle occupant and pedestrian fatalities. *American Journal of Public Health*, 93(9), 1541-1545.

Farrell, S., O'Mahony, M., & Caulfield, B. (2005). Attitudes and behavioral responses to measures to deal with workplace parking. *Transportation Research Record: Journal of the Transportation Research Board*, 1932, 178-187.

Filleul, L., Rondeau, V., Vandentorren, S., Le Moual, N., Cantagrel, A., Annesi-Mausano, I., Charpin, D., Declercq, C., Neukirch, F., Paris, C., Vervloet, D., Brochard, P., Tessier, J.F., Kauffmann, F., & Baldi, I. (2005). Twenty-five year mortality and air pollution: Results from the French PAARC survey. *Occupational and Environmental Medicine,* 62, 453-460.

Finkelstein, M.M., Jerrett, M., & Sears, M.R. (2005). Environmental inequality and circulatory disease mortality gradients. *Journal of Epidemiology and Community Health*, 59, 481-487.

Finkelstein, M.M., Jerrett, M., DeLuca, P., Finkelstein, N., Verma, D.K., Chapman, K., & Sears, M.R. (2003). Relation between income, air pollution and mortality: A cohort study. *Canadian Medical Association Journal*, 169(5), 397-402.

Frank, L., Andresen, M.A., & Schmid, T.L. (2004). Obesity relationships with community design, physical activity, and time spent in cars. *American Journal of Preventive Medicine*, 27(2), 87-96.

Frank, L.D. & Engelke, P.O. (2001). The built environment and human activity patterns: Exploring the impacts of urban form on public health. *Journal of Planning Literature*, 16(2), 202-218.

Frank, L.D., Sallis, J.F., Conway, T.L., Chapman, J.E., Saelens, B.E., & Bachman, W. (2006). Many pathways from land use to health: Associations between neighborhood walkability and active transportation, body mass index, and air quality. *Journal of the American Planning Association*, 72(1), 75-87.

Frank, L.D., Stone, B., & Bachman, W. (2000). Linking land use with household vehicle emissions in the central Puget Sound: Methodological framework and findings. *Transportation Research Part D*, 5, 173-196.

Grabowski, D.C. & Morrisey, M.A. (2006). Do higher gasoline taxes save lives? *Economics Letters*, 90, 51-55.

Grabowski, D.C. & Morrisey, M.A. (2004). Gasoline prices and motor vehicle fatalities. *Journal of Policy Analysis and Management*, 23(3), 575-593.

Graham, D.J. & Glaister, S. (2002). The demand for automobile fuel: A survey of elasticities. *Fuel Prices and Driving*, 36, 1-26.

Green, R.S., Smorodinsky, S., Kim, J.J., McLaughlin, R., & Ostro, B. (2004). Proximity of California public schools to busy roads. *Environmental Health Perspectives*, 112, 61-66.

Greenstein, R., Parrott, S., & Sherman, A. (2008). *Designing climate-change legislation that shields low-income households from increased poverty and hardship*. Washington, D.C.: Center on Budget and Policy Priorities. Retrieved May 4, 2009 from http://www.cbpp.org/files/10-25-07climate.pdf.

Gregg, E.W., Gerzoff, R.B., Caspersen, C.J., Williamson, D.F., & Narayan, K.M. (2003). Relationship of walking to mortality among US adults with diabetes. *Archives of Internal Medicine*, 163(12), 1440-1447.

Gunier, R.B., Hertz, A., Von Behren, J., & Reynolds, P. (2003). Traffic density in California: Socioeconomic and ethnic differences among potentially exposed children. *Journal of Exposure Analysis and Environmental Epidemiology*, 13(3), 240-246.

Handy, S. (1996). Understanding the link between urban form and non-working traveling behavior. *Journal of Planning Education and Research*, 15:183-198.
Hess, D.B. (2001). The effects of free parking on commuter mode choice: Evidence from travel diary data. *Transportation Research Record: Journal of the Transportation Research Board*, 1753, 35-42.

Heath, G.W., Brownson, R.C., Kruger, J., Miles, R., Powell, K.E., Ramset, L.T., & the Task Force on Community Preventive Services. (2006). The effectiveness of urban design and land use and transport policies and practices to increase physical activity: A systematic review. *Journal of Physical Activity and Health*, 3(S1), S55-S76.

Hoehner, C.M., Brennan Ramirez, L.K., Elliot, M.B., Handy, S.L., & Brownson, R.C. (2005). Perceived and objective environmental measures and physical activity among urban adults. *American Journal of Preventive Medicine*, 28(2S2), 105-116.

Hong, T. & Farley, T.A. (2008). Urban residents' priorities for neighborhood features: A survey of New Orleans residents after hurricane Katrina. *American Journal of Preventive Medicine*, 34(4), 353-356.

Hu, F.B., Willett, W.C., Li, T., Stampfer, M.J., Colditz, G.A., & Manson, J.E. (2004). Adiposity as compared with physical activity in predicting mortality among women. *New England Journal of Medicine*, 351(26), 2694-2703.

Humpel, N., Owen, N., & Leslie, E. (2002). Environmental factors associated with adults' participation in physical activity. *American Journal of Preventive Medicine*, 22(3), 188-199.

Ilgen, E., Karfich, N., Levsen, K., Angerer, J., Schneider, P., Heinrich, J., Wichmann, H.E., Dunemann, L., & Begerow, J. (2001). *Atmospheric Environment*, 35, 1235-1252.

Insurance Institute for Highway Safety (2006). *Fatality Facts 2006*. Retrieved on April 20 from http://www.iihs.org/research/fatality_facts_2006/olderpeople.html.

Israel, B.A., Schulz, A.J., Parker, E.A., Becker, A.B., Allen, A.J., & Guzman, J.R. (2003). Critical issues in developing and following community based participatory research principles. In M. Minkler & N. Wallerstein (Eds.). *Community-Based Participatory Research for Health* (p 53-76). San Francisco: Jossey-Bass.

Jacobsen, P.L. (2003). Safety in numbers: More walkers and bicyclists, safer walking and bicycling. *Injury Prevention*, 9, 205-209.

Kinney, P.L., Aggarwal, M., Northridge, M.E., Janssen, N.A.H., & Shepard, P. (2000). Airborne concentrations of $PM_{2.5}$ and diesel exhaust particles on Harlem sidewalks: A community-based pilot study. *Environmental Health Perspectives*, 108(3), 213-218.

Kirchner, C.E., Gerber, E.G., & Smith, B.C. (2008). Designed to deter: Community barriers to physical activity for people with visual or motor impairments. *American Journal of Preventive Medicine*, 34(4), 349-352.

Kitamura, R., Mokhtarian, P.L., & Laidet, L. (1997). A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area. *Transportation*, 24, 125-158.

Koepsell, T., McCloskey, L., Wolf, M., Vernez Moudon, A., Buchner, D., Kraus, J., & Patterson, M. (2002). Crosswalk markings and the risk of pedestrian-motor vehicle collisions in older pedestrians. *Journal of the American Medical Association*, 17(6), 2136-2143.

Leden, L. (2002). Pedestrian risk decrease with pedestrian flow. A case study based on data from signalized intersections in Hamilton, Ohio. *Accident Analysis and Prevention*, 34, 457-464.

Lee, C. & Vernez Moudon, A. (2004). Physical activity and environment research in the health field: Implications for urban and transportation planning practice and research. *Journal of Planning Literature*, 19(2), 147-181.

Lee, I.M. (2003). Physical activity and cancer prevention: Data from epidemiologic studies. *Medical Science and Sports Exercise*, 35(11), 1823-1827.

Leigh, J.P. & Geraghty, E.M. (2008). High gasoline prices and mortality from motor vehicle crashes and air pollution. *Journal of Occupational and Environmental Medicine*, 50, 249-254.

Lena, T.S., Ochieng, V., Carter, M., Holguin-Veras, J., & Kinney, P.L. (2002). Elemental carbon and $PM_{2.5}$ levels in an urban community heavily impacted by truck traffic. *Environmental Health Perspectives*, 110(10), 1009-1015.

Li, F., Harmer, P.A., Cardinal, B.J., Bosworth, M., Acock, A., Johnson-Shelton, D., & Moore, J.M. (2008). Built environment, adiposity, and physical activity in adults aged 50-75 years. *American Journal of Preventive Medicine*, 35(1), 38-46.

Litman, T. (2004). *London congestion pricing: Implications for other cities*. Victoria Transport Policy Institute. Retrieved April 15, 2009 from http://www.vtpi.org/london.pdf.

Lovegrove, G.R. & Sayed, T. (2006). Macro-level collision prediction models for evaluating neighbourhood traffic safety. *Canadian Journal of Civil Engineering*, 33, 609-621.

Lucy, W.H. (2003). Mortality risk associated with leaving home: Recognizing the relevance of the built environment. *American Journal of Public Health*, 93(9), 1564-1569.

Manson, J.E., Nathan, D.M., Krolewski, A.S., Stampfer, M.J., Willett, W.C., & Hennekens, C.H. (1992). A prospective study of exercise and incidence of diabetes among US male physicians.

Journal of the American Medical Association, 268(1), 63-67.

May, A.D. & Milne, D.S. (2000). Effects of alternative road pricing systems on network performance. *Transportation Research Part A*, 34, 407-436.

McCann, B.A. & Ewing, R. (2003). *Measuring the health effects of sprawl: A national analysis of physical activity, obesity, and chronic disease*. Smart Growth America. Retrieved April 28, 2009 from http://www.smartgrowthamerica.org/report/HealthSprawl8.03.pdf.

McCormack, G.R., Giles-Corti, B., & Bulsara, M. (2008). The relationship between destination proximity, destination mix and physical activity behaviors. *Preventive Medicine*, 46, 33-40.

McCormack, G., Giles-Corts, B., Lange, A., Smith, T., Martin, K., & Pikora, T.J. (2004). An update of recent evidence of the relationship between objective and self-report measures of the physical environment and physical activity behaviours. *Journal of Science and Medicine in Sports*, 7(1S), 81-92.

Metro (2004). *Street connectivity: An evaluation of case studies in the Portland region*. Retrieved December 9, 2008 from http://www.oregonmetro.gov/files/planning/connectivityreport.pdf.

Michael, Y.L., Green, M.K., & Farquhar, S.A. (2006). Neighborhood design and active aging. *Health and Place*, 12(4), 734-740.

Morawska, L., Thomas, S., Gilbert, D., Greenaway, C., & Rijnders, E. (1999). A study of the horizontal and vertical profile of submicrometer particles in relation to a busy road. *Atmospheric Environment*, 33, 1261-1274.

Myers, J., Kaykha, A., George, S., Abella, J., Zaheer, N., Lear, S., Yamazaki, T.,& Froelicher, V. (2004). Fitness versus physical activity patterns in predicting mortality in men. *American Journal of Medicine*, 117(12), 912-918.

Namdeo, A. & Mitchell, G. (2008). An empirical study of estimating vehicle emissions under cordon and distance based road user charging in Leeds, UK. *Environmental Monitoring and Assessment*, 136, 45-51.

National Highway Traffic Safety Administration (2001). *Traffic Safety Facts 2000: Pedestrians*. Washington, DC: US Department of Transportation. Report DOT HS 809331.

Neckerman, K.M., Lovasi, G.S., Davies, S., Purciel, M., Quinn, J., Feder, E., Raghunath, N., Wasserman, B., & Rundle, A. (2009). Disparities in urban neighborhood conditions: Evidence from GIS measures and field observation in New York City. *Journal of Public Health Policy*, 30, S264-S285.

Oguma, Y. & Shinoda-Tagawa, T. (2004). Physical activity decreases cardiovascular disease risk in women: review and meta-analysis. *American Journal of Preventive Medicine*, 26(5), 407-418.

Oregon DEQ (2006). *Portland air toxics assessment*. Retrieved April 14, 2009 from http://www.deq.state.or.us/aq/toxics/pata.htm.

Oregon Department of Human Services*. Asthma Pediatric Disparities Initiative*. Retrieved April 17, 2009.

Oregon Department of Human Services (2007). *Keeping Oregonians healthy: Preventing chronic disease by reducing tobacco use, improving diet, and promoting physical activity and preventive screenings.*

Oregon Department of Human Services and Oregon Health and Science University (2009). *Healthy Aging in Oregon Counties*. Retrieved May 5, 2009 from http://www.oregon.gov/DHS/ph/hpcdp/docs/healthyagingreport/healthyagingorecountiesweb.pdf.

Owen, N., Humpel, N., Leslie, E., Bauman, A., & Sallis, J.F. (2004). Understanding environmental influences on walking: Review and research agenda. *American Journal of Preventive Medicine*, 27(1), 67-76.

Pope, C.A., Burnett, R.T., Thun, M.J., Calle, E.E., Krewski, D., Ito, K., & Thurston, G.D. (2002). Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution. *Journal of the American Medical Association*, 287, 1132-1141.

Pope, C.A., Ezzati, M., & Dockery, D.W. (2009). Fine particulate air pollution and life expectancy in the United States. *New England Journal of Medicine*, 360(4), 376-386.

Pucher, J. & Dijkstra, L. (2000). Making walking and cycling safer: Lessons from Europe. *Transportation Quarterly*, 54(3), 25-50.

Retting, R.A., Ferguson, S.A., & McCartt, A.T. (2003). A review of evidence-based traffic measures designed to reduce pedestrian-motor vehicle crashes. *American Journal of Public Health*, 93(9), 1456-1463.

Robinson, D.L. (2005). Safety in numbers in Australia: More walkers and bicyclists, safer walking and bicycling. *Health Promotion Journal of Australia*, 16(1), 47-51.

Rufolo, A.M. & Kimpel, T.J. (2008). Response to Oregon's experiment in road pricing. *Transportation Research Record: Journal of the Transportation Research Board*, 2079, 1-7.

Rufolo, A.M. & Kimpel, T.J. (in press). Transit's effect on mileage responses to Oregon's experiment in road pricing. *Transportation Research Record: Journal of the Transportation*

Research Board.

Saelens, B.E. & Handy, S.L. (2008). Built environment correlates of walking: A review. *Medicine and Science in Sports and Exercise*, 40(7S), S550-S566.

Saelens, B.E., Sallis, J.F., & Frank, L.D. (2003). Environmental correlates of walking and cycling: Findings from the Transportation, Urban Design, and Planning Literature. *Annals of Behavioral Medicine*, 25(2), 80-91.

Schefer, D. & Rietvald, P. (1997). Congestion and safety on highways: Towards an analytical model. *Urban Studies*, 34(4), 679-692.

Schindler, C., Keidel, D., Gerbase, M.W., Zemp, E., Bettschart, R., Brandli, O., Brutsche, M.H., Burdet, L., Karrer, W., Knopfli, B., Pons, M., Rapp, R., Bayer-Oglesby, L., Kunzli, N., Schwartz, J., Liu, L.J.S., Ackermann-Liebrich, U., Rochat, T., & the SAPALDIA Team (2009). Improvements in PM10 Exposure and Reduced Rates of Respiratory Symptoms in a Cohort of Swiss Adults (SAPALDIA). *American Journal of Respiratory and Critical Care Medicine*, 179(7), 579-587.

Sipes, K.M. & Mendelsohn, R. (2001). The effectiveness of gasoline taxation to manage air pollution. *Ecological Economics*, 36, 399-309.

Skov, H., Hansen, A.B., Lorenzen, G., Andersen, H.V., Lofstrom, P., & Christensen, C.S. (2001). Benzene exposure and the effect of traffic pollution in Copenhagen, Denmark. *Atmospheric Environment*, 35, 2463-2471.

Spivock, M., Gauvin, L., Riva, M., & Brodeur, J.M. (2008). Promoting active living among people with physical disabilities: Evidence for neighborhood-level buoys. *American Journal of Preventive Medicine*, 34(4), 291-298.

Taylor, L.M., Leslie, E., Plotnikoff, R.C., Owen, N., & Spence, J.C. (2008). Associations of perceived community environmental attributes with walking in a population-based sample of adults with type 2 diabetes. *Annals of Behavioral Medicine*, 35, 170-178.

The Coalition for a Livable Future & Portland State University (2007). *The regional equity atlas: Metropolitan Portland's geography of opportunity*. Portland, OR: The Coalition for a Livable Future. Retrieved May 1, 2009 from http://www.equityatlas.org/chapters/EquityAtlas.pdf.

The Governor's Climate Change Integration Group (2008). *Final Report to the Governor: A framework for addressing rapid climate change*. Salem, OR: Oregon Department of Energy. Retrieved May 5, 2009 from http://www.oregon.gov/ENERGY/GBLWRM/docs/CCIGReport08Web.pdf.

Timperio, A., Crawford, D., Telford, A., & Salmon, J. (2004). Perceptions about the local neighborhood and walking and cycling among children. *Preventive Medicine*, 38, 39-47.

Tonne, C., Beevers, S., Armstrong, B., Kelly, F., & Wilkinson, P. (2008). Air pollution and mortality benefits of the London Congestion Charge: Spatial and socioeconomic inequalities. *Occupational and Environmental Medicine*, 65(9), 620-627.

U.S. Census Bureau (2003). *American Housing Survey for the Portland Metropolitan Area: 2002*. Current Housing Reports, Series H170/02-34. Retrieved April 15, 2009 from http://www.census.gov/prod/2003pubs/h170-02-34.pdf.

U.S. Department of Health and Human Services (1996). *Physical Activity and Health: A Report of the Surgeon General*. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion. Retrieved April 16, 2009 from http://www.cdc.gov/nccdphp/sgr/pdf/sgrfull.pdf.

U.S. EPA (2008a). *Health and environmental impacts of NOx*. Retrieved April 28, 2009 from http://www.epa.gov/air/urbanair/nox/hlth.html.

U.S. EPA (2008b). *Ground-level ozone: Health and environment*. Retrieved April 28, 2009 from http://www.epa.gov/air/ozonepollution/health.html.

U.S. EPA (2008c). *Particulate matter: Health and environment*. Retrieved April 28, 2009 from http://www.epa.gov/air/particlepollution/health.html.

U.S. EPA (2008d). *Health and environmental impacts of CO*. Retrieved April 28, 2009 from http://www.epa.gov/air/urbanair/co/hlth1.html.

U.S. EPA (2008e). Health and environmental impacts of SO_2. Retrieved April 28, 2009 from http://www.epa.gov/air/urbanair/so2/hlth1.html.

U.S. EPA (1994). Environmental fact sheet: Air toxics from motor vehicles. Retrieved May 4, 2009 from http://www.epa.gov/OTAQ/f02004.pdf.

Vernez Moudon, A., Lee, C., Cheadle, A.D., Garvin, C., Johnson, D.B., Schmid, T.L., & Weathers, R.D. (2007). Attributes of environments supporting walking. *American Journal of Health Promotion*, 21(5), 448-459.

Villanueva, K., Giles-Corti, B., & McCormack, G. (2008). Achieving 10,000 steps: A comparison of public transport users and drivers in a university setting. *Preventive Medicine*, 47, 338-341.

Watters, P., O'Mahony, M., & Caulfield, B. (2006). Response to cash outs for work place parking and work place parking charges. *Transport Policy*, 13, 503-510.

Wener, R.E. & Evans, G.W. (2007). A morning stroll: Levels of physical activity in car and mass transit commuting. *Environment and Behavior*, 39(1), 62-74.

Wheeler, S.M. (2008). The evolution of built landscapes in metropolitan regions. *Journal of Planning Education and Research*, 27, 400-416.

White, J.B. (2008). The Next Car Debate: Total Miles Driven. *The Wall Street Journal*, February 5.

World Health Organization (2002). *A physically active life through everyday transport with a special focus on children and older people and examples and approaches from Europe*. Copenhagen: WHO Regional Office for Europe. Retrieved May 5, 2009 from http://www.euro.who.int/document/e75662.pdf.

World Health Organization (2003). *Social determinants of health: The solid facts*. 2nd Edition. R. Wilkinson and M. Marmot (Eds.). Retrieved May 5, 2009 from http://www.euro.who.int/DOCUMENT/E81384.PDF.

Wu, Y.C. & Batterman, S.A. (2006). Proximity of schools in Detroit, Michigan to automobile and truck traffic. *Journal of Exposure Science and Environmental Epidemiology*, 16, 457-470.

Yamamoto, T., Fukii, S., Kitamura, R., & Yoshida, H. (2000). An analysis of time allocation, departure time and route choice behavior under congestion pricing. *Transportation Research Record: Journal of the Transportation Research Board*, 1725, 95-101.

Zhu, Y., Hinds, W.C., Kim, S., Shen, S., & Sioutas, C. (2002). Study of ultrafine particles near a major highway with heavy-duty diesel traffic. *Atmospheric Environment*, 36, 4323-4335.

Zhu, X., BArch, & Lee, C. (2008). Walkability and safety around elementary schools: Economic and ethnic disparities. *American Journal of Preventive Medicine*, 34(4), 282-290.

VIII. APPENDIX

A. Population Increase

In 2005, the population in Oregon was estimated to be 2.8 million people. By 2040, the population in Oregon is expected to total nearly 5.5 million people, with 78% of those people residing in the 10 counties that contain the six metropolitan areas in Oregon (Benton, Clackamas, Deschutes, Jackson, Lane, Linn, Marion, Multnomah, Polk, and Washington counties). The 2.7 million population increase in Oregon is the equivalent of adding nearly four more counties with the population of Multnomah County (Table 1).

Table 1. Population Projection from 2000 to 2040 in selected counties.

County	2005 Population	2040 Population	Increase by 2040
Benton	82,138	99,886	21.6%
Clackamas	363,240	620,703	70.9%
Deschutes	139,994	257,088	83.6%
Jackson	194,005	297,496	53.3%
Lane	333,855	471,511	41.2%
Linn	106,023	146,260	38.0%
Marion	302,913	448,671	48.1%
Multnomah	687,073	842,009	22.6%
Polk	65,434	135,937	107.7%
Washington	489,742	920,852	88.0%

Note: Data from the Office of Economic Analysis.

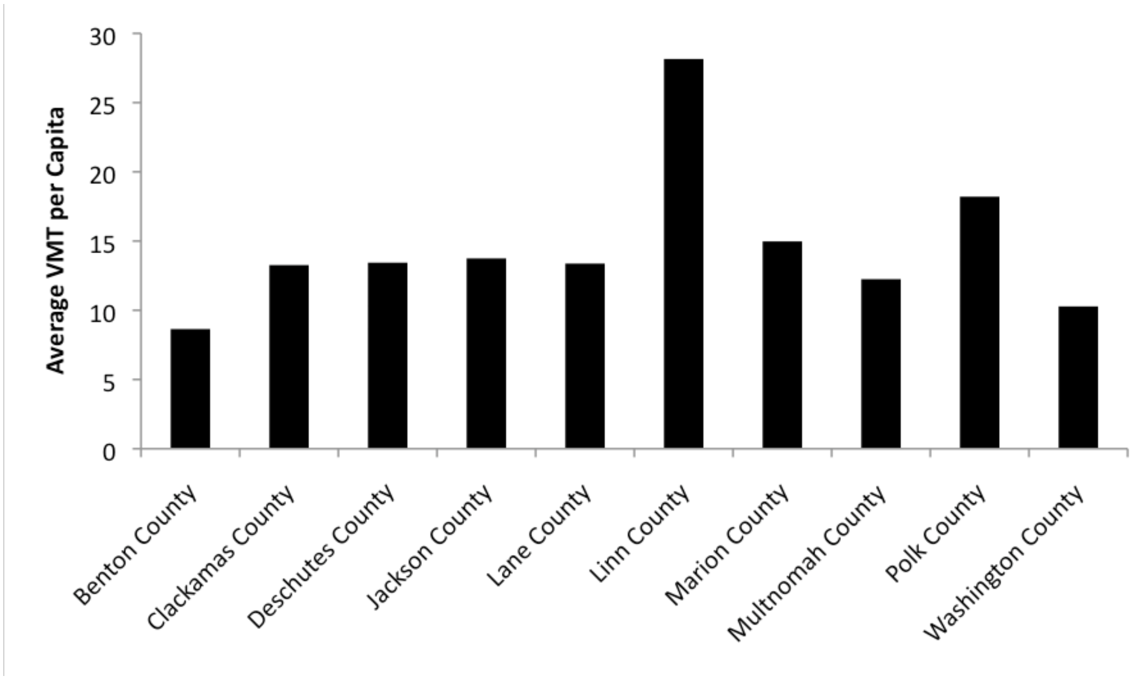
An increase in population will lead to more drivers on our roads and the problems that come with more drivers: increased pollution, congestion, and collisions.

B. Vehicle-Centered Society

Communities in the metropolitan United States have become increasingly auto-oriented and disconnected from public transportation (Wheeler, 2008). Although modern zoning laws were developed to benefit the health of populations, they also created longer distances to travel between where we live, work, and play—with the result being that walking and bicycling to destinations are less of an option than they were in the past (Frank & Engelke, 2001).

Oregonians living in metropolitan counties drive an average of 9-28 miles per day on Oregon highways (Figure 1) and have an 18-24 minute commute to work (Table 2). As the population grows, the time spent to get to places will likely increase due to increasing congestion that cannot be addressed with road expansion due to finite land resources in metropolitan areas.

Figure 1: Average daily vehicle miles traveled per person on state highways.



Notes: The table account for VMT on state highways only, therefore total VMT for each county is likely higher. Daily VMT per person = average total daily VMT in 2002-2007 / estimated population in 2005. Vehicle miles traveled data from the Oregon Department of Transportation. Population data from the Office of Economic Analysis.

Table 2: Average travel time to work for workers 16 years and older.

County	Mean (in minutes)
Jackson	18.9
Deschutes	18.7
Lane	19.9
Benton	17.8
Linn	22.2
Marion	23.5
Polk	23.4
Washington	23.7
Clackamas	26.2
Multnomah	23.8

Note: Data from US Census 2000 Summary File 3, Table QT-P23 (Journey to Work).

In 2000, the majority of Oregonians drove to work alone (Table 3). Although these data are relatively dated, it is unlikely that a large proportion of Oregon's population has shifted is mode of travel away from individual vehicles in the past decade. In 2000, 4.8% of workers 16 years and older used a bicycle to commute to work in Benton County, the highest percentage of all the metropolitan counties. Multnomah County had the greatest proportion of workers 16 years and older walking and taking public transit to work, 4.6% and 11.1%, respectively.

Table 3. Mode of transportation to work for workers 16 years and older.

County	Drove Alone		Biked		Walked		Public Transit	
	Number	%	Number	%	Number	%	Number	%
Jackson	61,332	77.4	669	0.8	2,817	3.6	532	0.7
Deschutes	41,132	75.2	695	1.3	1,241	2.3	432	0.8
Lane	109,374	71.6	4,648	3.0	6,363	4.2	5,014	3.3
Benton	26,682	70.7	1,822	4.8	2,910	7.7	600	1.6
Linn	35,991	79.3	145	0.3	1,321	2.9	128	0.3
Marion	90,914	72.8	827	0.7	3,742	3.0	2,618	2.1
Polk	21,447	74.5	268	0.9	1,131	3.9	242	0.8
Clackamas	130,574	78.2	477	0.3	3,456	2.1	5,098	3.1
Washington	172,650	75.1	935	0.4	5,021	2.2	13,433	5.8
Multnomah	220,006	65.6	5,013	1.5	15,284	4.6	37,300	11.1

Note: Data from US Census 2000 Summary File 3, Table QT-P23 (Journey to Work).

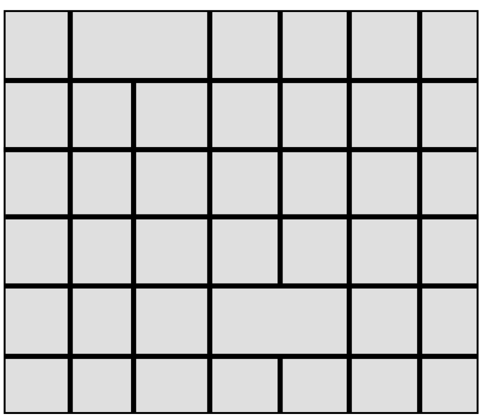
C. Street Connectivity

One factor influencing Oregonians' utilization of alternative transportation is the "connectivity" of our streets. Street connectivity is defined as "a system of streets with multiple routes and connections serving the same origins and destinations" (Metro, 2004, p. 3). Places with high connectivity have multiple points at which to access the area as well as many parallel routes and connecting roads within the area.

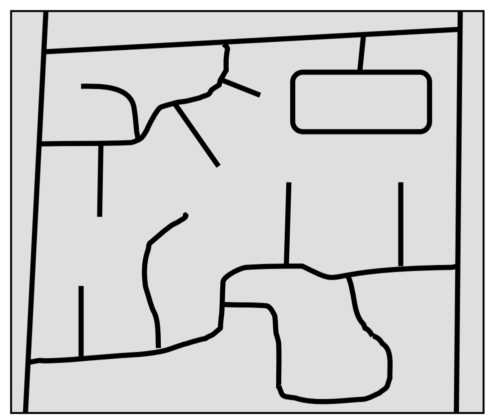
Development that took place during the mid and late 19th century resulted in more traditional grid-patterned neighborhoods (Wheeler, 2008). Grid neighborhoods have higher street connectivity (Figure 2) and this facilitates alternative transportation compared to typical suburban development. Suburban neighborhoods typically begin with cul-de-sacs and progress to major arterial streets, with low levels of connectivity and higher traffic volume on the main roads (Figure 2). These development patterns discourage modes of travel other than the individual vehicle due to longer travel times to reach a potential destination (Metro, 2004; Dill, 2004).

Figure 2. Examples of high and low street connectivity.

Highly Connected Street Network:



Poorly Connected Street Network:



Street connectivity is commonly measured by two terms: gamma and alpha (Dill, 2004). Gamma represents the ratio of actual number of street segments to maximum possible, with higher numbers representing areas with more gridded street patterns and lower numbers representing areas with more cul-de-sacs. Alpha represents the ratio of the actual number of complete loops to the maximum number of possible loops, with higher numbers representing a higher level of complexity and connectivity. This can be used to evaluate the number of alternative routes to travel from one location to another.

In Oregon, Multnomah and Deschutes counties were ranked highest out of the metropolitan counties on the proportion of gridded street development patterns and high connectivity (Table 4). These counties include the metropolitan areas of Portland and Bend, respectively. Clackamas and Washington counties, which both include suburbs of Portland, were ranked lowest for their proportion of gridded street development, indicating they have more cul-de-sac developments, as well as having the lowest connectivity. As a result, residents of Clackamas and Washington counties have environments that are less conducive to alternative transportation than the more well-connected counties.

Table 4. Connectivity of Oregon's metropolitan counties.

County	Low Gamma[1,2]		High Gamma		Low Alpha[1,3]		High Alpha	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Benton	10	52.6	9	47.4	10	52.6	9	47.4
Clackamas	44	71.0	18	29.0	43	69.4	19	30.7
Deschutes	8	38.1	13	61.9	8	38.1	13	61.9
Jackson	23	63.9	13	36.1	23	63.9	13	36.1
Lane	48	61.5	30	38.5	48	61.5	30	38.5
Linn	11	55.0	9	45.0	11	55.0	9	45.0
Marion	31	60.8	20	39.2	30	58.8	21	41.2
Multnomah	33	19.4	137	80.6	33	19.4	137	80.6
Polk	8	66.7	4	33.3	8	66.7	4	33.3
Washington	60	74.1	21	25.9	61	75.3	20	24.7

[1] Low and High Gamma and Alpha are based on a median split from the selected counties pooled data (Low Gamma ≤ 0.4149, Low Alpha ≤ 0.1197).
[2] Gamma = ratio of actual number of street segments to maximum possible. Range 0-1; higher numbers represent areas with more gridded street patterns and lower numbers represent areas with more cul-de-sacs.
[3] Alpha = ratio of the actual number of complete loops to the maximum number of possible loops. Range 0-1; higher numbers represent a higher level of complexity and connectivity.
Note: Data from the RAND Center for Population Health and Health Disparities, which is funded by grant 1-P50-ES012383 from the National Institute of Environmental Health Sciences. For further information on the CPHHD, go to http://www.rand.org/health/centers/pophealth/index.html.

D. Physical Activity and Active transportation

The connectivity of Oregon's neighborhoods is an important factor contributing to the use of active transportation. Active transportation is any mode of travel that involves a physically active portion of the trip, such as walking, bicycling, or even public transit—since it usually involves physical activity at one or both ends of the trip. Integrating physical activity into daily routines, for example walking to work rather than driving, is an important way to increase activity levels among people who have neither the time nor the inclination to participate in leisure exercise (Frank & Engelke, 2001).

The Surgeon General reported that routine moderate physical activity reduces the risk of premature mortality, coronary heart disease, hypertension, colon cancer, and type 2 diabetes. It also can improve mental health and the health of muscles, bones, and joints (U.S. Department of Health and Human Services, 1996). In addition, physical activity is associated with reduced cardiovascular (Gregg, Gerzoff, Caspersen, Williamson, & Narayan, 2003) and cancer (Hu, Willett, Li, Stampfer, Colditz, & Manson, 2004) mortality. Physical activity is also associated with lowered risk of breast cancer in women (Lee, 2003) and stroke (Oguma & Shinoda-Tagawa, 2004). In Oregon's metropolitan counties, slightly more than half of adults 18 years and older meet physical activity recommendations of 30 minutes or more of moderate activity five days per week or 20 minutes or more of vigorous activity three days per week (Table 5). Lack of physical activity is also a contributing factor to overweight and obesity. In Oregon, over half of adults 18 years and older in the metropolitan counties are either overweight or obese (Table 5).

Table 5. Percent adults 18 years and older meeting physical activity requirements* and percent obese and overweight.

County	Percent of adults meeting physical activity requirements*	Percent of obese adults (BMI > 30 kg/m²)	Percent of overweight adults (30 > BMI ≥ 25 kg/m²)
Jackson	58.0	20.9	36.2
Deschutes	57.5	18.3	38.8
Lane	58.8	23.0	35.7
Benton	58.2	16.4	37.5
Linn	54.9	30.5	35.0
Marion	49.6	25.1	39.4
Polk	57.9	21.0	37.0
Washington	51.3	20.4	37.1
Clackamas	54.6	21.1	38.1
Multnomah	56.0	19.9	34.8

* Physical activity requirements are met if an individual completes 30 minutes or more of moderate physical activity 5 times per week or 20 minutes or more of vigorous activity 3 times per week.

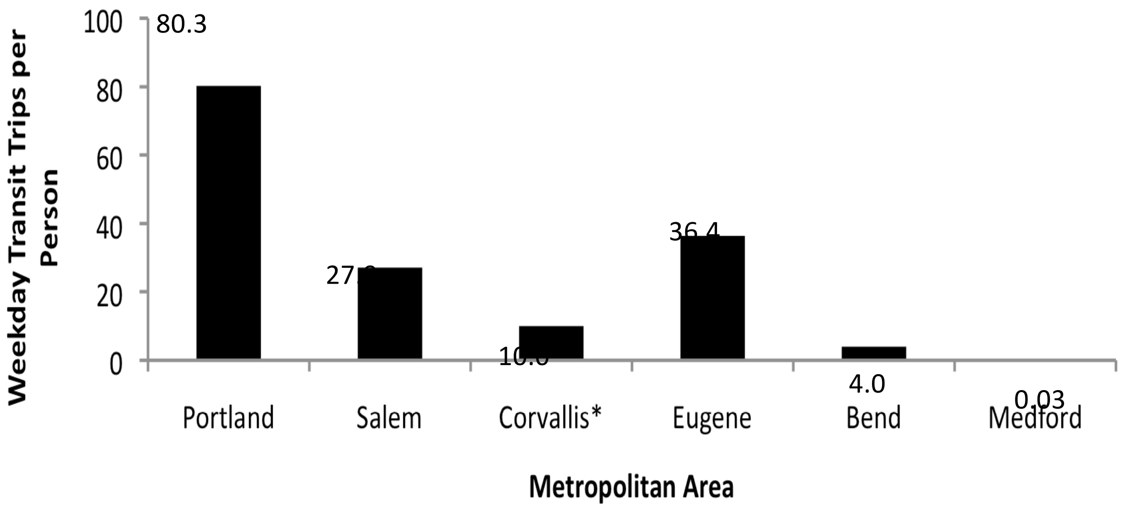
Note: Data from Keeping Oregonians Healthy (Oregon Department of Human Services, 2007), Behavioral Risk Factor Surveillance System, 2002-2005

E. Public Transit

With an increasing population and a finite amount of land, road expansion will become less of an option to reduce congestion and public transit frequency and coverage will become increasingly important. Public transit users often meet public heath recommendations for physical activity by walking to and from transit (Besser & Dannenberg, 2005).

Currently, use of public transit compared to individual vehicles is low in Oregon's metropolitan counties (Table 3). In the Portland metropolitan area, 80 trips are made per person each year by public transit and in the Eugene metropolitan area 36 public transit trips are made per person each year. However, the Portland and Eugene metropolitan areas have much higher rates of public transit compared to the Medford-Ashland area, which averages only 0.03 trips per person each year (Figure 3).

Figure 3. Average Annual Weekday Transit Trips per Person by Metropolitan Transit Area.



Note: Data for all metropolitan areas, except Corvallis, from the National Transit Database, 2007. Since Corvallis does not report to the National Transit Database, Corvallis data is from personal communication with the Corvallis Area Metropolitan Planning Organization and from the years 2007-2008.

The pedestrian environment at the local and neighborhood scale contributes greatly to the success of public transit. The ability to forgo car ownership requires that one has competitive forms of transit and non-motorized movement (Frank & Engelke, 2001). Research suggests that one factor that influences the success of public transit is population density (Ewing, Schieber, & Zegeer, 2003). Therefore, increasing population density will be a critical factor in ensuring that public transit is utilized. Other factors, such as mixed use development and pedestrian friendly streets could also be factors in supporting the success of public transit.

F. Air Pollution

The propensity of Oregonians to drive individual vehicles and the design of our neighborhoods influences more than physical activity levels. Air pollution from transportation is an increasing problem as our population increases and we drive more cars on Oregon's roads. In 2004, transportation accounted for 34% of greenhouse gas emissions in the Oregon. Total greenhouse gas emissions have increased by 22% since 1990 (The Governor's Climate Change Integration Group, 2008).

The Federal Clean Air Act established air quality standards for six air pollutants, including nitrogen oxides, ozone, sulfur dioxide, particulate matter, carbon monoxide, and lead. The emission of these pollutants is at least partially attributed to on-road vehicles. Most pollutants are emitted directly from vehicles, but ozone is formed from the reaction of nitrogen oxides with volatile organic compounds in the presence of sunlight. Nitrogen oxides also react with other chemicals to form particulate matter. In Oregon's metropolitan counties, 46-69% of carbon monoxide and 33-71% of nitrogen oxides were attributed to on-road vehicles in 2002 (Table 7).

Table 7. Percent of selected air emissions that come from on-road vehicles.

County	Carbon Monoxide	Nitrogen Oxides	Volatile Organic Compounds	Particulate Matter	Sulfur Dioxide
Benton	63	60	18	4	16
Clackamas	52	64	19	4	20
Deschutes	63	68	26	3	26
Jackson	54	62	22	3	11
Lane	68	62	27	5	19
Linn	65	66	31	3	13
Marion	68	69	31	5	19
Multnomah	57	33	19	9	8
Polk	69	71	29	5	22
Washington	46	58	15	7	12

Note: Data from US Environmental Protection Agency, 2002.

The primary health problems associated with nitrogen oxides and volatile organic compounds results from their creation of ozone. Ground-level ozone is also know as smog and can cause respiratory irritation, compromised respiratory function, aggravate asthma, increase susceptibility to respiratory illness (e.g., bronchitis and pneumonia), and cause permanent lung damage with prolonged exposure. Populations at highest risk for the adverse effects of ozone include children, adults with lung diseases (e.g., asthma), and those working or spending leisure time outdoors (U.S. EPA, 2008a; U.S. EPA 2008b). Approximately one in ten adults in Oregon's metropolitan counties has asthma (Table 8).

Table 8: Percent of adults 18 years and older with asthma, 2002-2005, data from BRFSS, Keeping Oregonians Healthy (2007).

County	Percent with Asthma
Benton	9
Clackamas	10
Deschutes	9
Jackson	8
Lane	11
Linn	12
Marion	9
Multnomah	9
Polk	7
Washington	9

Particulate matter causes similar respiratory health effects as those from ozone as well as contributing to irregular heartbeat, nonfatal heart attacks, and premature death for people with heart or lung disease (U.S. EPA, 2008c). Carbon monoxide reduces oxygen delivery to the body's organs and tissues (U.S. EPA, 2008d). Sulfur dioxide can cause difficulty in breathing for people spending active time outdoors or those with compromised lung function as well as causing premature death. Continuing exposure to sulfur dioxide can cause respiratory disease and exacerbate existing heart disease (U.S. EPA, 2008e).

On-road vehicles are also major sources of air toxics, including benzene, formaldehyde, acetaldehyde, 1,3-butadiene, acrolein, and diesel particulate matter. Air toxics are associated with a wide range of adverse health impacts, including respiratory disease, neurological and developmental impacts, and cancer (U.S. EPA, 1994).

People living in close proximity to busy roads have the greatest exposure to air pollution attributable to on-road vehicles. In 2002, nearly one in six housing units in the Portland metropolitan area was located within 300 feet of a four-lane or wider highway, a railroad, or an airport. This exposure is not equally distributed in our population, however. Black or Hispanic residents are more likely than the average resident to live in close proximity to these sources of pollution (U.S. Census Bureau, 2003). Low income residents are at greatest risk of pediatric asthma in Oregon (Oregon Department of Human Services).

G. Collisions

Injuries and fatalities from collisions involving a vehicle become more common as individual vehicle use increases. In 2007, a total of 13 bicyclists, 43 pedestrians, and 257 drivers were killed in a collision involving a car in the Oregon metropolitan counties (Table 9).

Table 9. Fatalities and Injuries from Car Collisions, 2007, data from Oregon Department of Transportation.

	Bicycles		Pedestrians		Drivers	
County	**Injuries**	**Fatalities**	**Injuries**	**Fatalities**	**Injuries**	**Fatalities**
Benton	30	0	20	0	439	7
Clackamas	37	0	58	2	2,289	32
Deschutes	19	1	20	1	1,114	13
Jackson	28	0	33	2	1,459	16
Lane	90	3	45	7	2,331	43
Linn	20	1	13	1	882	28
Marion	57	0	53	5	2,554	31
Multnomah	194	5	241	18	6,205	51
Polk	8	1	9	1	487	9
Washington	60	2	73	6	3,456	27
Total	543	13	565	43	21,216	257