From: Richard Abrams <abramsrl@gmail.com>
Date: Mon, Jun 8, 2015 at 3:50 PM

Subject: Comment on Hyperion Bridge Bike Lanes
To: Sharon Gin <Sharon.Gin@lacity.org>, My La <my.la@lacity.org>, Hollywoodians Encouraging Logical Planning <HwoodCA@gmail.com>, saveHywd@gmail.com, RSM <AbramsRL@gmail.com>, Richard MacNaughton <macnaughtonesq@gmail.com>

Dear Gentlepersons:

On behalf of both Hollywoodians Encouraging Logical Planning [HELP] and Citizens Coalition Los Angeles [CCLA], I am submitting the following hyper-links for addition to the administrative record for the Hyperion Bridge matter [Council File # 05-0173
Glendale Boulevard-Hyperion Avenue Complex of Bridges Improvement Project California Environmental].

http://bit.ly/1G9NlRP October 28, 2010, Study: Separated Bikeways Mean Better Air Quality for Bikers, Walkers, Posted by Jonathan Maus (Publisher/Editor) on October 28th, 2010 at 1:10 pm

http://bit.ly/1Qf66Jl Air Pollution and Children's Health, A fact sheet by Cal/EPA's Office of Environmental Health Hazard Assessment and the American Lung Association of California, [02/28/02] [revised 11/26/03]

http://1.usa.gov/1BPmNz9 August 14, 2014, EPA, Near Roadway Air Pollution and Health

Would you be so kind as to add these to the Administrative Record and have them distributed to councilmembers?

Thank you in advance for your attention to this matter.

Rick

City of Los Angeles Mail Michael Espinosa <michael.espinosa@lacity.org>
Response to BOE Techical Memorandum Issued 5/28/2015 concerning the Glendale Boulevard-Hyperion Avenue Complex of Bridges Council File No. 05-0173
1 message
Robert Peppey <r.peppey@yahoo.com>Sat, Jun 6, 2015 at 8:50 AM
Reply-To: Robert Peppey <r.peppey@yahoo.com>
To: "councilmember.ofarrell@lacity.org" <councilmember.ofarrell@lacity.org>, "info@davidryu.com" <info@davidryu.com>, "councilmember.cedillo@lacity.org" <councilmember.cedillo@lacity.org>, "councilmember.price@lacity.org" <councilmember.price@lacity.org>, "councilmember.buscaino@lacity.org" <councilmember.buscaino@lacity.org>, "councilmember.martinez@lacity.org" <councilmember.martinez@lacity.org>, "councilmember.bonin@lacity.org" <councilmember.bonin@lacity.org>, "david.ryu@davidryu.com" <david.ryu@davidryu.com>, "councilmember.wesson@lacity.org" <councilmember.wesson@lacity.org>, "councilmember.krekorian@lacity.org" <councilmember.krekorian@lacity.org>, "councilmember.blumenfield@lacity.org" <councilmember.blumenfield@lacity.org>, "councilmember.fuentes@lacity.org" <councilmember.fuentes@lacity.org>, "councilmember.parks@lacity.org" <councilmember.parks@lacity.org>, "councilmember.huizar@lacity.org" <councilmember.huizar@lacity.org>, "councilmember.englander@lacity.org" <councilmember.englander@lacity.org>, "paul.koretz@lacity.org" <paul.koretz@lacity.org>, "michael.espinosa@lacity.org" <michael.espinosa@lacity.org>
Cc: Steve Lopez <steve.lopez@latimes.com>, "Elinor.Mondok@lacity.org" <Elinor.Mondok@lacity.org>, "Fernando.Campos@lacity.org" <Fernando.Campos@lacity.org>, "Geraldine.Rodriguez@lacity.org" <Geraldine.Rodriguez@lacity.org>, "Heather.Repenning@lacity.org" <Heather.Repenning@lacity.org>, "Kevin.James@lacity.org" <Kevin.James@lacity.org>, "Matt.Szabo@lacity.org" <Matt.Szabo@lacity.org>, "Mike.Davis@lacity.org" <Mike.Davis@lacity.org>, "Shelley.Wong@lacity.org" <Shelley.Wong@lacity.org>, "Teri.Schmidt@lacity.org" <Teri.Schmidt@lacity.org>, "Ana.Guerrero@lacity.org" <Ana.Guerrero@lacity.org>, "Sarah.Dusseault@lacity.org" <Sarah.Dusseault@lacity.org>, Chad Molnar <chad.molnar@lacity.org>, Laura McLennan <laura.mclennan@lacity.org>, "ellen.isaacs@lacity.org" <ellen.isaacs@lacity.org>, "Patricia.Whelan@lacity.org" <Patricia.Whelan@lacity.org>, "jenny.chavez@lacity.org" <jenny.chavez@lacity.org>, "Arturo.Chavez@lacity.org" <Arturo.Chavez@lacity.org>, "jim.dantona@lacity.org" <jim.dantona@lacity.org>, "paloma.perez@lacity.org" <paloma.perez@lacity.org>, "deron.williams@lacity.org" <deron.williams@lacity.org>, "stephanie.magnien@lacity.org" <stephanie.magnien@lacity.org>, "joan.pelico@lacity.org" <joan.pelico@lacity.org>, "rebecca.valdez@lacity.org" <rebecca.valdez@lacity.org>, "Bernard.Parks.Jr@lacity.org" <Bernard.Parks.Jr@lacity.org>, "paul.habib@lacity.org" <paul.habib@lacity.org>, "christine.peters@lacity.org" <christine.peters@lacity.org>, "david.giron@lacity.org" <david.giron@lacity.org>, "jeanne.min@lacity.org" <jeanne.min@lacity.org>, "Semee.Park@lacity.org" <Semee.Park@lacity.org>, "Brenton.Tesler@lacity.org" <Brenton.Tesler@lacity.org>, "Doug.Tripp@lacity.org" <Doug.Tripp@lacity.org>, "Hannah.Lee@lacity.org" <Hannah.Lee@lacity.org>, "Nicole.Bernson@lacity.org" <Nicole.Bernson@lacity.org>, "John.S.Lee@lacity.org" <John.S.Lee@lacity.org>, Seleta Reynolds <seleta.reynolds@lacity.org>, Daniel Mitchell <daniel.mitchell@lacity.org>, Patrice Lattimore <patrice.lattimore@lacity.org>, Alan Aletti <alan.aletti@lacity.org>

In response to the BOE's Technical Memo the attached rebuttal report shows:

1. The impacts of the Recommended Option have not been adequately analyzed, especially in lieu of the Willits settlement.

2. There is a significant pedestrian and bicyclist safety risk on the side of the bridge lacking a sidewalk that has not been mitigated by BOE's report and recommended option.

3. Failure to mitigate this safety risk will result in serious injury or death and will expose the city to tremendous financial burden.

4. BOE's Technical Memorandum plays a statistical number game to quantify and minimize the risk. No matter how you play the numbers the risk is real.

Council File No. 05-0173
City Clerk please post to Council File
City Council Agenda Date: 6/09/2015

Sincerely,

Robert Peppey
3523 Crestmont Avenue
Los Angeles, CA 90026
r.peppey@yahoo.com

Bridge001.pdf
5461K

RESPONSE TO THE TECHNICAL MEMORANDUM ON BICYCLE AND PEDESTRIAN FACILITIES ASSESSMENT

INTRODUCTION

On May 28, 2015, The City of Los Angeles, Bureau of Engineering, submitted a Technical Memorandum (TM) by Psomas, regarding bicycle and pedestrian facilities on the Glendale Boulevard-Hyperion Avenue Complex of Bridges. It included an inventory of facilities, a comparison of existing and proposed conditions, and most significantly, an evaluation of significant thresholds for bicycle and pedestrian safety based on the Los Angeles CEQA Thresholds Guide (2006) and recommendations to enhance bike and pedestrian travel and safety.

The objective of this TM response is to outline the technical deficiencies in the City's analysis of bicycle and pedestrian travel and safety and the failure of the recommended mitigation measures to eliminate the recognized safety risk factors.

EXISTING CONDITIONS

The existing conditions indicated in the TM are correctly listed, with two substandard sidewalks on either side of the bridge, and no ADA Compliant Pedestrian Route (PAR) along Hyperion Ave. Additionally, other unsafe pedestrian conditions are listed regarding unsafe pedestrian crossings.

BICYCLE AND PEDESTRIAN VOLUMES

While this response does not take exception to the pedestrian and bicycle data collection numbers, it does take exception to the criteria and methodology that fails to provide a co-factor for the lack of any existing bicycle lanes or limited ADA accessibility and substandard sidewalk facilities into the data. Existing volumes should further take into account what alternative routes pedestrians and bicyclist are taking to circumvent and avoid the safety risks on the existing bridge with minimal substandard pedestrian sidewalks and no bicycle facilities. Use of this data is an observational failure in the TM's evaluation of risks and disadvantages.

FUTURE CONDITIONS: ADVANTAGES AND DISADVANTAGES

Improvements in the TM's recommended option (attachment) fail to minimize or eliminate the certain key bicycle and pedestrian safety risk factors.

1. While the new six-foot sidewalk along the west side of Hyperion Ave over I-5 and the Los Angeles River provides ADA compliant PAR on one side of the bridge, it fails to provide a PAR for pedestrian on the opposite of the bridge thereby adding a ½ mile of pedestrian travel distance.

2. While the new pedestrian bridge to be constructed across the Los Angeles River on the Old Red Car piers east of the Hyperion Bridge provides much needed access to the bike path from the Atwater side of the bridge, it fails to provide a compliant PAR for pedestrian travel from Atwater to Silver Lake and Los Feliz.

3. Longer travel paths for pedestrians starting or ending their trips on the east-side of Glendale Blvd between the Los Angeles River and Glenhurst Ave exist. The disadvantages listed in the TM incorrectly minimize the estimates of travel times for both able-bodied and disabled pedestrians. It fails to recognize that much of the pedestrian activity will be on a significant grade. Assuming the travel distances are correctly indicated in the TM, the significant travel time impacts on pedestrians are more correctly reflected as shown.

    - Able-bodied: Longer travel time of 2.6 minutes at 2 ft/s walking speed for 310 ft distance.
    - Disabled: Longer travel time of 17.2 minutes at 1.5 ft/s for 1550 ft distance. This travel time can be compounded due to the 5 percent grade in the Atwater to Silver Lake travel path.

The disadvantages in the TM's recommended improvements are based on incorrect assumptions and miscalculations. By having a sidewalk on only one side of the road, there is a significant safety risk of conflicts between bicyclists and pedestrians walking on the bike lane along the east side of Hyperion Avenue between Waverly and Glenfeliz/Glenhurst .

The TM itself recognizes that factors such as the distance between crossing opportunities, alternate routes, roadside environment, and vehicular speeds are factors that play into the benefits of having sidewalks on both sides of the bridge.

1. The TM incorrectly assumes that pedestrian volume percentages will remain equally split (75% vs. 25%) between the sides of the bridge when a new bike lanes are added on both sides of the bridge with only one sidewalk on the west side. Like water, pedestrians often find the path of least resistance and if the bike lane provides an opportunity for the easier flow for walkers, a higher percentage of pedestrians could utilize the east side bike lane. The current percentage split exists because the west side substandard sidewalk is still measurably wider and safer than the substandard east side sidewalk.

2. The TM indicates that 19% of pedestrians are disabled nationally and will be unable to negotiate the stair access to the Red car bridge, and may walk in the bike lane. This is a high risk factor that the TM minimizes, and fails to recognize the risk factors are compounded with bicyclist coming down the 5 percent grade at speeds that can easily exceed 20 mph, and conflicts with slow to respond disabled pedestrians.

3. The TM incorrectly calculates the pedestrians walking in the bike lane as less than one in the observation time of 12 hours. The pedestrian origin data collected from the impacted areas still fails to recognize that the 24 pedestrians counted in the data collection is biased data and has

not taken into account the other factors listed above. The conflict between even one pedestrian and a bicyclist can result in serious injury or death for both pedestrian and bicyclist. The conflict is not "minimal" as the TM suggests. To state the conflict is "minimal, the TM is making a subjective measurement of value of human life.

CONCLUSION

The City's analysis of bicycle and pedestrian travel and safety and the recommended mitigation measures fails to adequately mitigate and sufficiently eliminate the recognized safety risk factors. Thereby, the Bureau of Engineering's proposed recommendation measures fail to minimize impacts for a negative declaration to the affected environmental resource areas under CEQA . It is recommended that the environmental document be revised to address the known safety risk factors to pedestrians and bicyclists.

ATTACHMENT

Technical Memorandum

To: City of Los Angeles Bureau of Engineering

From: Alejandro Angel, PhD, PE, PTOE and Arief Naftali, PE, TE

cc: Anissa Voyiatzes, PE

Date: May 28, 2015

Re: **Bicycle and Pedestrian Facilities Assessment**

INTRODUCTION

On May 15, 2015, the City of Los Angeles Board of Public Works recommended adoption of the IS/MND for the Glendale Boulevard-Hyperion Avenue Complex of Bridges, which included a recommended option for Hyperion Avenue from Waverly Drive to Glendale Drive.

The objectives of this technical memorandum are to:

- Inventory the pedestrian and bicycle facilities in the project area both under existing and proposed conditions
- Compare conditions for bicyclists and pedestrians under current and proposed conditions
- Evaluate the significance thresholds for bicycle and pedestrian safety based on the Los Angeles CEQA Thresholds Guide (2006)
- Recommend additional measures to enhance bike and pedestrian travel and safety

EXISTING CONDITIONS

Bicycle and Pedestrian Facilities

The following facilities exist on or in the vicinity of the Hyperion bridge to connect the Silver Lake and Atwater Village areas:

- Sidewalks:
  - Sidewalks exist on both sides of the Hyperion bridge over I-5, and over the L.A. River.

- There are stairs connecting the sidewalk on the west side of the Hyperion bridge to Glendale Blvd between I-5 and the L.A. River.
- In the vicinity of the Waverly Drive underpass, the sidewalk along Hyperion Avenue is too narrow (2-ft wide) to be usable. Instead, safer pedestrian connectivity is achieved by a sidewalk going up to the Waverly Drive level and coming back down to Hyperion Avenue at Ettrick Street.

- ADA Compliant Pedestrian Access Route (PAR): Due to the constraint under Waverly Drive, and the grade of the alternative sidewalk to get to Waverly Drive and back down, there is no direct PAR along Hyperion Avenue. The nearest route crossing over I-5 and the LA River is Glendale Boulevard, which adds ½ mile of travel distance for pedestrians with origins or destinations in the vicinity of the Hyperion/Rowena intersection.

- Bike Lanes: There are no bike lanes on Hyperion Avenue or Glendale Boulevard across the L.A. River or I-5.

- Access and Conflict Points:
  - Signalized crosswalks exist at both ends of the project (Hyperion/Rowena and Glendale/Glenfeliz/Glenhurst)
  - Pedestrians using Hyperion Avenue have to negotiate an uncontrolled crossing of Glendale Blvd at the east end of the bridge (same condition exists on both sides of the bridge).
  - Pedestrians on northbound Glendale Blvd have to negotiate an uncontrolled crossing of the I-5 northbound off ramp.
  - Due to the grade differences between the roadway and existing ground, there are very few access points on Hyperion Avenue between Rowena and Glenfeliz/Glenhurst. All driveways and side streets are required to stop for both traffic and pedestrians along Hyperion Avenue.

Bicycle and Pedestrian Volumes

Bicycle and Pedestrian Volumes were collected in March of 2014 as part of a series of Technical Memorandums prepared by Psomas in 2014. The data collected is presented in *"Technical Memorandum #1, Existing and Future Traffic Demand"* (Psomas, June 2014) and included 12-hour bicycle and pedestrian counts (7 AM-7PM), as well as 30 intercept surveys of bicyclists and pedestrians (20 pedestrians, 10 bicyclists). Some highlights from those counts include:

- During the 12-hr period, 24 pedestrians use the east sidewalk on the Hyperion bridge. 82 pedestrians (approximately 75% of all pedestrians on Hyperion) use the west sidewalk.

- During the 12-hr period, 39 bicyclists traveled northbound on the Hyperion Avenue bridge, while 44 bicyclists (53%) traveled in the southbound direction.

- Some level of "wrong way" bike riding is taking place on the sidewalks. To some extent, this may be related to the fact that some riders may not feel comfortable riding with traffic without dedicated bike lanes.

- From the intercept surveys, the most common origin and destinations for bicycles and pedestrians were John Marshall H.S., fitness gyms, retail/services near the Hyperion/Rowena intersection, and locations near Glendale Blvd north of Glenfeliz/Glenhurst.

FUTURE CONDITIONS

The City's recommended option for Hyperion Avenue from Waverly Drive to Glendale Drive is depicted below in Figures 1 and 2.

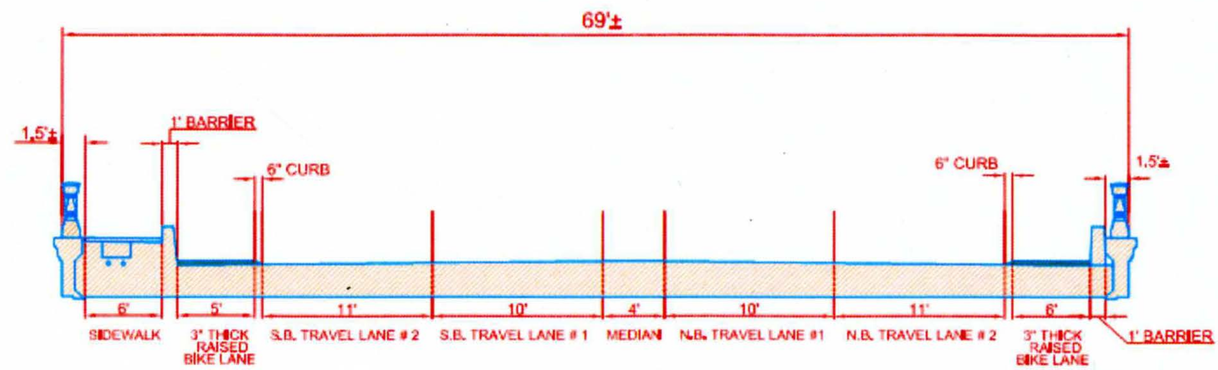

Figure 1: Hyperion Avenue Bridge over I-5, Riverside Drive and LA River (Looking North)

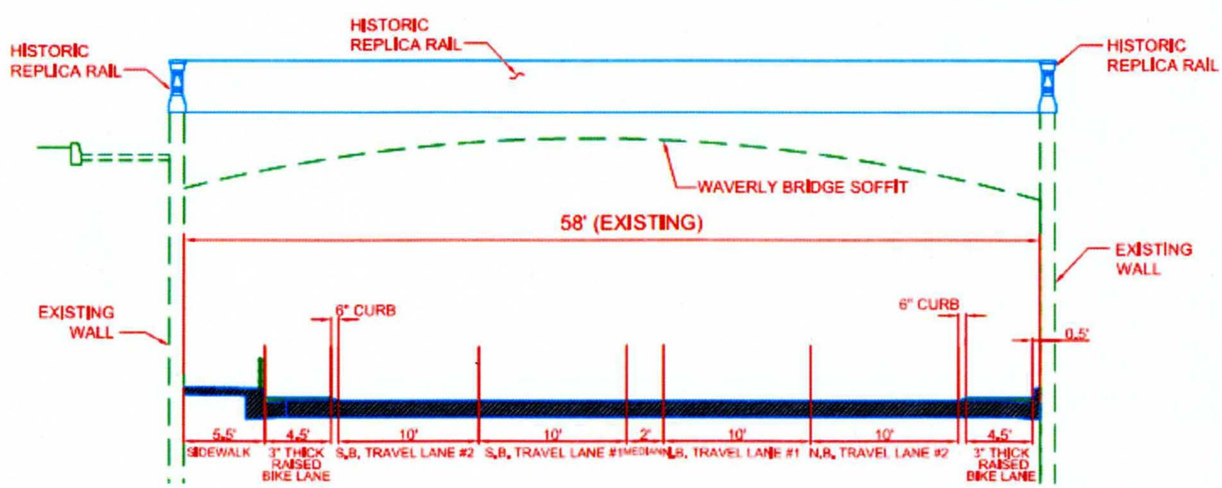

Figure 2: Hyperion Avenue at Waverly Drive (Looking North)

Based on Figures 1 and 2 and on additional project documents, the bicycle and pedestrian facilities will include the following improvements:

- Sidewalks: 6 ft sidewalk along the west side of Hyperion Avenue over I-5 and the LA River (5.5 ft under Waverly Drive).
- ADA Compliant Pedestrian Access Route (PAR): The new sidewalk will provide an ADA-compliant PAR from Silver Lake to Atwater Village.
- Bike Lanes: Raised bike lanes on both sides of Hyperion Avenue
- Access and Conflict Points:
  - Existing signalized crossings as well as number/location of driveways and access points will remain the same.
  - A signalized pedestrian crossing of Glendale Boulevard will be added at the east end of the Hyperion bridge.
  - A new signalized crossing will be provided for pedestrians at the proposed realignment of the I-5 northbound off ramp onto Glendale Blvd (see Figure 3).
  - A new pedestrian bridge will be constructed across the LA River on the old Red Car piers east of the Hyperion bridge (see Figure 3 below).

Figure 3: Proposed Pedestrian Bridge and Signalized Crossing of Realigned I-5 Northbound Off Ramp

COMPARISON OF EXISTING AND PROPOSED BICYCLE AND PEDESTRIAN FACILITIES

Figure 4 presents the existing and proposed pedestrian facilities, as well as other key pedestrian features along or near Hyperion Avenue.

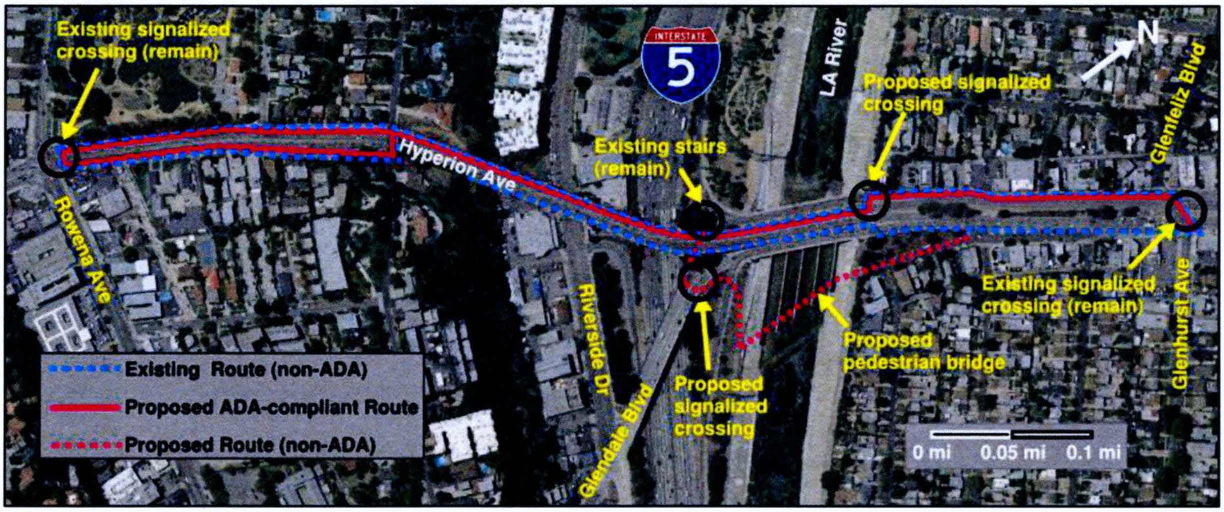

Figure 4 Comparison of Existing and Proposed Pedestrian Facilities

Based on Figure 4, as well as on information previously presented on this memorandum, the following are summaries of advantages and disadvantages of the recommended improvements when compared to the existing conditions.

<u>Advantages of the recommended improvements</u>

1. Improved conditions for disabled pedestrians by adding an ADA-compliant Pedestrian Access Route (PAR) from one end of the project to the other. Eliminating the extremely narrow sidewalk (2-ft wide) near Waverly Drive will also help improve safety in the vicinity of the underpass.

2. Improve safety for pedestrians crossing southbound Glendale Blvd at the east end of the Hyperion bridge by installing a signalized crossing.

3. Provides an additional pedestrian facility with the new Red Car bridge over the LA River. The recommended signalized crosswalks at the Glendale Blvd/I-5 NB Off-ramp will minimize vehicle-pedestrian conflicts for people walking to and from the new Red Car bridge or Glendale Blvd.

4. Enhances bicyclist safety and encourages bicycling by adding raised bike lanes on both sides of Hyperion Avenue.

<u>Disadvantages of the recommended improvements</u>

1. Eliminates the proposed sidewalk on the east side of the Hyperion bridge. This will require longer travel paths for pedestrians starting or ending their trips on the east side of Glendale Blvd between the LA River and Glenhurst Avenue. For able-bodied pedestrians who can negotiate

the stairs on the Hyperion bridge and use the Red Car pedestrian bridge, the increase in travel distance will be up to approximately 310 ft (1.5 min at 3.5 ft/s walking speed). Disabled pedestrians would have to travel to the Glenfeliz/Glenhurst intersection and back track on the other side of the road, adding up to approximately 1,550 ft in travel distance (7.4 min at 3.5 ft/s). The alternative routes described here are illustrated in the Appendix. However, it should be noted that there is no existing ADA-compliant route along Hyperion Avenue from Silver Lake to Atwater Village (the alternative route from Rowena to Glendale Blvd is longer than the PAR from the recommended option).

EVALUATION OF CEQA SIGNIFICANCE THRESHOLDS FOR BICYCLE AND PEDESTRIAN SAFETY

This section focuses on evaluating the significance thresholds for bicycle and pedestrian safety based on the Los Angeles CEQA Threshold Guide (2006), Section L.5., Project Access. The assessment of the thresholds is done using a mix of qualitative and quantitative tools.

The determination of significance for Bicycle and Pedestrian safety is based on issues associated with conflicts between pedestrians or bikes and vehicles at access and other conflict points. Table 1 lists each criterion, the effects of the recommended option and whether or not there are significant impacts.

Table 1. Summary of CEQA Bicycle and Pedestrian Thresholds Assessment

CEQA Threshold Guidelines Criterion	Effect of Project	Significant Impact?
Amount of pedestrian activity at access points	Pedestrian activity is expected to continue to steadily increase. The removal of the sidewalk on the east side of Hyperion Avenue will eliminate conflicts at those access points, but will increase pedestrian activity along the west side of the road.	No
Features that affect the visibility of pedestrians and bicyclists to drivers (and vice versa).	The location, grade, width, and traffic control for side streets and driveways will remain unchanged. Therefore, no impacts are expected. Furthermore, the addition of bike lanes will improve visibility of drivers to bicyclists and pedestrians (and vice versa)	No
Type of bike facility the project driveways cross and level of utilization	The project will add class II bike lanes, which is expected to have two key beneficial effects: 1) Provide a dedicated, delineated space for bicyclists making drivers more aware of them; and 2) improve sight visibility for drivers at all access points by shifting vehicles away from the curb line.	No
Physical conditions such as curves, slopes, walls, landscaping or others that could result in vehicle/pedestrian, or vehicle/bicycle crashes	No changes are proposed to physical conditions that would affect the listed crash types. In fact, the widening of the narrow sidewalk under Waverly Drive will help reduce vehicle/pedestrian crashes.	No

Another question that has been asked is the pedestrian safety impact of the recommended option having sidewalk on only one side of the road, and the likelihood of conflicts between bicycles and pedestrians walking on the bike lane along the east side of Hyperion Avenue between Waverly and Glenfeliz/Glenhurst.

The *Highway Safety Manual* (AASHTO, 2010) and the *Crash Modification Factors (CMF) Clearinghouse* (http://www.cmfclearinghouse.org/) have information to quantify the safety effect of various improvements. Although there are CMFs to calculate the safety benefits of adding sidewalks along a corridor without sidewalks, there are no CMFs to evaluate the safety impact of having sidewalks on both sides of the road as opposed to just one side.

Review of other National guides and resources did not identify any widely accepted means of quantitatively assessing the benefits of having sidewalks on both sides of the road. The authors believe that part of the reason for that is the fact that the benefits of having sidewalks on both sides of the road instead of one side are highly dependent on factors such as distance between crossing opportunities, alternative routes, roadside environment, vehicular speeds, pedestrian volumes, etc.

Although doing a strictly quantitative analysis of the Hyperion project is not feasible, it is possible to develop an approximate analysis with the following assumptions/information:

- As stated early in this memorandum, 75% of the pedestrians already use the west sidewalk along Hyperion. Therefore, pedestrians that may walk on the northbound bike lane are limited to those who use the east sidewalk (currently 24 pedestrians over the peak 12 hours).

- Of the pedestrians currently using the east sidewalk, only those with origins or destinations between the LA River and Glenhurst Avenue would have to cover a greater travel distance. Those with origins/destinations within Atwater village north of Glenhurst Avenue would most likely use the west sidewalk and cross Glendale Blvd at the Glenfeliz/Glenhurst signal. The area of potential impact is depicted in Figure 5.

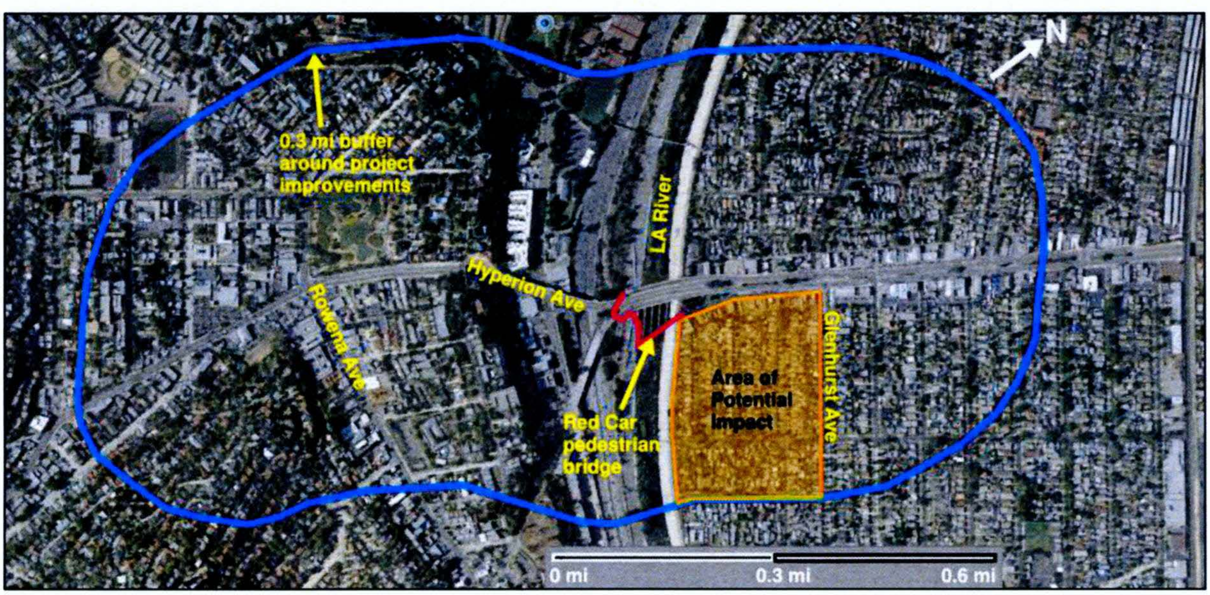

Figure 5 Area Potentially Impacted by Lack of Sidewalk on East Side of the Hyperion Bridge

- 20 Pedestrian intercept surveys (roughly a 20% sample of the 12-hr pedestrian volume) were conducted in 2014. None of the origins or destinations identified by pedestrians are located within the area of potential impact (east of Glendale Blvd between the LA River and Glenhurst Avenue). That does not mean that there is no pedestrian traffic to or from that area, but it does indicate that trips from that area represent a small percentage of the pedestrians on the east sidewalk.

- Able-bodied pedestrians with origins/destinations in the area of potential impact can use the stairs from the Hyperion bridge to access the proposed Red Car pedestrian bridge, thus minimizing the additional travel length (maximum difference is 310 ft as previously reported), and therefore would have little incentive to walk on the bike lane.

- On the *2012 National Survey of Bicyclist and Pedestrian Attitudes and Behavior (NHTSA, 2013, Table 12.1)*, 19% of pedestrians nationwide reported having a disability, health impairment or condition that limits walking. Those pedestrians would most likely be unable to negotiate the stairs to access the Red Car bridge. Instead they should use the west sidewalk, but may decide to walk on the bike lane for convenience.

From the above information, the number of pedestrians that may walk on the bike lane could be conservatively estimated if it is assumed that 10% of pedestrians using the existing east sidewalk have origins/destinations in the area of potential impact, that 19% of those pedestrians are disabled, and that all of those disabled pedestrians would walk on the bike lane (which is a conservative assumption).

Pedestrians walking on bike lane = 24 ped x 10% x 19% = 0.46 pedestrians

Based on the calculation above, even if pedestrian volumes double, the estimated number of pedestrians likely to walk along the bike lane is less than 1 for the 12 hours between 7 AM and 7 PM. The likelihood of 1 pedestrian conflicting with one of the 44 daily bicyclists using the bridge is minimal. As a result, it is concluded that the risk of pedestrian/bicycle conflicts is extremely low. Also, as previously stated, even with the need to go to Glenhurst and backtrack, the new route is shorter than the shortest existing ADA-compliant route.

ADDITIONAL RECOMMENDED BICYCLE AND PEDESTRIAN MEASURES

This analysis found that when compared to existing conditions, the recommended improvements for the Hyperion bridge project provide significant benefits in terms of bicycle accommodation, universal ADA accessibility, enhanced safety (visibility, signal control) at conflict points, and alternative pedestrian routes. The main impact is the loss of the existing sidewalk on the east side of the bridge. While that was found to not be a significant impact, the following additional measures are recommended to enhance pedestrian safety and make sure that pedestrians in the area are aware of and know how to use the available alternatives:

- Install guide signs for pedestrians directing them to the available routes (i.e. near the Hyperion bridge stairs to show access to the LA River and the Red Car River Park).
- Consider installation of regulatory signs prohibiting walking along the bike lanes.
- Develop educational materials (maps, brochures, etc.) and outreach showing how bicycles and pedestrians can traverse the project area during and after construction.

Zwartz' talking

and he's not holding back!

The Hyperion Bridge Project [Bike Lanes]

Kudos To Los Angeles City Bureau of Engineering
By Scott Zwartz
June 8, 2015

. When a city agency does a good job, we should applaud them. The 6-3-2015 Bureau of Engineering Report on the Hyperion Bridge Project merits our kudos. 6-3-15 BofE Hyperion Rpt

. At the same time, we must realize that poor data in means poor conclusions out. As Zwartz Talk showed in its prior article on The City's Mobility Plan 2035 and the Hyperion Bridge Bike Lanes http://bit.ly/1GkfZiv , the City has deprived all of us of vital data concerning the health hazards of Bike Lanes on major boulevards like the Hyperion Bridge. Thus, Zwartz Talk does not fault the Bureau of Engineering because the City withheld the scientific studies which show that the worldwide consensus is that due to the adverse health impacts of air pollution, wherever possible **Bike Lanes should be located away from major roads**.

. The Bureau of Engineering was not the only person who was mislead into overlooking the serious health hazard to children from placing Bike Lanes inches from auto emissions. Councilman-elect David Ryu made the same error.

. On the same day that the Bureau of Engineering released its report, Councilmember-elect David Ryu released his letter supporting the worst possible alternative. Ryu 6-3-15 L

. Ryu's Option is: remove one northbound vehicle lane, have two Bike Lanes and sidewalks on both sides. After learning what the B of E has said, Zwartz Talk hopes that Councilmember-elect Ryu will revise his opinion to reflect the facts, science and law.

Here is what the Bureau of Engineering said about that Option.

. 1. *The Removal of the One Northbound Lane Would Immediately Reduce the Bridge's LOS from LOS B to LOS D.*

. On page 22, the B of E report says," From a CEQA perspective, this would be a significant impact."

. Councilmember-elect Ryu naively relied on a non-city report obtained by CD#13 Councilmember O'Farrell which said that removing one northbound vehicle lane would have "very minor impact to automobiles on the bridge."

. **Wrong!** An immediate downgrade to an LOS of D is MAJOR. Councilman-elect Ryu will want to explain on what basis he wrote that removal of one vehicle lane would "*improve traffic flow.*" Not even O'Farrell's hired-gun said removing one auto travel lane would improve traffic flow.

. 2. *Remove One Vehicle Lane Means Litigation and a Revised IS/MND for the Entire Project.*

. Any significant impact requires a revised EIR. The Bureau of Engineering was explicit that the removal of one auto travel lane is significant and requires that the project be recirculated.

The 2013 IS/MND did not include an alternative with three vehicle lanes. Approval of such an alternative would require additional CEQA review (at minimum revision and recirculation of an IS/MND and if any potentially significant impact could not be mitigated to less than significant, an Environmental Impact Report would be required).

Another Problem with the Hyperion Bridge Project – the Failure to Assess the Alternative of Bike Lanes over the Old Piers of the Red Car Line

. LA Weekly openly discussed this alternative http://bit.ly/1EHAQYI, but the City appears to have withheld this alternative from the Bureau of Engineering. This is a third major CEQA flaw – the failure to study all reasonable alternatives.

Garcettism's© Materially False Data Harms City Projects

. Once again, we are faced with litigation and delay of a project due to what Zwartz Talk has termed Garcettism© – the intentional use of false data in order to mislead citizens into approving projects which then end up in litigation.

. As Zwartz Talk recently pointed out, Bike Lanes on major boulevards pose a very serious health risk to cyclists, especially children http://bit.ly/1GkfZiv. Garcettism© deliberately withheld from Angelenos the worldwide consensus against locating Bike Lanes on major boulevards, wherever feasible. Garcettism© withheld this vital information not only from the Hyperion Project but also from Garcetti's Mobility Plan 2035.

. The serious Health Risk of Bike Lanes on major boulevards constitutes additional significant new data that requires the recirculation of the IS/MND. When the significant CEQA impact of the immediate downgrade of the Hyperion Bridge Project from an LOS of B to an LOS of D is added to the Serious Health Risks to locating the Bike Lanes on the bridge itself, not only will the IS/MND need to be recirculated, but a full CEQA EIR will be required.

. As Bureau of Engineering pointed out, this delay jeopardizes the CalTrans design funds which are presently set to expire on June 30, 2017.

. Under Garcettism©, the city is constantly involved in needless litigation due to Garcetti's habitual use of Wishful Thinking and Fatally Flawed Data.

. In January 2015, Judge Allan Goodman rejected Garcetti's update to the Hollywood Community Plan due to its Wishful Thinking and Fatally Flawed Data which subverted the law. 2014-1-15 J. Goodman Decision

. Garcettism also caused the losses in the projects at Hollywood and Gower (Judge Ann Jones), The Target Loss at Sunset and Western (Judge Fruin), the rejection of The Millennium and the fiasco with CIM Group's Sunset and Gordon project (both Judge James Chalfant). Now the Hyperion Bridge Project is headed to litigation – simply because of the Garcetti Administration cannot be honest.

. A significant result of Garcettism© is that it stops projects which virtually everyone wants, such as the Hyperion Bridge project and the Target Store in Hollywood. In the Target Store litigation, even the petitioners wanted a Target Store at that location, but not at the cost of lawlessness. The devil is not necessarily in the projects themselves nor in the citizens who bring the litigation to force the Garcetti Administration to follow the law. The time-consuming and expensive litigation arises from the hubris of Garcettism© which places its own whims above both science and the law.

Conclusions:

. The IS/MND needs to be re-circulated. The City could save a lot of time and maybe not lose the CalTrans design funding, if it voluntarily authorizes a CEQA Draft EIR – now, ASAP, forthwith, without delay.

. At least four areas should be in the Notice of Preparation for an honest Environment Impact Report:

. 1. The Health Risks of placing Bike Lanes on major boulevards.

. 2. The significant impact of the downgrading Hyperion Bridge to a LOS of D. Only 45/100 of 1% of those who use the bridge are bicyclists.

. 3. A full study of the construction of Hyperion Bridge Bike Lanes on the old piers for the Red Car, per the LA Weekly article.

. 4. The rejection of Garcettism's© reliance on false data and myths rather than using science and full disclosure.

One comment on "The Hyperion Bridge Project [Bike Lanes]"

Bom Latonge
06/09/2015
Edit
You piece of shit.

Like
Like

Reply

This entry was posted on 06/08/2015 by scottzwartz and tagged Bike Lanes, Garcetti, Hyperion.
http://wp.me/p65tcV-1K
Previous post

Zwartz' talking

and he's not holding back!

City’s Bike Lanes Pose Health Danger to Children

City’s Bike Lanes Pose Serious Health Danger to Children
by Scott Zwartz
Sunday, June 7, 2015

. Young people’s lung are susceptible to the toxic impact of air pollution in Bike Lanes on major boulevards and places like the Hyperion Bridge.

http://1.usa.gov/1MwIU3K Environ Health Perspect. 2010 Jun; 118(6): 783–789. Published online 2010 Feb 25. doi: 10.1289/ehp.0901622 PMCID: PMC2898854 Research Commuters’ Exposure to Particulate Matter Air Pollution Is Affected by Mode of Transport, Fuel Type, and Route

http://bit.ly/1QeUINz November 2003, Air Pollution and Children’s Health, Ca VEPA’s Office of Environmental Health Hazard Assessment [Use of Hyper Links]

. While all cyclists suffer from the toxic impact from riding along boulevards with high concentrations of air pollution, the young are at a much greater risk.

. Nonetheless, Garcetti’s Mobile Pan 2035 [MP 2035] is urging parents and others to have children and teens use so called “protected bike lanes” along major boulevards. In the Atwater area, Garcetti and councilmember-elect Ryu are promoting Bike Lanes on the Hyperion Bridge despite the fact the City recognized that it has a viable option to construct Bike Lanes over the piers for the old Red Car.

The Myths and Lies of Garcettism ©

. Zwartz Talk would not bring Garcettism© into this discussion without evidence of his Mobility Plan 2035’s conscious deception to mislead Angelenos. Many Angelenos fall for the Myth of Bike Lanes in heavily trafficked boulevards because they are preceded with the word “protected.”

. The word “Protected” diverts the public’s attention in two ways:

. 1. Like a magician who wants us to look over “there” while he does some stuff over “here,” the words “protected Bike Lanes” bring to mind the danger of accidents with cars.

. 2. That way The Mobility Plan 2035 misdirects our attention away from the significant Health Risks

. The health danger of our children slowly accumulating fine particulate matter deep into their lungs is not as visually dramatic as their being run down by a bus, but it is real. Worldwide, studies agree that Bike Lanes should be away from major boulevards.

When Citizens Raised The Health Dangers, The City Responded With Deceptions

. When citizens did, however, raise the health danger in response to the Draft EIR, Garcettism© came into play. The City’s responses are in the Final EIR’s Master Response 4: Potential Air Quality Effects from Project. [Response 4]

. The City’s responses are so far off the mark, that the best word to describe them is fraudulent. They are reminiscent of the Tobacco Industry’s claims that smoking is good for you. For example:

The studies reveal that pedestrians and cyclists experience lower fine particulate matter and CO exposure concentrations in comparison to those inside vehicles (the vehicle shell provides no protection to passengers). *Final EIR for MP 2035, page 2-17*

The Final EIR Response is Misleading:

. 1. The issue is not air *inside* vehicles vs *outside* vehicles

. 2. The issue is whether bike lanes should be ***on major boulevards*** or located away from boulevards on residential streets.

. 3. The study which the City cites, The Kaur Study, is based on The Netherlands which has a network of Bike Lanes which are already removed from busy streets.

. 4. The City omits the most important finding from the Kaur Study:

In general, the exposure studies examined revealed pedestrians and cyclists to experience lower fine particulate matter and CO exposure concentrations in comparison to those inside vehicles—the vehicle shell provided no protection to the passengers. **Proximity to the pollutant sources had a significant impact on exposure concentration levels experienced, consequently individuals should be encouraged to use back street routes.** *Kaur Study Abstract http://bit.ly/1MzVC1N*

. When one reads what the City wrote in its Response, it is maddening to see that they quoted the abstract right up to the point that the Kaur Study completely repudiated the idea that Bike Lanes should be on heavily traffic boulevards.

. Because we are discussing the health of our children and pointing out the Myths and Lies of Garcettism©, we need to emphasize this intentional deception. The Kaur Study conclusion to keep Bike Lanes away from major streets is right there up front in the article’s abstract. There was no need to wade through a lot of science stuff. Right there was the article’s conclusion: “**Proximity to the pollutant sources had a significant impact on exposure concentration levels experienced, consequently individuals should be encouraged to use back street routes.**”

World Consensus That Bikes Lane

Should Not be On Major Boulevards

. In fact, the world has a consensus that Bike Lanes should not be placed on heavily traffic boulevards. There is no way that the Garcetti Administration could have inadvertently missed the worldwide agreement. Had Garcetti allowed the EIR to fully acknowledge the world's decision on the location of Bike Lanes, there would be no Bike Lanes proposed for Reseda Boulevard, Sherman Way, Devonshire. Manchester, Venice, Westwood, Vermont south of Slauson, Martin Luther King, or the Hyperion Bridge.

. Following is a sampling of the studies of which conclude that Bike Lanes should be away from major boulevards.

. 1. http://1.usa.gov/1MwIU3K Environ Health Perspect. 2010 Jun; 118(6): 783–789. Published online 2010 Feb 25. doi: 10.1289/ehp.0901622 PMCID: PMC2898854 Research Commuters' Exposure to Particulate Matter Air Pollution Is Affected by Mode of Transport, Fuel Type, and Route

Results: We found that median PNC exposures were highest in diesel buses (38,500 particles/cm3) and for cyclists along the high-traffic intensity route (46,600 particles/cm3) and lowest in electric buses (29,200 particles/cm3). Median PM10 exposure was highest from diesel buses (47 μg/m3) and lowest along the high- and low-traffic bicycle routes (39 and 37 μg/m3). The median soot exposure was highest in gasoline-fueled cars (9.0 × 10-5/m), diesel cars (7.9 × 10-5/m), and diesel buses (7.4 × 10-5/m) and lowest along the low-traffic bicycle route (4.9 × 10-5/m). **Because the minute ventilation (volume of air per minute) of cyclists, which we estimated from measured heart rates, was twice the minute ventilation of car and bus passengers, we calculated that the inhaled air pollution doses were highest for cyclist**s. With the exception of PM10, we found that inhaled air pollution doses were lowest for electric bus passengers. [**bold** added]

. 2. http://bit.ly/1F3cF65 2011 Determination of Personal Exposure to Traffic Pollution While Travelling by Different Modes, National Institute of Water and Atmospheric Research, Auckland, New Zealand

This research also makes it clear that the exposure of cyclists can be substantially reduced further by providing **cyclists with spatial separation from vehicle exhaust**, and that substantial benefits can be achieved by relatively small degrees of separation (5-10m) [16 to 32 feet]. *Conclusion of New Zealand Study page 10*

. 3. http://1.usa.gov/1JB3XST 2013, Oregon Climate Smart Communities Scenarios Health Impact Assessment

There is evidence that drivers and passengers of cars and buses are exposed to air pollution at levels similar to or exceeding those of pedestrians and cyclists [118 – 120]. **There is also evidence that air pollution exposure is higher for pedestrians and bicyclists along busy roadways than next to roads with less traffic**. A study underway in Portland has demonstrated that pedestrian exposure on a high – volume roadway is greater than driving exposure, but less than bus exposure. Travel along lower – volume roadways significantly reduced pedestrian exposure [121]. *Oregon Study pages 31-32*

. While the Oregon Study focused on air-quality inside cars, it was able to extrapolate to people living, walking and cycling near heavily trafficked roads.

Those outside of cars may also be impacted, including residents of housing less than 300 meters (~1,000 feet) from a major road (more than 10,000 motor vehicles per day), and **bicycle and pedestrian commuters along major roads**. *Oregon Study Page 32*

. Rather than inform the public that Bike Lanes along major boulevards pose a significant health risk to children, the Mobility Plan 2035 obfuscated this widely known fact. If the public knew about the health risks, it would not tolerate the construction of Bike Lanes in the worst possible locations.

. 4. http://bit.ly/1eX5Spv Education Code § 17213 prohibits School within 500 feet of Freeway or major traffic corridor

. Since 2003 California Education Code § 17213 prohibits a new school to be built "within 500 feet of the edge of the closest traffic lane of a freeway or other busy traffic corridor" unless there is no alternative. State law recognizes the health hazard of being close to a busy traffic corridor. Yet, **The City plans to construct Bike Lanes in the busy, high pollution corridors** which the State deems such a health hazard that schools have to be 500 feet away.

Summary:

. The worst possible place for a child to ride a bike is in a Bike Lane on a busy street like Reseda Boulevard, Sherman Way, Devonshire. Manchester, Venice, Westwood, Vermont south of Slauson, Martin Luther King, or Hyperion Bridge, etc. Garcetti's Mobility Plan 2035 went out of its way to mislead and deceive people into believing that we should built Bike Lanes in the worst possible places.

Conclusion:

. The **Mobility Plan 2035** is materially defective due to its fatally flawed data. Whenever significant new information is available prior to the adoption of the Final EIR by the City Council, the City has to redo the EIR or that portion of the EIR to which the new information pertains.

. The **Hyperion Bridge** should have no Bike Lanes on the bridge itself, but instead the City should use the piers for the old Red Cars.

10 comments on "City's Bike Lanes Pose Health Danger to Children"

Pingback: Morning Links: Hollywood bike parking becomes a homeless site; a blogger argues bike lane air is bad for LA kids |

Edit
Guest
06/08/2015


Edit

Here you go, "Study: Separated bikeways mean better air quality for bikers, walkers"

http://bikeportland.org/2010/10/28/study-cycle-tracks-mean-better-air-quality-for-bikers-walkers-41754

And protected bike lanes mean we can plant more trees, which surely is goof for the air (see pictures in the post)

http://la.streetsblog.org/2014/05/22/sweet-new-protected-bikeway-on-beautiful-rosemead-blvd-in-temple-city/

★Like
Like

Reply
scottzwartz
06/08/2015

 Edit

Thank you for both articles. I would be interested whether there is any study of the air pollution on the Rosemead Bike Lane. At this point, my main focus is on the health of riding close to the auto emissions. Also, one needs to consider the LOS of the street and the the number of cyclists. The Hyperion Bridge for example would go from a LOS of B to a LOS of D — immediately — if one vehicle lane were removed for a bike lane. Cyclist, however, are only 45/100 of 1% of the bridge’s traffic.

That information should have been presented earlier so that people could make an informed decision.

★Like
Like

Reply

Coolguyz1234
06/08/2015
Edit

We don’t use LOS anymore we use VMT. So the LOS is not to be considered. Cyclists are such a such a small % of the bridge’s traffic because the is no bike infrastructure and because of the nature of the road which is a de facto freeway. If for instance there were wide sidewalks on both sides, big protected bike lanes and slower, calmer traffic then more people would use those facilities.

★Like
Like

scottzwartz
06/08/2015
 Edit

The City used LOS and we are accustomed to using LOS, but the City should also stay current. I cannot, however, use VMT (Vehicle Miles Traveled) when I can find no data on the Bridge’s VMT.

Attracting more cyclists to the bridge would worsen the health hazard. The City needs to make a commitment to keep Bike Lanes away from the air pollution of vehicle admissions whenever possible. There is an alternative route for bicycles which the City should use.

Because the City has withheld this material information from the public, the Hyperion Bridge Project will need a CEQA EIR. Hopefully, one thing citizens will learn is that wishful thinking and false data are very harmful to city planning in the long run.

★Like
Like

Private
06/08/2015
Edit

Your thesis is that cars poison kids therefore we should create more public space for cars. Did you copy and paste this from The Onion?

I’ve also noticed that the sidewalk on Glendale between Riverside and Rowena is the same distance from traffic lanes as bike lanes would be from traffic on the Hyperion Bridge. For the safety of the children we should ban moms from using strollers on that sidewalk. Better yet, let's just remove those sidewalks to add traffic lanes to protect the kids.

★Like
Like

Reply
scottzwartz
06/08/2015
 Edit
Did you take the time to read the hyper-links? Most likely not as you show no understanding of the science. when people materially misconstrue what has been written, I take that to mean they have no legitimate critique.

★Like
Like

Reply
Bob Gunderson (@Bob_Gunderson)
06/08/2015
 Edit
Thank you so much for this important information. Kids are entitled to dirty air in the city, but they are undeserving of bike lanes.

★Like
Like

Reply
scottzwartz
06/08/2015
 Edit
see also
http://bit.ly/1IqxxJ7 a follow-up article limited to the Hyperion Bridge

★Like
Like

Reply
Sergio Lamborghini
06/09/2015
 Edit
Great article You dumdum.

★Like
Like

Reply

This entry was posted on 06/07/2015 by scottzwartz.
http://wp.me/p65tcV-1x
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Research

Commuters' Exposure to Particulate Matter Air Pollution Is Affected by Mode of Transport, Fuel Type, and Route

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The authors declare they have no actual or potential competing financial interests.

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Abstract

Go to:

Background Commuters are exposed to high concentrations of air pollutants, but little quantitative information is currently available on differences in exposure between different modes of transport, routes, and fuel types.

Objectives The aim of our study was to assess differences in commuters' exposure to traffic-related air pollution related to transport mode, route, and fuel type.

Methods We measured particle number counts (PNCs) and concentrations of $PM_{2.5}$ (particulate matter ≤ 2.5 μm in aerodynamic diameter), PM_{10}, and soot between June 2007 and June 2008 on 47 weekdays, from 0800 to 1000 hours, in diesel and electric buses, gasoline- and diesel-fueled cars, and along two bicycle routes with different traffic intensities in Arnhem, the Netherlands. In addition, each-day measurements were taken at an urban background location.

Results We found that median PNC exposures were highest in diesel buses (38,500 particles/cm^3) and for cyclists along the high-traffic intensity route (46,600 particles/cm^3) and lowest in electric buses (29,200 particles/cm^3). Median PM_{10} exposure was highest from diesel buses (47 μg/m^3) and lowest along the high- and low-traffic bicycle routes (39 and 37 μg/m^3). The median soot exposure was highest in gasoline-fueled cars (9.0 × 10^{-5}/m), diesel cars (7.9 × 10^{-5}/m), and diesel buses (7.4 × 10^{-5}/m) and lowest along the low-traffic bicycle route (4.9 × 10^{-5}/m). Because the minute ventilation (volume of air per minute) of cyclists, which we estimated from measured heart rates, was twice the minute ventilation of car and bus passengers, we calculated that the inhaled air pollution doses were highest for cyclists. With the exception of PM_{10}, we found that inhaled air pollution doses were lowest for electric bus passengers.

Conclusions Commuters' rush hour exposures were significantly influenced by mode of transport, route, and fuel type.

Keywords: air pollution, commuting, cycling, particles, soot, transport

In Europe, people spend 1–1.5 hr/day traveling (World Health Organization 2005). Because most of the traveling occurs during rush hours, commuting contributes significantly to total exposure to transport-related air pollution. Exposure to air pollution in traffic has been related to short-term cardiovascular and respiratory health effects in a small number of studies (Adar et al. 2007; McCreanor et al. 2007; Peters et al. 2004; Riediker et al. 2004; Strak et al. 2009).

Air pollution levels in various transport modes have been compared in a limited number of studies. In most studies, exposure to particulate matter was higher in buses and cars than were exposures encountered during walking or cycling (Kaur et al. 2007). Rank et al. (2001) measured higher total dust concentrations when driving in cars than when riding on bicycles. Adams et al. (2001a, 2002) detected highest exposures to PM ≤ 2.5 μm in aerodynamic diameter ($PM_{2.5}$) in buses, followed by cars, and lowest on bicycles. They found that elemental carbon (EC) exposure was highest when riding in cars, followed by buses, and lowest when riding on bicycles. In another study, McNabola et al. (2008) found that $PM_{2.5}$ exposures were highest in buses, followed by cars and bicycles, and lowest when walking. In contrast, Briggs et al. (2008) found exposures to coarse, fine, and ultrafine particles to be higher when walking on sidewalks than when driving in a car. Boogaard et al. (2009) found slightly higher particle number counts (PNCs) and $PM_{2.5}$ exposure levels when driving in cars than when riding on bicycles.

Exposure levels are influenced by the mode of transport and by the route and type of vehicle. For walkers and cyclists, PM exposures are higher on high-traffic routes than on low-traffic routes (Adams et al. 2001a; Kaur et al. 2005; McNabola et al. 2008; Strak et al. 2009; Thai et al. 2008). Adams et al. (2001a) measured higher $PM_{2.5}$ levels in open-back buses than in closed buses, and Hammond et al. (2006) measured three to four times higher PNC in diesel buses than in compressed natural gas buses or buses with oxidation catalysts. Several studies concluded that a significant portion (up to 30%) of air pollutants in (school) buses is due to self-pollution (Adar et al. 2008; Behrentz et al. 2004). For example, opening windows during driving, idling of the bus, and opening bus doors led to higher in-bus exposures (Asmi et al. 2009; Hammond et al. 2006).

It is currently difficult to precisely quantify differences in air pollution exposure between different modes of transport. One reason is that in most studies, exposures in different modes were not measured simultaneously; thus, background concentrations may have been different. Some studies reported air pollution levels from background monitoring stations to indicate different conditions between the different sampling days (Adams et al. 2001a; Fondelli et al. 2008; Thai et al. 2008). However, different particle samplers often were used to measure exposure of commuters and at fixed sites (typically routine monitors), which made quantitative comparisons between commuters' exposure and urban background sites difficult.

To overcome some of the limitations of previous studies, we decided to conduct a larger scale study that systematically compares exposure levels between different modes of transport. The aim of the present study was to quantify differences in exposure to air pollutants in traffic compared with simultaneously measured urban background concentrations and to examine the differences in air pollution exposure associated with commuting by car, bus, and bicycle.

Materials and Methods

Go to:

The TRAVEL (Transport Related Air Pollution, Variance in Commuting, Exposure and Lung Function) study examined commuters' exposure to air pollution and associated health effects. Exposures to PNC, $PM_{2.5}$, PM_{10}, and soot were measured in diesel and gasoline-fueled cars, in diesel and electric trolley buses, and along two bicycle routes with low- and high-traffic intensity. To determine doses of inhaled air pollution, we estimated minute ventilation (ventilation rate per minute) for the three commuting modes by measuring the heart rates of 34 volunteers. The relation between heart rate and minute ventilation was determined for each volunteer (Zuurbier et al. 2009).

Transport modes and urban background We collected particle samples between 0800 and 1000 hours on 47 weekdays (Tuesdays and Thursdays), with samples collected for each mode of transportation on approximately one-third of the days. Collection days were evenly spaced over 1 year, from June 2007 until June 2008, to include a range of meteorological conditions.

In total, we had 47 sampling days; of these, one-third of the collections were made in cars, one-third in buses, and one-third on bicycles. The measurements were taken in varying order. Thus, on one-third of the days, we measured exposures simultaneously in a diesel and a gasoline-fueled car. The cars were new rental, multiperson vehicles; we used two diesel models—the Ford S-Max and the Volkswagen Sharan, and four gasoline-fueled models—Ford Galaxy, Renault Espace, Seat Alhambra, and Peugeot 807. Car windows were closed during sampling, and air conditioning was set at a moderate level.

On one-third of the days we measured exposures in an electric trolley bus and a diesel bus simultaneously, during the regular service of the buses; hence, during the trip passengers got on and off. The buses were not equipped with air conditioning, windows were closed during sampling, and smoking was not allowed. The mean age of both diesel and electric buses was 7 years old (the two newest buses were 5 years old, the two oldest buses were 18 and 10 years old). Diesel buses were retrofitted with particulate filters.

On the remaining one-third of the days we measured exposures simultaneously along two cycling routes with different traffic intensity. Technicians rode three-wheeled cargo bicycles to transport the equipment.

The 22-km route was the same for the cars, buses, and the high-traffic bicycle route. It covered the center of Arnhem, a medium-sized Dutch city (145,000 inhabitants), and followed roads with an average traffic intensity of 15,000 vehicles/day (range, 7,000–30,000 vehicles/day). To examine the difference in exposure when cycling along high- and low-traffic roads, the second bicycle route followed roads with less traffic, at some distance from the other route (Figure 1). We selected the streets with the least amount of traffic to maximize the contrast with the high-traffic route. Average traffic intensity on this 22-km route was approximately 5,000 vehicles/day and varied from car-free roads to roads with 30,000 vehicles/day on small sections of the route that overlapped with the high-traffic route. The cars drove the route twice, the buses went around one and two-third times, and the bicycles were driven around once and doubled a small portion (10%) of the route to complete 2 hr.

Figure 1
Map of routes. BG, urban background measurement site; dotted line, low-traffic bicycle route; solid line, car, bus, and high-traffic bicycle route. ©2009 Google – Map data ©2009 Tele Atlas.

On each sampling day, at the same time interval, we collected samples at an urban background location that was situated near the start and end point of the route, 250 m from main roads (Figure 1), using the same types of samplers.

Measurement methods We measured PNCs with three portable, real-time condensation particle counters (CPCs; model 3007, TSI, Inc., Shoreview, MN, USA). This CPC uses 1-propanol as condensation liquid and measures particles > 10 nm. One-second averages were recorded. We compared quality assurance tests on the three CPC3007 units with one TSI CPC3022 unit [see Supplemental Material (doi:10.1289/ehp.0901622)].

We measured $PM_{2.5}$ using real-time active-sampling personal DataRAMs (model 1200; MIE Inc., Bedford, MA, USA), equipped with $PM_{2.5}$ cyclones (model GK 2.05 KTL; BGI Inc., Waltham, MA, USA) and pumps with a flow of 4 ± 0.4 L/min (AFC400s, BGI Inc.). The DataRAMs were calibrated by the manufacturer against SAE fine (ISO fine) (International Organization for Standardization, Geneva, Switzerland) dust. One-second averages were recorded. Before each measurement, we performed a zero check using a high-efficiency particulate (HEPA) filter (provided by TSI). A correction factor was used to correct for relative humidity (RH) [see Supplemental Material (doi:10.1289/ehp.0901622)].

We collected PM_{10} on 37-mm 2-µm pore-size Teflon filters, using Harvard Impactors (Air Diagnostics and Engineering Inc., Naples, ME, USA) and pumps (model SP-280E, Air Diagnostics and Engineering Inc., Harrison, ME) with a flow of 10 ± 0.5 L/min.

We determined soot content of the filters using a smoke stain reflectometer (model M43D, Diffusion Systems Ltd., London, UK). We measured reflectance at five different positions on each filter and calculated the average into an absorbance coefficient according to ISO 9835 (Cyrys et al. 2003). To facilitate calculation of doses, we converted soot (absorption) levels into EC concentrations using the equation EC = 1.6053 × absorption – 0.2620 (Cyrys et al. 2003). Exposures are expressed as soot (absorption) levels and doses as EC.

Additional details on quality assurance are reported in the Supplemental Material (doi:10.1289/ehp.0901622).

We used voice recorders on 3 of the 16 bicycle sampling days to record events such as passing mopeds and passing buses. We obtained meteorological data (temperature, rain, wind speed, wind direction) from a meteorological station near the city center of Arnhem.

To estimate the minute ventilation during commuting by bicycle, car, and bus, heart rates of the participants were recorded during commuting using Polar RS400 heart rate monitors (Polar Electro, Kempele, Finland). All participants performed a submaximal bicycle ergometer test during which heart rate and minute ventilation were measured simultaneously at increasing cycling intensity. Minute ventilation was measured using a pneumotachometer (Jaeger, Viasys Healthcare, Hoechberg, Germany). The tests have been described in more detail elsewhere (Zuurbier et al. 2009). We used the mean ventilation rates of the participants to calculate doses of inhaled air pollution.

Data analysis We used Wilcoxon signed-rank tests to test differences between the simultaneously measured air pollution concentrations in the various transport modes and the urban background concentration, because parametric *t*-tests were influenced by outliers. We defined level of significance as $p < 0.05$. For the continuous PNC and $PM_{2.5}$ data, we compared 2-hr mean values. For comparisons between measurements in transport and at the urban background location and between two modes that were measured simultaneously, we calculated ratios for each sampling day and calculated median and interquartile ranges of the daily ratios.

To compare measurements that were taken on different sampling days, we corrected air pollution concentrations for absolute differences between the mean background concentrations during all sampling days and the background concentration of each sampling day, following previous studies (Cyrys et al. 2003). We used Kruskal–Wallis tests to test for differences between transport modes. We only used days with complete data sets in the analyses, and all analyses were performed using SAS (version 9.1; SAS Institute Inc., Cary, NC, USA).

Results

Go to:

Short-term exposure variability Figure 2 shows examples of the observed temporal variations of the PNCs found during commuting by car, bus, and bicycle. The PNCs on both bicycle routes were characterized by short, high peaks of 400,000–500,000 particles/cm^3. Using the voice recorder data, we found that some of the peaks during cycling could be attributed to passing mopeds and buses and to cycling on busy roads. PNCs in cars and buses showed fewer, lower peaks, mostly < 200,000 particles/cm^3. Peaks in cars and buses typically lasted up to 5 min.

Figure 2

PNCs. (*A*) Bus sampling day, 22 January 2008. Black, diesel bus; gray, electric bus; dotted line, urban background. The diesel bus left and arrived about 15 min later than the electric bus. To facilitate geographical comparison, the time of the diesel **...**

PNCs were clearly higher in the city center where streets are enclosed by high buildings on both sides, which causes a street canyon effect [see Supplemental Material, Figure 3 (doi:10.1289/ehp.0901622)].

Illustrations of real-time $PM_{2.5}$ concentrations show short peaks of concentrations exceeding 200 μg/m^3 (Figure 3). Mean $PM_{2.5}$ concentrations show less clear patterns of higher concentrations in the city center than did the PNCs [see Supplemental Material, Figure 4 (doi:10.1289/ehp.0901622)].

Figure 3

$PM_{2.5}$. (*A*) Bus sampling day, 15 April 2008. Black, diesel bus; gray, electric bus; dotted line, urban background. The diesel bus left and arrived about 15 min later than the electric bus. To facilitate geographical comparison, the time of the diesel bus **...**

Differences in exposure between modes of transport and background Figure 4 and Table 1 summarize exposure levels during commuting. Levels of all measured pollutants were significantly higher for all modes of transport compared with urban background levels. We found the smallest contrast between commuting and background concentrations for PM_{10} and the largest contrast for soot. Absolute $PM_{2.5}$ concentration levels should be interpreted with care, because concentrations from the light-scattering method were frequently higher than the gravimetrically determined PM_{10} concentrations. Differences between in-traffic exposure and background PNC exposures are smaller for 2-hr median values than for 2-hr mean values, especially for bicycles. This is explained by the many peaks occurring during bicycle rides that affected mean values more than median values. For $PM_{2.5}$, differences between median and mean values are small, reflecting fewer peaks in $PM_{2.5}$ [see Supplemental Material, Table 1 (doi:10.1289/ehp.0901622)].

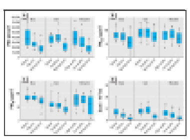

Figure 4

Exposures in modes of transport and at the urban background location on corresponding sampling days. (*A*) Two-hour average PNCs (particles/cm^3). Two-hour average $PM_{2.5}$ (*B*), PM_{10} (*C*), and soot (*D*; fraction of PM_{10}). Box-and-whisker plots indicate lower **...**

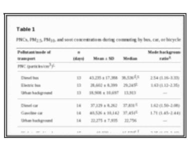

Table 1

PNCs, $PM_{2.5}$, PM_{10}, and soot concentrations during commuting by bus, car, or bicycle.

Soot concentrations and PNCs were higher in diesel buses than in electric buses (Table 1, Figure 4). On 7 of the 15 bus sampling days, the diesel buses were retrofitted with diesel particulate filters. Differences in pollutant concentrations measured on the diesel buses with and without filter were small and not significant. For example, the median ratio for soot concentrations in diesel buses compared with electric buses was 1.3, both with and without filters on the diesel buses.

Concentrations of all pollutants in gasoline-fueled cars were similar to concentrations in diesel cars. Sixteen different cars of six models were used throughout the study, so comparisons of different car models were not possible. The average soot concentration ratio of diesel to gasoline-fueled cars was 0.87 (range, 0.65–1.19) for the 13 days with diesel cars equipped with particulate filters, and 1.00 and 1.16 on the 2 days with diesel cars without filters.

Soot levels and PNCs were higher along high-traffic bicycle routes than along low-traffic bicycle routes.

Average meteorological conditions differed between the three types of sampling days [see Supplemental Material, Table 2 (doi:10.1289/ehp.0901622)]. There was more rainfall and higher wind speed on bus sampling days. Background concentrations of PNCs, $PM_{2.5}$, and soot were significantly lower on bus sampling days than on car and bicycle sampling days. Background PM_{10} was significantly lower on car sampling days compared with bus and bicycle sampling days.

After correction for differences in background levels, PNC was highest along the high-traffic bicycle route and lowest in electric buses (Table 2). PM_{10} exposure was highest in diesel cars and diesel buses and lowest along both bicycle routes. Soot exposure was highest in diesel buses and gasoline-fueled cars and lowest along both bicycle routes and in electric buses. $PM_{2.5}$ showed a different pattern: concentrations along the bicycle routes and in cars were higher than in buses. $PM_{2.5}$ results were sensitive to RH, probably related to the applied correction factor. When only taking into account samples with mean RH < 90%, $PM_{2.5}$ differences between diesel and electric buses and between diesel and gasoline-fueled cars remained significant, but differences among buses, cars, and bicycles disappeared.

Table 2
Exposure levels of PNC, $PM_{2.5}$, PM_{10}, and soot.

Relative differences in PNC and $PM_{2.5}$ exposures between diesel and electric buses, diesel, and gasoline-fueled cars and the two bicycle routes were similar in the first and second (less busy) hour of the commute. Buses and cars drove the same route, but in the second hour the buses drove more slowly and thus less of the route than did the cars. The differences in PNC and $PM_{2.5}$ exposures between buses and cars were the same in the first hour compared with the full 2 hr.

Differences in inhaled doses Because of their increased physical activity, minute ventilation of cyclists was higher than that of car and bus passengers. In this study the estimated minute ventilation of cyclists was on average 23.5 L/min, varying from 11.6 to 47.7 L/min between the 34 men and women. The average minute ventilation of car passengers was 11.8 L/min, varying from 5.1 to 20.9 L/min, and the average minute ventilation of bus passengers was 12.7 L/min, varying from 5.4 to 19.5 L/min (Zuurbier et al. 2009).

On average, the minute ventilation of cyclists was 2.1 times higher than that of car passengers and 2.0 times higher than that of bus passengers. Minute ventilation of bus passengers was 1.1 times higher than that of car passengers.

Inhaled doses of all air pollutants were highest in cyclists (Table 2). Inhaled doses of PNC and $PM_{2.5}$ of cyclists was twice as high as that of car and bus passengers, whereas inhaled doses of PM_{10} and EC (calculated using the soot levels) were substantially less than twice as high. PM_{10} dose was higher for bus than car passengers, whereas EC doses were comparable for passengers of diesel buses and both cars and lowest for passengers of electric buses.

Discussion

Go to:

Exposures to PNC, soot, PM_{10}, and $PM_{2.5}$ during commuting were significantly elevated compared with urban background concentrations. Exposures were higher in diesel buses than in electric buses and higher along high-traffic bicycle routes compared with low-traffic bicycle routes, especially for soot and PNC. Exposure levels in diesel and gasoline-fueled cars were comparable. PM_{10} and soot exposures of cyclists were lowest, whereas PNC exposure in electric buses was lowest. Because of their increased minute ventilation, the inhaled doses of all studied air pollutants were highest for cyclists. Inhaled doses of electric bus passengers were lowest for all studied air pollutants except for PM_{10}.

Comparison with urban background The substantial contrast in commuters' exposure compared with the urban background is consistent with previous studies (Kaur et al. 2007). Our study has added a comparison made simultaneously with the same equipment, thus ruling out potential bias related to temporal variation and sampling method.

The $PM_{2.5}$ contrast is larger than found in previous studies. This could be related to the measurements being performed in the rush hour only versus typically daily samples in the fixed-site monitoring studies or to sampling errors of the DataRAMs. We corrected $PM_{2.5}$ readings for RH. When omitting $PM_{2.5}$ values with RH > 90%, differences among buses, cars, and bicycles disappeared.

Differences between diesel and electric buses, diesel and gasoline-fueled cars, and bicycle routes PNC and soot levels were 32% and 46% higher in diesel buses compared with electric powered buses. Diesel buses have not been compared with electric buses before. In-bus exposures are affected by the bus doors opening frequently to let passengers on and off the bus, letting in the air pollution from outside. For diesel buses, a portion of the diesel exhaust of the bus itself contributes to the in-bus exposure. The contrast agrees with the self-pollution of up to 30% reported for U.S. school buses (Adar et al. 2008; Behrentz et al. 2004). The smaller difference in PM_{10} exposure between diesel and electric buses can be explained by passengers causing resuspension of PM_{10} in both types of buses (Song et al. 2009). Differences between buses with and without retrofitted particulate filters were small and not significant, but the number of measurements may not have been sufficient to detect differences.

Our study suggests that the use of clean buses may be beneficial both for urban air quality and for bus passengers.

We found no significant differences between levels of air pollutants in diesel and gasoline-fueled cars, except for soot: In-car exposures to soot were lower in diesel cars than in gasoline-fueled cars. Possibly because of the limited number of samples in diesel cars without particulate filters, we did not detect a potential impact of particulate filters on the soot exposure in diesel cars. The major difference between cars and buses is that doors do not open regularly, so infiltration of exhaust from the car itself is less likely. We used new cars (maximum of 6 months of use). In older diesel cars, exposure levels might be higher, but from this study we conclude that for new cars there is no difference in PM exposure inside the vehicles. The rental cars were all about the same size, but not of the same model. Thus, measured air pollution levels are representative of these types of cars in general.

Cyclists on the high-traffic route were exposed to 40% higher levels of PNC and 35% higher levels of soot compared with cyclists on the low-traffic route. Exposure to PM_{10} and $PM_{2.5}$ did not differ significantly. Kaur et al. (2005) found a 40% difference in PNC exposure among cyclists and pedestrians who traveled along high- versus low-traffic roads in Central London. Strak et al. (2009) found differences in PNC and soot of 60% and 40%, respectively, between two cycling routes with different traffic intensities, but no difference in $PM_{2.5}$. Adams et al. (2001b) found differences in $PM_{2.5}$ of 20–50% between low- and high-traffic bicycle routes in Central London.

Contrasts in commuters' exposures in this study were slightly smaller than in most other studies, probably because the exposure levels on the high-traffic route were lower, especially lower than in Central London. Despite efforts to select streets with very low traffic, sections of the low-traffic bicycle route were used as a shortcut to avoid the congested major streets during morning rush hour. The car-free roads in the route were frequently used by mopeds, which have been shown to be an important source of cyclists' exposure to PNCs

(Boogaard et al. 2009).

By choosing a low-traffic route, cyclists can reduce their air pollution exposure. However, within the current Dutch infrastructure it is not easy to avoid all contact with motorized traffic.

Differences in exposure between modes of transport Compared with cyclists, PM_{10} exposures of bus and car passengers were 60% and 20% higher, respectively. The small study of Rank et al. (2001) detected 70% more total PM exposure in cars compared with exposure on bicycles, similar to our data. Resuspension of coarse PM probably partly explains the difference in exposure. The significantly higher soot concentration in cars and diesel buses versus cyclists is in agreement with results of Adams et al. (2002), who measured 70% higher EC exposures in cars compared with cyclists and 20% higher EC in buses compared with cyclists.

Exposures to $PM_{2.5}$ were comparable in all modes in our study. In electric buses levels were slightly lower and in gasoline-fueled cars slightly higher than in all other modes. Kaur et al. (2005) and Boogaard et al. (2009) also found only small differences in $PM_{2.5}$ concentrations between cars, diesel buses, and bicycles. Average differences in PNC exposure were small among cyclists, car, and diesel bus passengers in the present study. Diesel bus passengers and cyclists along the high-traffic route experienced 10–30% higher PNC exposure than did car passengers and cyclists on the low-traffic route. PNC exposure in electric buses was clearly lowest. Boogaard et al. (2009) reported slightly higher PNC exposure in cars compared with cyclists. Kaur et al. (2005) reported slightly higher PNC exposure of bus and car passengers compared with cyclists. Absolute PNC levels were much higher in London, as can be expected because of higher traffic intensity in London compared with the relatively small city of Arnhem. PNCs on bicycle routes were characterized by short, high peaks, whereas PNCs in cars and buses showed fewer, lower peaks. Indicators of frequency distribution, such as the 95th percentile of the values, may reflect exposure differences more completely.

Inhaled doses of air pollutants Inhaled pollution doses were highest for cyclists, because of the higher minute ventilation (Zuurbier et al. 2009). We found almost two times higher pollution doses in cyclists for PNC; the differences in soot (EC) and PM_{10} were more modest. In view of the heavy equipment slowing down the speed of the cargo bike, the speed of cycling in the study was relatively low (12 km/hr) compared with average cycling speeds, which are around 15 km/hr, so this study may underestimate minute ventilation levels and consequently the inhaled dose of air pollutants during normal cycling. However, in the one previous study that compared minute ventilation of cyclists (cycling at 17 km/hr) with that of car drivers (van Wijnen et al. 1995), the ratio was 2.3, comparable to our average ratio of 2.1.

Traveling time also influences the doses of inhaled air pollutants. Because traveling time depends on the route and on the time of day—during rush hour cyclists and buses using separate bus lanes may travel faster than cars, whereas in most other situations cars travel faster—we did not take this into account in our study.

Potential policy implications This study shows that exposure to air pollutants is significantly lower in electric powered buses than in diesel buses. The use of clean buses, such as electric buses, is therefore beneficial not only for outdoor air quality but also for bus passengers. Policy makers are encouraged to increase the use of clean buses, such as electric buses.

Cyclists are exposed to air pollutants from surrounding traffic. The higher minute ventilation of cyclists especially increases the inhaled doses of air pollutants. Health implications of exposure to short, high peaks during cycling instead of the lower, longer peaks in cars and buses are not clear but could be important (Peters et al. 2004). Because the positive health effects of cycling (Baumann 2004; de Geus et al. 2009, 2008; Hendriksen et al. 2000) likely outweigh the health risks of increased pollution loads, and because cyclists do not emit any air pollutants and thus contribute to clean air, cycling should not be discouraged. Cyclists should be encouraged to choose for low-traffic routes by making them aware of the potential health benefits and by route planners with options to choose for low-traffic routes. City planners should create bicycle lanes with less (preferably no) contact with motorized traffic. In view of the intimate mixing of bicycles and mopeds in the Netherlands, further improvements can be expected from the replacement of spark engine by electric mopeds.

Footnotes

Go to:

Supplemental Material is available online (doi:10.1289/ehp.0901622 via http://dx.doi.org/).

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Air Pollution and Children's Health

A fact sheet by
Cal/EPA's Office of Environmental Health Hazard Assessment and
The American Lung Association of California.

In the past 30 years, state and federal air-quality programs have made great progress in reducing air pollution. However, there has been an increasing awareness in recent years that children may be more susceptible than adults to the harmful effects of air pollutants.

The California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA) assesses health risks from environmental contaminants. OEHHA currently is reviewing whether the state's ambient air quality standards are adequate to protect the health of infants and children and is working to identify toxic air contaminants that may cause infants and children to be especially susceptible to illnesses. The American Lung Association of California (ALAC) and its 15 local associations work to prevent lung disease and promote lung health. Since 1904, the American Lung Association has been fighting lung disease through education, community service, advocacy and research.

This fact sheet by OEHHA and ALAC provides information on air pollution and children's health.

Why may children be at greater risk than adults from air pollution?

In many cases, children may have greater exposure than adults to airborne pollutants. Infants and children generally breathe more rapidly than adults, which increases their exposure to any pollutants in the air. Infants and children often breathe through their mouths, bypassing the filtering effect of the nose and allowing more pollutants to be inhaled. Children generally spend significantly more time outdoors than adults, especially during summer months when smog levels are highest.

Children are often more susceptible to the health effects of air pollution because their immune systems and developing organs are still immature. For example, lead that is inhaled is more easily deposited in the fast-growing bones of children. Irritation or inflammation caused by air pollution is more likely to obstruct their narrower airways. It may also take less exposure to a pollutant to trigger an asthma attack or other breathing ailment due to the sensitivity of a child's developing respiratory system. Exposure to toxic air contaminants during infancy or childhood could affect the development of the respiratory, nervous, endocrine and immune systems, and could increase the risk of cancer later in life.

What are the major kinds of air pollutants and their impacts on children?

"Criteria" Air Pollutants

Several common air pollutants are regulated under the state and federal Clean Air Acts and are known as "criteria" air pollutants. Two of the most widespread criteria pollutants are particulate matter (PM) and ozone. PM consists of microscopic particles less than one-seventh the width of a human hair. These particles come from a variety of both manmade and natural sources, such as diesel engines, smoke from fireplaces as well as forest and agricultural fires, and dust from tilled farmland. PM can bypass the body's natural defenses and penetrate deep into the lungs. The elderly, children and people with existing respiratory or cardiac diseases are considered to be especially sensitive to the harmful effects of PM. Recent studies suggest that PM may exacerbate asthma and cause coughs and other respiratory symptoms in children. Recent studies also suggest that prolonged exposure to PM may also affect the growth and functioning of children's lungs. Researchers found that as children grow up in smoggier areas, there is a notable lag in lung function growth.

Ozone is the major component of urban smog. It is formed by chemical reactions in the atmosphere involving sunlight and various gases in motor vehicle exhaust and industrial emissions. Ozone is a powerful respiratory irritant that can cause lung inflammation, transient decreases in lung function, shortness of breath, chest pain, wheezing, coughing and exacerbation of respiratory illnesses such as asthma. Long-term and repeated ozone exposures may lead to chronically reduced lung function.

OEHHA provides detailed analyses of health information on PM, ozone and other common pollutants to the California Air Resources Board (ARB), which sets ambient air quality standards for those pollutants. These air quality standards have been established at levels that are intended to protect the health of all Californians. Unfortunately, PM and ozone levels in most urban areas of California frequently exceed the ambient air quality standards. ARB and local air districts operate regulatory programs under state and federal requirements to reduce airborne levels of these pollutants to the ambient air quality standards.

Other "criteria pollutants" include nitrogen dioxide, carbon monoxide, lead, sulfur dioxide, sulfates and hydrogen sulfide.

ARB is sponsoring a major 10-year study of the effects of air pollution on children's health. Information on this study is available at ARB's web site at http://www.arb.ca.gov/research/abstracts/98-320.htm.

Toxic Air Contaminants

California also regulates the emissions of other pollutants, known as toxic air contaminants, which may pose a present or potential hazard to human health or contribute to an increase in deaths or serious illnesses. OEHHA provides assessments of the health risks from various toxic air contaminants to ARB, which can enact control measures designed to reduce the exposure of Californians to these contaminants. More than 200 chemicals are currently listed as toxic air contaminants in California.

Many toxic air contaminants are present in motor vehicle exhaust and industrial emissions, and are formed from the combustion of other chemicals. Among these byproducts of combustion are dioxins and polycyclic organic matter (POM), which may affect the development of the fetus and increase cancer risks later in life. Particles found in diesel exhaust may make children more susceptible to allergies and asthma. Other toxic contaminants have numerous sources. Acrolein, which may exacerbate asthma, is found in motor vehicle exhaust, tobacco and wood smoke, some industrial emissions, and is also formed in the atmosphere from chemical reactions involving other pollutants. Some toxic air contaminants, such as lead, are naturally occurring in the environment. Lead has been banned as an additive in gasoline and household paint but is present in some industrial emissions. It can cause developmental problems and harm the central nervous system.

What is California doing to improve health protection for children?

The Legislature in 1999 approved the Children's Environmental Health Protection Act (Senate Bill 25), authored by Senator Martha Escutia, which seeks to ensure that California's air quality programs protect the health of infants and children. The Act requires ARB, in consultation with OEHHA, to review all ambient air quality standards to determine whether they adequately protect the health of the public, including children. The Act also requires OEHHA to identify toxic air contaminants that may cause infants and children to be especially susceptible to illness, and it requires ARB to determine the adequacy of existing control measures for toxic air contaminants or the need for new control measures to protect the health of the public, particularly infants and children.

The initial stage of the ambient air quality standards review was completed in December 2000. ARB and OEHHA concluded that PM and ozone may cause health effects in children even at levels meeting the state's ambient air quality standards. The amount of time children play outdoors and their higher breathing rates are some of the reasons why children may be more sensitive to these pollutants than adults. The review also found evidence that levels of nitrogen dioxide (a pollutant in motor vehicle exhaust and many kinds of industrial emissions) that meet the ambient air quality standard may harm asthmatic children.

OEHHA completed a detailed review of the PM standards in May 2002. Based on this review, OEHHA recommended, and ARB adopted, stricter new PM standards in June 2002. (The report containing the results of the PM review and the new standards can be accessed at www.oehha.ca.gov/air/toxic_contaminants/PM10notice.html#may). OEHHA is conducting a detailed review of the ozone standard and is developing recommended revisions to the standard for ARB's consideration. After this is completed, OEHHA will review the nitrogen dioxide standard.

ARB and local air districts may have to develop new regulations to reduce emissions and ultimately reduce airborne levels of these pollutants to comply with the new PM standards and any future new standards for ozone and nitrogen dioxide.

The Act also requires OEHHA to identify toxic air contaminants that may cause infants and children to be especially susceptible to illnesses. ARB will review and, if necessary, revise or adopt any control measures needed to reduce the public's exposure to these contaminants. The Act required OEHHA to identify up to five contaminants in 2001. These contaminants - dioxin, lead, POM, diesel exhaust particles, and acrolein - are briefly discussed in the previous section. More detailed information is available at www.oehha.ca.gov/air/toxic_contaminants/SB25finalreport.htm.

OEHHA is developing guidelines for use in evaluating the adequacy of existing air toxics regulations. Beginning in 2004, OEHHA will annually evaluate selected toxic air contaminants and identify unhealthful levels of exposure to these contaminants. OEHHA will use these evaluations beginning in 2005 to annually update the list of toxic air contaminants that impact infants and children.

The Act also requires ARB to evaluate the adequacy of its current air-quality monitoring program to determine children's exposure to air pollutants, and it created the Children's Environmental Health Center within the California Environmental Protection Agency to coordinate Cal/EPA's activities and provide advice to the Governor and Cal/EPA Secretary on matters of children's environmental health.

In addition to complying with the requirements of the Children's Environmental Health Protection Act, OEHHA is taking two other steps in the area of children's health protection. OEHHA is developing improvements to scientific methods used to gauge cancer risks that children may face from exposure to contaminants in the environment. Also, OEHHA is refining methods to assess health risks from contaminants that may conceivably exist at proposed and existing school sites. These two projects are intended to improve the ability of scientists and regulators to make decisions that protect children from contaminants in the air, water, soil and food as well as elsewhere in the environment.

These efforts represent a commitment by the State of California to ensure that children have the opportunity to grow up in a healthy environment.

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Review

Fine particulate matter and carbon monoxide exposure concentrations in urban street transport microenvironments

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Abstract

Personal exposure studies are crucial alongside microenvironment and ambient studies in order to get a better understanding of the health risks posed by fine particulate matter and carbon monoxide in the urban transport microenvironment and for making informed decisions to manage and reduce the health risks. Studies specifically assessing the $PM_{2.5}$, ultrafine particle count and carbon monoxide personal exposure concentrations of adults in an urban transport microenvironment have steadily increased in number over the last decade. However, no recent collective summary is available, particularly one which also considers ultrafine particles; therefore, we present a review of the personal exposure concentration studies for the above named pollutants on different modes of surface transportation (walking, cycling, bus, car and taxi) in the urban transport microenvironment. Comparisons between personal exposure measurements and concentrations recorded at fixed monitoring sites are considered in addition to the factors influencing personal exposure in the transport microenvironment.

In general, the exposure studies examined revealed pedestrians and cyclists to experience lower fine particulate matter and CO exposure concentrations in comparison to those inside vehicles—the vehicle shell provided no protection to the passengers. Proximity to the pollutant sources had a significant impact on exposure concentration levels experienced, consequently individuals should be encouraged to use back street routes. Fixed monitoring stations were found to be relatively poor predictors of CO and $PM_{2.5}$ exposure concentration levels experienced by individuals in the urban transport microenvironment. Although the mode of transport, traffic and meteorology parameters were commonly identified as significant factors influencing exposure concentrations to the different pollutants under examination, a large amount of the exposure concentration variation in the exposure studies remained unexplained.

Keywords

Exposure concentrations; Urban transport microenvironment; $PM_{2.5}$; Ultrafine particle count; Carbon monoxide

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Research

Commuters' Exposure to Particulate Matter Air Pollution Is Affected by Mode of Transport, Fuel Type, and Route

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Abstract

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Background Commuters are exposed to high concentrations of air pollutants, but little quantitative information is currently available on differences in exposure between different modes of transport, routes, and fuel types.

Objectives The aim of our study was to assess differences in commuters' exposure to traffic-related air pollution related to transport mode, route, and fuel type.

Methods We measured particle number counts (PNCs) and concentrations of $PM_{2.5}$ (particulate matter ≤ 2.5 µm in aerodynamic diameter), PM_{10}, and soot between June 2007 and June 2008 on 47 weekdays, from 0800 to 1000 hours, in diesel and electric buses, gasoline- and diesel-fueled cars, and along two bicycle routes with different traffic intensities in Arnhem, the Netherlands. In addition, each-day measurements were taken at an urban background location.

Results We found that median PNC exposures were highest in diesel buses (38,500 particles/cm^3) and for cyclists along the high-traffic intensity route (46,600 particles/cm^3) and lowest in electric buses (29,200 particles/cm^3). Median PM_{10} exposure was highest from diesel buses (47 µg/m^3) and lowest along the high- and low-traffic bicycle routes (39 and 37 µg/m^3). The median soot exposure was highest in gasoline-fueled cars (9.0 $\times 10^{-5}$/m), diesel cars (7.9×10^{-5}/m), and diesel buses (7.4×10^{-5}/m) and lowest along the low-traffic bicycle route (4.9×10^{-5}/m). Because the minute ventilation (volume of air per minute) of cyclists, which we estimated from measured heart rates, was twice the minute ventilation of car and bus passengers, we calculated that the inhaled air pollution doses were highest for cyclists. With the exception of PM_{10}, we found that inhaled air pollution doses were lowest for electric bus passengers.

Conclusions Commuters' rush hour exposures were significantly influenced by mode of transport, route, and fuel type.

Keywords: air pollution, commuting, cycling, particles, soot, transport

In Europe, people spend 1–1.5 hr/day traveling (World Health Organization 2005). Because most of the traveling occurs during rush hours, commuting contributes significantly to total exposure to transport-related air pollution. Exposure to air pollution in traffic has been related to short-term cardiovascular and respiratory health effects in a small number of studies (Adar et al. 2007; McCreanor et al. 2007; Peters et al. 2004; Riediker et al. 2004; Strak et al. 2009).

Air pollution levels in various transport modes have been compared in a limited number of studies. In most studies, exposure to particulate matter was higher in buses and cars than were exposures encountered during walking or cycling (Kaur et al. 2007). Rank et al. (2001) measured higher total dust concentrations when driving in cars than when riding on bicycles. Adams et al. (2001a, 2002) detected highest exposures to PM ≤ 2.5 μm in aerodynamic diameter ($PM_{2.5}$) in buses, followed by cars, and lowest on bicycles. They found that elemental carbon (EC) exposure was highest when riding in cars, followed by buses, and lowest when riding on bicycles. In another study, McNabola et al. (2008) found that $PM_{2.5}$ exposures were highest in buses, followed by cars and bicycles, and lowest when walking. In contrast, Briggs et al. (2008) found exposures to coarse, fine, and ultrafine particles to be higher when walking on sidewalks than when driving in a car. Boogaard et al. (2009) found slightly higher particle number counts (PNCs) and $PM_{2.5}$ exposure levels when driving in cars than when riding on bicycles.

Exposure levels are influenced by the mode of transport and by the route and type of vehicle. For walkers and cyclists, PM exposures are higher on high-traffic routes than on low-traffic routes (Adams et al. 2001a; Kaur et al. 2005; McNabola et al. 2008; Strak et al. 2009; Thai et al. 2008). Adams et al. (2001a) measured higher $PM_{2.5}$ levels in open-back buses than in closed buses, and Hammond et al. (2006) measured three to four times higher PNC in diesel buses than in compressed natural gas buses or buses with oxidation catalysts. Several studies concluded that a significant portion (up to 30%) of air pollutants in (school) buses is due to self-pollution (Adar et al. 2008; Behrentz et al. 2004). For example, opening windows during driving, idling of the bus, and opening bus doors led to higher in-bus exposures (Asmi et al. 2009; Hammond et al. 2006).

It is currently difficult to precisely quantify differences in air pollution exposure between different modes of transport. One reason is that in most studies, exposures in different modes were not measured simultaneously; thus, background concentrations may have been different. Some studies reported air pollution levels from background monitoring stations to indicate different conditions between the different sampling days (Adams et al. 2001a; Fondelli et al. 2008; Thai et al. 2008). However, different particle samplers often were used to measure exposure of commuters and at fixed sites (typically routine monitors), which made quantitative comparisons between commuters' exposure and urban background sites difficult.

To overcome some of the limitations of previous studies, we decided to conduct a larger scale study that systematically compares exposure levels between different modes of transport. The aim of the present study was to quantify differences in exposure to air pollutants in traffic compared with simultaneously measured urban background concentrations and to examine the differences in air pollution exposure associated with commuting by car, bus, and bicycle.

Materials and Methods

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The TRAVEL (Transport Related Air Pollution, Variance in Commuting, Exposure and Lung Function) study examined commuters' exposure to air pollution and associated health effects. Exposures to PNC, $PM_{2.5}$, PM_{10}, and soot were measured in diesel and gasoline-fueled cars, in diesel and electric trolley buses, and along two bicycle routes with low- and high-traffic intensity. To determine doses of inhaled air pollution, we estimated minute ventilation (ventilation rate per minute) for the three commuting modes by measuring the heart rates of 34 volunteers. The relation between heart rate and minute ventilation was determined for each volunteer (Zuurbier et al. 2009).

Transport modes and urban background We collected particle samples between 0800 and 1000 hours on 47 weekdays (Tuesdays and Thursdays), with samples collected for each mode of transportation on approximately one-third of the days. Collection days were evenly spaced over 1 year, from June 2007 until June 2008, to include a range of meteorological conditions.

In total, we had 47 sampling days; of these, one-third of the collections were made in cars, one-third in buses, and one-third on bicycles. The measurements were taken in varying order. Thus, on one-third of the days, we measured exposures simultaneously in a diesel and a gasoline-fueled car. The cars were new rental, multiperson vehicles; we used two diesel models—the Ford S-Max and the Volkswagen Sharan, and four gasoline-fueled models—Ford Galaxy, Renault Espace, Seat Alhambra, and Peugeot 807. Car windows were closed during sampling, and air conditioning was set at a moderate level.

On one-third of the days we measured exposures in an electric trolley bus and a diesel bus simultaneously, during the regular service of the buses; hence, during the trip passengers got on and off. The buses were not equipped with air conditioning, windows were closed during sampling, and smoking was not allowed. The mean age of both diesel and electric buses was 7 years old (the two newest buses were 5 years old, the two oldest buses were 18 and 10 years old). Diesel buses were retrofitted with particulate filters.

On the remaining one-third of the days we measured exposures simultaneously along two cycling routes with different traffic intensity. Technicians rode three-wheeled cargo bicycles to transport the equipment.

The 22-km route was the same for the cars, buses, and the high-traffic bicycle route. It covered the center of Arnhem, a medium-sized Dutch city (145,000 inhabitants), and followed roads with an average traffic intensity of 15,000 vehicles/day (range, 7,000–30,000 vehicles/day). To examine the difference in exposure when cycling along high- and low-traffic roads, the second bicycle route followed roads with less traffic, at some distance from the other route (Figure 1). We selected the streets with the least amount of traffic to maximize the contrast with the high-traffic route. Average traffic intensity on this 22-km route was approximately 5,000 vehicles/day and varied from car-free roads to roads with 30,000 vehicles/day on small sections of the route that overlapped with the high-traffic route. The cars drove the route twice, the buses went around one and two-third times, and the bicycles were driven around once and doubled a small portion (10%) of the route to complete 2 hr.

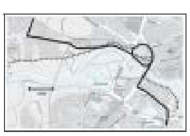

Figure 1
Map of routes. BG, urban background measurement site; dotted line, low-traffic bicycle route; solid line, car, bus, and high-traffic bicycle route. ©2009 Google – Map data ©2009 Tele Atlas.

On each sampling day, at the same time interval, we collected samples at an urban background location that was situated near the start and end point of the route, 250 m from main roads (Figure 1), using the same types of samplers.

Measurement methods We measured PNCs with three portable, real-time condensation particle counters (CPCs; model 3007, TSI, Inc., Shoreview, MN, USA). This CPC uses 1-propanol as condensation liquid and measures particles > 10 nm. One-second averages were recorded. We compared quality assurance tests on the three CPC3007 units with one TSI CPC3022 unit [see Supplemental Material (doi:10.1289/ehp.0901622)].

We measured $PM_{2.5}$ using real-time active-sampling personal DataRAMs (model 1200; MIE Inc., Bedford, MA, USA), equipped with $PM_{2.5}$ cyclones (model GK 2.05 KTL; BGI Inc., Waltham, MA, USA) and pumps with a flow of 4 ± 0.4 L/min (AFC400s, BGI Inc.). The DataRAMs were calibrated by the manufacturer against SAE fine (ISO fine) (International Organization for Standardization, Geneva, Switzerland) dust. One-second averages were recorded. Before each measurement, we performed a zero check using a high-efficiency particulate (HEPA) filter (provided by TSI). A correction factor was used to correct for relative humidity (RH) [see Supplemental Material (doi:10.1289/ehp.0901622)].

We collected PM_{10} on 37-mm 2-μm pore-size Teflon filters, using Harvard Impactors (Air Diagnostics and Engineering Inc., Naples, ME, USA) and pumps (model SP-280E, Air Diagnostics and Engineering Inc., Harrison, ME) with a flow of 10 ± 0.5 L/min.

We determined soot content of the filters using a smoke stain reflectometer (model M43D, Diffusion Systems Ltd., London, UK). We measured reflectance at five different positions on each filter and calculated the average into an absorbance coefficient according to ISO 9835 (Cyrys et al. 2003). To facilitate calculation of doses, we converted soot (absorption) levels into EC concentrations using the equation EC = 1.6053 × absorption – 0.2620 (Cyrys et al. 2003). Exposures are expressed as soot (absorption) levels and doses as EC.

Additional details on quality assurance are reported in the Supplemental Material (doi:10.1289/ehp.0901622).

We used voice recorders on 3 of the 16 bicycle sampling days to record events such as passing mopeds and passing buses. We obtained meteorological data (temperature, rain, wind speed, wind direction) from a meteorological station near the city center of Arnhem.

To estimate the minute ventilation during commuting by bicycle, car, and bus, heart rates of the participants were recorded during commuting using Polar RS400 heart rate monitors (Polar Electro, Kempele, Finland). All participants performed a submaximal bicycle ergometer test during which heart rate and minute ventilation were measured simultaneously at increasing cycling intensity. Minute ventilation was measured using a pneumotachometer (Jaeger, Viasys Healthcare, Hoechberg, Germany). The tests have been described in more detail elsewhere (Zuurbier et al. 2009). We used the mean ventilation rates of the participants to calculate doses of inhaled air pollution.

Data analysis We used Wilcoxon signed-rank tests to test differences between the simultaneously measured air pollution concentrations in the various transport modes and the urban background concentration, because parametric *t*-tests were influenced by outliers. We defined level of significance as $p < 0.05$. For the continuous PNC and $PM_{2.5}$ data, we compared 2-hr mean values. For comparisons between measurements in transport and at the urban background location and between two modes that were measured simultaneously, we calculated ratios for each sampling day and calculated median and interquartile ranges of the daily ratios.

To compare measurements that were taken on different sampling days, we corrected air pollution concentrations for absolute differences between the mean background concentrations during all sampling days and the background concentration of each sampling day, following previous studies (Cyrys et al. 2003). We used Kruskal–Wallis tests to test for differences between transport modes. We only used days with complete data sets in the analyses, and all analyses were performed using SAS (version 9.1; SAS Institute Inc., Cary, NC, USA).

Results

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Short-term exposure variability Figure 2 shows examples of the observed temporal variations of the PNCs found during commuting by car, bus, and bicycle. The PNCs on both bicycle routes were characterized by short, high peaks of 400,000–500,000 particles/cm^3. Using the voice recorder data, we found that some of the peaks during cycling could be attributed to passing mopeds and buses and to cycling on busy roads. PNCs in cars and buses showed fewer, lower peaks, mostly < 200,000 particles/cm^3. Peaks in cars and buses typically lasted up to 5 min.

Figure 2

PNCs. (*A*) Bus sampling day, 22 January 2008. Black, diesel bus; gray, electric bus; dotted line, urban background. The diesel bus left and arrived about 15 min later than the electric bus. To facilitate geographical comparison, the time of the diesel **...**

PNCs were clearly higher in the city center where streets are enclosed by high buildings on both sides, which causes a street canyon effect [see Supplemental Material, Figure 3 (doi:10.1289/ehp.0901622)].

Illustrations of real-time $PM_{2.5}$ concentrations show short peaks of concentrations exceeding 200 μg/m^3 (Figure 3). Mean $PM_{2.5}$ concentrations show less clear patterns of higher concentrations in the city center than did the PNCs [see Supplemental Material, Figure 4 (doi:10.1289/ehp.0901622)].

Figure 3

$PM_{2.5}$. (*A*) Bus sampling day, 15 April 2008. Black, diesel bus; gray, electric bus; dotted line, urban background. The diesel bus left and arrived about 15 min later than the electric bus. To facilitate geographical comparison, the time of the diesel bus **...**

Differences in exposure between modes of transport and background Figure 4 and Table 1 summarize exposure levels during commuting. Levels of all measured pollutants were significantly higher for all modes of transport compared with urban background levels. We found the smallest contrast between commuting and background concentrations for PM_{10} and the largest contrast for soot. Absolute $PM_{2.5}$ concentration levels should be interpreted with care, because concentrations from the light-scattering method were frequently higher than the gravimetrically determined PM_{10} concentrations. Differences between in-traffic exposure and background PNC exposures are smaller for 2-hr median values than for 2-hr mean values, especially for bicycles. This is explained by the many peaks occurring during bicycle rides that affected mean values more than median values. For $PM_{2.5}$, differences between median and mean values are small, reflecting fewer peaks in $PM_{2.5}$ [see Supplemental Material, Table 1 (doi:10.1289/ehp.0901622)].

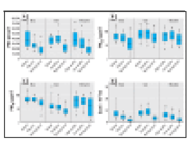

Figure 4

Exposures in modes of transport and at the urban background location on corresponding sampling days. (*A*) Two-hour average PNCs (particles/cm^3). Two-hour average $PM_{2.5}$ (*B*), PM_{10} (*C*), and soot (*D*; fraction of PM_{10}). Box-and-whisker plots indicate lower **...**

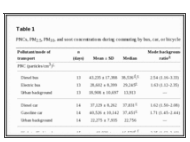

Table 1

PNCs, $PM_{2.5}$, PM_{10}, and soot concentrations during commuting by bus, car, or bicycle.

Soot concentrations and PNCs were higher in diesel buses than in electric buses (Table 1, Figure 4). On 7 of the 15 bus sampling days, the diesel buses were retrofitted with diesel particulate filters. Differences in pollutant concentrations measured on the diesel buses with and without filter were small and not significant. For example, the median ratio for soot concentrations in diesel buses compared with electric buses was 1.3, both with and without filters on the diesel buses.

Concentrations of all pollutants in gasoline-fueled cars were similar to concentrations in diesel cars. Sixteen different cars of six models were used throughout the study, so comparisons of different car models were not possible. The average soot concentration ratio of diesel to gasoline-fueled cars was 0.87 (range, 0.65–1.19) for the 13 days with diesel cars equipped with particulate filters, and 1.00 and 1.16 on the 2 days with diesel cars without filters.

Soot levels and PNCs were higher along high-traffic bicycle routes than along low-traffic bicycle routes.

Average meteorological conditions differed between the three types of sampling days [see Supplemental Material, Table 2 (doi:10.1289/ehp.0901622)]. There was more rainfall and higher wind speed on bus sampling days. Background concentrations of PNCs, $PM_{2.5}$, and soot were significantly lower on bus sampling days than on car and bicycle sampling days. Background PM_{10} was significantly lower on car sampling days compared with bus and bicycle sampling days.

After correction for differences in background levels, PNC was highest along the high-traffic bicycle route and lowest in electric buses (Table 2). PM_{10} exposure was highest in diesel cars and diesel buses and lowest along both bicycle routes. Soot exposure was highest in diesel buses and gasoline-fueled cars and lowest along both bicycle routes and in electric buses. $PM_{2.5}$ showed a different pattern: concentrations along the bicycle routes and in cars were higher than in buses. $PM_{2.5}$ results were sensitive to RH, probably related to the applied correction factor. When only taking into account samples with mean RH < 90%, $PM_{2.5}$ differences between diesel and electric buses and between diesel and gasoline-fueled cars remained significant, but differences among buses, cars, and bicycles disappeared.

Table 2
Exposure levels of PNC, $PM_{2.5}$, PM_{10}, and soot.

Relative differences in PNC and $PM_{2.5}$ exposures between diesel and electric buses, diesel, and gasoline-fueled cars and the two bicycle routes were similar in the first and second (less busy) hour of the commute. Buses and cars drove the same route, but in the second hour the buses drove more slowly and thus less of the route than did the cars. The differences in PNC and $PM_{2.5}$ exposures between buses and cars were the same in the first hour compared with the full 2 hr.

Differences in inhaled doses Because of their increased physical activity, minute ventilation of cyclists was higher than that of car and bus passengers. In this study the estimated minute ventilation of cyclists was on average 23.5 L/min, varying from 11.6 to 47.7 L/min between the 34 men and women. The average minute ventilation of car passengers was 11.8 L/min, varying from 5.1 to 20.9 L/min, and the average minute ventilation of bus passengers was 12.7 L/min, varying from 5.4 to 19.5 L/min (Zuurbier et al. 2009).

On average, the minute ventilation of cyclists was 2.1 times higher than that of car passengers and 2.0 times higher than that of bus passengers. Minute ventilation of bus passengers was 1.1 times higher than that of car passengers.

Inhaled doses of all air pollutants were highest in cyclists (Table 2). Inhaled doses of PNC and $PM_{2.5}$ of cyclists was twice as high as that of car and bus passengers, whereas inhaled doses of PM_{10} and EC (calculated using the soot levels) were substantially less than twice as high. PM_{10} dose was higher for bus than car passengers, whereas EC doses were comparable for passengers of diesel buses and both cars and lowest for passengers of electric buses.

Discussion

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Exposures to PNC, soot, PM_{10}, and $PM_{2.5}$ during commuting were significantly elevated compared with urban background concentrations. Exposures were higher in diesel buses than in electric buses and higher along high-traffic bicycle routes compared with low-traffic bicycle routes, especially for soot and PNC. Exposure levels in diesel and gasoline-fueled cars were comparable. PM_{10} and soot exposures of cyclists were lowest, whereas PNC exposure in electric buses was lowest. Because of their increased minute ventilation, the inhaled doses of all studied air pollutants were highest for cyclists. Inhaled doses of electric bus passengers were lowest for all studied air pollutants except for PM_{10}.

Comparison with urban background The substantial contrast in commuters' exposure compared with the urban background is consistent with previous studies (Kaur et al. 2007). Our study has added a comparison made simultaneously with the same equipment, thus ruling out potential bias related to temporal variation and sampling method.

The $PM_{2.5}$ contrast is larger than found in previous studies. This could be related to the measurements being performed in the rush hour only versus typically daily samples in the fixed-site monitoring studies or to sampling errors of the DataRAMs. We corrected $PM_{2.5}$ readings for RH. When omitting $PM_{2.5}$ values with RH > 90%, differences among buses, cars, and bicycles disappeared.

Differences between diesel and electric buses, diesel and gasoline-fueled cars, and bicycle routes PNC and soot levels were 32% and 46% higher in diesel buses compared with electric powered buses. Diesel buses have not been compared with electric buses before. In-bus exposures are affected by the bus doors opening frequently to let passengers on and off the bus, letting in the air pollution from outside. For diesel buses, a portion of the diesel exhaust of the bus itself contributes to the in-bus exposure. The contrast agrees with the self-pollution of up to 30% reported for U.S. school buses (Adar et al. 2008; Behrentz et al. 2004). The smaller difference in PM_{10} exposure between diesel and electric buses can be explained by passengers causing resuspension of PM_{10} in both types of buses (Song et al. 2009). Differences between buses with and without retrofitted particulate filters were small and not significant, but the number of measurements may not have been sufficient to detect differences.

Our study suggests that the use of clean buses may be beneficial both for urban air quality and for bus passengers.

We found no significant differences between levels of air pollutants in diesel and gasoline-fueled cars, except for soot: In-car exposures to soot were lower in diesel cars than in gasoline-fueled cars. Possibly because of the limited number of samples in diesel cars without particulate filters, we did not detect a potential impact of particulate filters on the soot exposure in diesel cars. The major difference between cars and buses is that doors do not open regularly, so infiltration of exhaust from the car itself is less likely. We used new cars (maximum of 6 months of use). In older diesel cars, exposure levels might be higher, but from this study we conclude that for new cars there is no difference in PM exposure inside the vehicles. The rental cars were all about the same size, but not of the same model. Thus, measured air pollution levels are representative of these types of cars in general.

Cyclists on the high-traffic route were exposed to 40% higher levels of PNC and 35% higher levels of soot compared with cyclists on the low-traffic route. Exposure to PM_{10} and $PM_{2.5}$ did not differ significantly. Kaur et al. (2005) found a 40% difference in PNC exposure among cyclists and pedestrians who traveled along high- versus low-traffic roads in Central London. Strak et al. (2009) found differences in PNC and soot of 60% and 40%, respectively, between two cycling routes with different traffic intensities, but no difference in $PM_{2.5}$. Adams et al. (2001b) found differences in $PM_{2.5}$ of 20–50% between low- and high-traffic bicycle routes in Central London.

Contrasts in commuters' exposures in this study were slightly smaller than in most other studies, probably because the exposure levels on the high-traffic route were lower, especially lower than in Central London. Despite efforts to select streets with very low traffic, sections of the low-traffic bicycle route were used as a shortcut to avoid the congested major streets during morning rush hour. The car-free roads in the route were frequently used by mopeds, which have been shown to be an important source of cyclists' exposure to PNCs

(Boogaard et al. 2009).

By choosing a low-traffic route, cyclists can reduce their air pollution exposure. However, within the current Dutch infrastructure it is not easy to avoid all contact with motorized traffic.

Differences in exposure between modes of transport Compared with cyclists, PM_{10} exposures of bus and car passengers were 60% and 20% higher, respectively. The small study of Rank et al. (2001) detected 70% more total PM exposure in cars compared with exposure on bicycles, similar to our data. Resuspension of coarse PM probably partly explains the difference in exposure. The significantly higher soot concentration in cars and diesel buses versus cyclists is in agreement with results of Adams et al. (2002), who measured 70% higher EC exposures in cars compared with cyclists and 20% higher EC in buses compared with cyclists.

Exposures to $PM_{2.5}$ were comparable in all modes in our study. In electric buses levels were slightly lower and in gasoline-fueled cars slightly higher than in all other modes. Kaur et al. (2005) and Boogaard et al. (2009) also found only small differences in $PM_{2.5}$ concentrations between cars, diesel buses, and bicycles. Average differences in PNC exposure were small among cyclists, car, and diesel bus passengers in the present study. Diesel bus passengers and cyclists along the high-traffic route experienced 10–30% higher PNC exposure than did car passengers and cyclists on the low-traffic route. PNC exposure in electric buses was clearly lowest. Boogaard et al. (2009) reported slightly higher PNC exposure in cars compared with cyclists. Kaur et al. (2005) reported slightly higher PNC exposure of bus and car passengers compared with cyclists. Absolute PNC levels were much higher in London, as can be expected because of higher traffic intensity in London compared with the relatively small city of Arnhem. PNCs on bicycle routes were characterized by short, high peaks, whereas PNCs in cars and buses showed fewer, lower peaks. Indicators of frequency distribution, such as the 95th percentile of the values, may reflect exposure differences more completely.

Inhaled doses of air pollutants Inhaled pollution doses were highest for cyclists, because of the higher minute ventilation (Zuurbier et al. 2009). We found almost two times higher pollution doses in cyclists for PNC; the differences in soot (EC) and PM_{10} were more modest. In view of the heavy equipment slowing down the speed of the cargo bike, the speed of cycling in the study was relatively low (12 km/hr) compared with average cycling speeds, which are around 15 km/hr, so this study may underestimate minute ventilation levels and consequently the inhaled dose of air pollutants during normal cycling. However, in the one previous study that compared minute ventilation of cyclists (cycling at 17 km/hr) with that of car drivers (van Wijnen et al. 1995), the ratio was 2.3, comparable to our average ratio of 2.1.

Traveling time also influences the doses of inhaled air pollutants. Because traveling time depends on the route and on the time of day—during rush hour cyclists and buses using separate bus lanes may travel faster than cars, whereas in most other situations cars travel faster—we did not take this into account in our study.

Potential policy implications This study shows that exposure to air pollutants is significantly lower in electric powered buses than in diesel buses. The use of clean buses, such as electric buses, is therefore beneficial not only for outdoor air quality but also for bus passengers. Policy makers are encouraged to increase the use of clean buses, such as electric buses.

Cyclists are exposed to air pollutants from surrounding traffic. The higher minute ventilation of cyclists especially increases the inhaled doses of air pollutants. Health implications of exposure to short, high peaks during cycling instead of the lower, longer peaks in cars and buses are not clear but could be important (Peters et al. 2004). Because the positive health effects of cycling (Baumann 2004; de Geus et al. 2009, 2008; Hendriksen et al. 2000) likely outweigh the health risks of increased pollution loads, and because cyclists do not emit any air pollutants and thus contribute to clean air, cycling should not be discouraged. Cyclists should be encouraged to choose for low-traffic routes by making them aware of the potential health benefits and by route planners with options to choose for low-traffic routes. City planners should create bicycle lanes with less (preferably no) contact with motorized traffic. In view of the intimate mixing of bicycles and mopeds in the Netherlands, further improvements can be expected from the replacement of spark engine by electric mopeds.

Footnotes

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Supplemental Material is available online (doi:10.1289/ehp.0901622 via http://dx.doi.org/).

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Climate Smart Communities Scenarios

Health Impact Assessment

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Executive Summary

Health impact assessment (HIA) provides decision-makers with information about how a proposed policy, program or project may affect the health of people, with a specific focus on equity. HIA differs from traditional public health assessment in an important way - the health impacts of a proposal are assessed before a final decision is made, allowing the results of the HIA to be considered in the decision-making process. HIA provides objective information that can be used to increase the positive health impacts of a project or policy and mitigate negative impacts.

The Oregon Health Authority (OHA) conducts HIAs on projects or policies with statewide impact and on local or regional issues when there is sufficient interest from community members or other agencies. OHA supports statewide HIA practice by facilitating the Oregon HIA Network, providing trainings, and awarding mini-grants to local health departments.

The Climate Smart Communities Scenarios (CSCS) project underway in the Portland, Oregon metropolitan (PDX metro) region is the focus of this HIA. The CSCS project is Metro Regional Government's (Metro) response to a legislative requirement to meet Oregon greenhouse gas (GHG) emissions reduction goals for small trucks and cars. While the law was passed in an effort to mitigate climate change and reduce air pollution, Metro is also considering impacts on public health, the economy, the environment and equity as part of the planning effort.

The HIA will help to support Metro in their consideration of public health and health equity in the selection and implementation of transportation and land use decisions related to GHG reduction policy in the Portland metropolitan region. Our recommendations in this report apply to the selection of the three Phase Two GHG-reduction scenarios to be further tested in 2013, as well as the development and adoption of a preferred scenario in 2014.

Changes to our climate have the potential to impact health in many ways [1]. For example, more summer heat waves with higher temperatures or longer durations would increase heat-related illness and death. Increased frequency and severity of winter storms could lead to impacts such as increased respiratory illness from mold exposure, and increased drowning [2, 3]. Plans and policies intended to help communities mitigate or adapt to climate change also have health implications.

Creating walkable and bikeable communities may increase the proportion of Portland metropolitan region residents who meet physical activity benchmarks and reduce the burden of chronic diseases that are associated with inactivity, while reducing vehicle travel and carbon emissions [4, 5]. In addition, advancements in fuel technology and policies related to fleet mix and turnover also may reduce GHG emissions in the region. Reducing greenhouse gas emissions will have inevitable health benefits for Oregonians by slowing down climate change and improving air quality.

Summary of Findings

OHA found that almost all of the policies under consideration could improve health, and that certain policy combinations were more beneficial than others. The majority of the health benefits result from increased physical activity, followed by reductions in road traffic crashes and lower exposure to particulate air pollution. Strategies that meet GHG reduction goals by decreasing vehicle miles traveled (VMT) will have the most positive impact on human health by increasing physical activity through active transportation and reducing injuries and fatalities from collisions.

The most health-promoting scenarios have similar elements: most ambitious levels of community design policies, intermediate and ambitious levels of pricing and incentives, highest levels of active transportation (including transit), lowest levels of single occupancy vehicle driving, and lowest levels of particulate air pollution. The majority of the health benefits come from increases in physical activity, followed by decreases in injuries and fatalities from collisions, and finally from decreased exposure to air pollution.

Some of the policies under consideration, or the way they are implemented, may also negatively affect health. For example, some communities in the Portland metropolitan region have poor access to active transportation infrastructure (sidewalks, bike routes, transit service). If these areas are not prioritized, implementation could worsen existing inequities, leading to increased health disparities for some of the region's residents.

The modeling tool used in this assessment shows positive health impacts due to reductions in motor vehicle crashes, but also revealed potential negative impacts from increased bike injuries. Understanding the range of potential impacts will help policy makers decide which strategies to prioritize and how to implement the strategies to maximize health and reduce health-related costs for local communities.

CSCS HIA Key Recommendations

- Develop and implement a preferred scenario that meets or surpasses the greenhouse gas emissions reduction target set for the region.
- To maximize public health benefits and meet the state target, emphasize strategies that best increase active transportation and physical activity: community design, pricing and incentives.
- Include strategies, such as community design, that can lead to decreases in road traffic injuries and fatalities for all populations in the region, in particular for children.
- Carry out additional quantitative health impact assessment of the three scenarios that are identified for further evaluation in spring 2013 to further inform development and adoption of a final preferred scenario. OHA recommends the use of ITHIM or a similar health impacts model for this future assessment.

Introduction

Health impact assessment (HIA) provides decision-makers with information about how a proposed policy, program or project may affect the health of people. HIA differs from traditional public health assessment in an important way - the health impacts of a proposal are assessed before a final decision is made, allowing the results of the HIA to be considered in the decision-making process. HIA provides objective information that can be used to increase the positive health impacts of a project or policy and mitigate negative impacts.

OHA conducts HIAs on projects or policies with statewide impact and on local or regional issues when there is sufficient interest from community members or other agencies. OHA supports statewide HIA practice by facilitating the Oregon HIA Network and providing trainings, and awarding small grants to local health departments.

Purpose

The Climate Smart Communities Scenarios (CSCS) [6] project underway in the Portland, Oregon metropolitan (PDX metro) region is the focus of this HIA. The CSCS project is a response by Portland metropolitan regional government (Metro) to a legislative requirement to meet Oregon greenhouse gas (GHG) emissions reduction goals for cars and small trucks. While the law was passed in an effort to mitigate climate change and reduce air pollution, Metro is also considering impacts on public health, the economy, the environment and equity as part of the planning effort. All of the findings and recommendations in this report focus on public heath.

The report provides a community profile, including information about current health conditions; results of a literature review on the links between proposed policies and health outcomes; quantitative assessment of land use and transportation policies tested in Phase One of the CSCS project; and recommendations for future work to expand the reach of positive impacts and mitigate negative health impacts.

The HIA will support Metro in their consideration of public health and health equity in the selection and implementation of transportation and land use decisions related to GHG reduction policy in the Portland metropolitan region. Metro's CSCS technical work group, the Metro Council, and other committees and stakeholders will use the report as they develop additional policy options to be tested in 2013, and in the creation of a final scenario to be adopted in 2014.

Climate Policy Background

Oregon passed a bill in 2007 that set goals for reducing GHG emissions in the state. House Bill 3543 states that Oregon will reduce emissions to 10 percent below 1990 levels by 2020, and to 75 percent below 1990 levels by 2050. In 2009, Oregon enacted House Bill 2001, which requires Metro to develop a preferred scenario that accommodates planned population and job growth and reduces GHG emissions from light vehicles. House Bill 2001 was a broad-based transportation bill that focused on sustainable transportation systems and funding, with the goal of ensuring that Oregon begins to address climate change. The law requires Metro to adopt the preferred scenario after public review and consultation with local governments. It also requires that local governments implement the preferred scenario through scheduled updates to transportation and land use plans.

The Oregon Land Conservation and Development Commission (LCDC) subsequently set light duty vehicle GHG emissions reduction targets for each of Oregon's six largest metropolitan areas in June 2011. In November 2012, the LCDC established administrative rules directing Metro to complete the scenario planning and adopt a preferred scenario by December 31, 2014. In the future, Oregon's other metropolitan planning organizations may also conduct similar scenario planning.

Metro's CSCS planning process will adopt a recommended transportation and land use scenario for the Portland metropolitan region that includes policies and strategies for reducing GHG emissions to meet the LCDC target. The adopted scenario will update regional policies and describe a general course of action for achieving the GHG emissions reduction target through policies, investments and actions at the state, regional and local levels.

The Oregon Health Authority (OHA) developed the CSCS HIA to support Metro's consideration of health impacts early in the scenario planning process and in future planning and implementation efforts.

Climate Policy and Health

Changes to our climate have the potential to impact health in many ways [1]. For example, more summer heat waves with higher temperatures or longer durations would increase heat-related illness and death. Increased frequency and severity of winter storms could lead to impacts such as increased respiratory illness from mold exposure, and increased drowning [2, 3]. Plans and policies intended to help communities mitigate or adapt to climate change also have health implications.

Creating walkable and bikeable communities may increase the proportion of Portland metropolitan region residents who meet physical activity benchmarks and reduce the burden of chronic diseases that are associated with inactivity, while reducing vehicle travel and carbon emissions [4, 5]. In addition, advancements in fuel technology and policies related to fleet mix and turnover also may reduce GHG emissions in the region. Reductions in air pollution may have positive impacts on health, including reductions in chronic diseases such as asthma or cancer, and acute conditions such as heart attack or stroke.

However, these policies or the way they are implemented may also negatively affect health. For example, some communities in the Portland metropolitan region have poor access to active transportation infrastructure (sidewalks, bike routes, transit service). If these areas are not prioritized, implementation could worsen existing inequities, leading to negative health effects for some of the region's residents. Understanding the range of potential impacts will help policy makers decide which strategies to prioritize and how to implement the strategies to maximize health and reduce health-related costs for local communities.

Climate Smart Communities Scenarios HIA

The CSCS HIA is intended to inform Phase Two of Metro's CSCS planning effort, which will include the development and evaluation of three alternative scenarios. Although the Phase Two scenario alternatives will draw from the 144 tested in the first phase of the CSCS project, the three scenarios will not necessarily match any of the 144 scenarios tested in Phase One. The three alternatives considered are framed around varying levels of community investment; each is designed to maximize public health, equity, economic, and environmental benefits.

In spring 2013, the Metro Council will direct staff to move forward to test the three alternatives developed in Phase Two, after gathering input from other community and business leaders at a regional summit. These alternatives will be assessed prior to the creation of a final scenario in Phase Three of the CSCS planning process. Results of the Phase Two assessment will be released in fall 2013 for discussion and to gather input to identify which policies, investments and actions should be included in a preferred scenario.

A final preferred scenario will be selected by the end of 2014 and will be implemented through policies, investments and actions at the regional and local levels, including Metro's Regional Transportation Plan and the Portland metropolitan region's growth management strategy and local plans.

The CSCS HIA will help to ensure that public health and health equity are considered in the selection and implementation of transportation and land use options related to GHG reduction policy in the Portland metropolitan region and potentially in Oregon's other metropolitan areas. The goals of the CSCS HIA are:

1. Provide evidence-based recommendations to aid decision-makers in understanding potential health impacts and tradeoffs of the CSCS policy options
2. Build and strengthen relationships between OHA and governing and planning bodies in the Portland metropolitan region
3. Promote consideration of health impacts in transportation planning and climate change mitigation efforts throughout the state
4. Promote HIA practice in Oregon

OHA followed the guidelines recommended in the North American HIA Practice Standards in developing each stage of the HIA. These stages include: screening, scoping, assessment, reporting and evaluation [7].

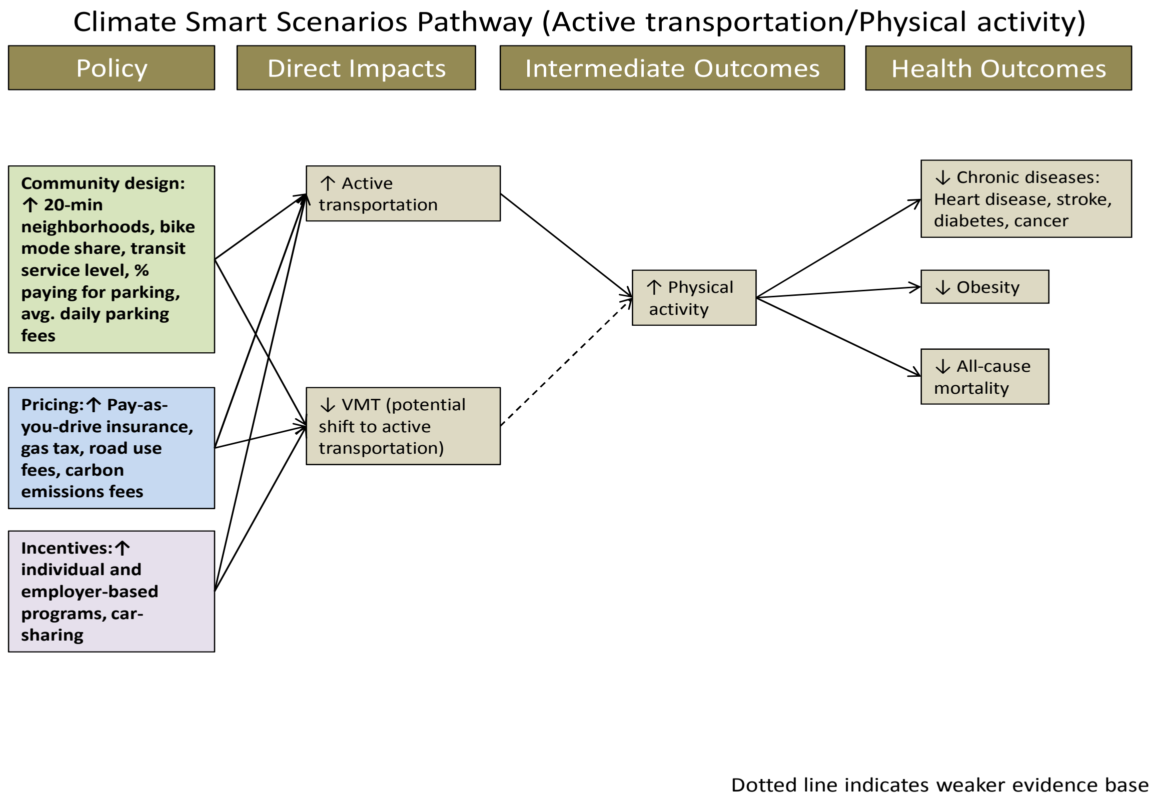
Screening and Scoping

In September 2011, OHA screened the CSCS HIA with partners at Metro and determined that an HIA could bring important health considerations to the CSCS decision-making process. In March 2012, OHA convened a group of 37 stakeholders representing planning, transportation and public health experts from around the Portland metropolitan region for a one-day workshop. Many of these stakeholders also represented local communities and vulnerable populations who will be potentially impacted by Metro's adoption of a preferred scenario. In the meeting, OHA provided an overview of Metro's CSCS planning project, gave an introduction to health impact assessment methodology, and presented the above CSCS HIA goals.

With the input and support of the advisory group, OHA determined priority health impacts, obtained necessary data, and found essential sources for the literature review. A list of advisory group members can be found in Appendix A.

Below is a sample pathway diagram that demonstrates the potential links between GHG reduction policy and program options and health impacts in the Portland metropolitan region. The pathways were drafted by OHA during the scoping phase of the assessment and revised with input from the advisory committee and information learned during the assessment. Additional pathways demonstrating potential links between policies and programs related to particulate air pollution exposure and roadway-related injuries and fatalities and health impacts are in the findings section of the report.

Pathway Diagrams 1 - Active transportation and physical activity



Assessment Methodology

OHA conducted a literature review about the proposed GHG reduction policies and the priority health determinants or impacts within our scope, which included physical activity, air pollution and road traffic injuries and fatalities. OHA identified the most relevant publications in each category for inclusion in the report's evidence base and rated their quality according to guidelines from the Agency for Healthcare Research and Quality [8]. A summary table is available on page 27.

In addition to the literature review, OHA used the Integrated Transport and Health Impact Modeling (ITHIM) tool in order to quantitatively determine which types of policy combinations had the most positive impact on health [9]. ITHIM is a comparative risk assessment model developed by Dr. James Woodcock at Cambridge University. ITHIM estimates changes to life expectancy and quality of life for scenarios based on known relationships between physical activity and chronic illnesses such as cardiovascular disease and diabetes; serious injuries and fatalities from motor vehicle related crashes; and illness and death from particulate air pollution exposure [9, 10].

Reporting and Evaluation

This report presents information about potential health benefits and impacts of the proposed GHG reduction policies evaluated in Phase One of the CSCS project. It also provides recommendations for expanding the reach of positive impacts and mitigating negative health impacts. Subject matter experts from OHA, the CSCS HIA Advisory Committee and Metro reviewed the report. The report will be disseminated to policymakers and community stakeholders in the Portland metropolitan region and to state and national partners. An evaluation will be completed in the summer of 2013 and will include an evaluation of the CSCS HIA process and its effectiveness in influencing the decision-making process.

Community Profile

The decision-makers and planners at Metro and the region's local governments have done significant work to understand the existing conditions related to health status and local health determinants, as shown in the region's planning documents, travel surveys and reports [11, 12]. The local health context is an essential consideration when choosing policies for inclusion in the 2014 preferred Climate Smart Communities Scenario and when implementing these policies. This existing conditions summary explores population and travel characteristics for the region's counties and presents information about the underlying health status of residents, with a particular focus on vulnerable populations who may experience worse health outcomes. County health measures are compared to the state or to national targets to provide context, as is customary in health assessments. The measures of health status and health determinants for Portland metropolitan region communities presented below relate to the CSCS policies that OHA assessed.

Population and Travel Characteristics/Infrastructure

The Portland metropolitan region has a population of nearly 1.5 million distributed across three counties (Clackamas, Multnomah, and Washington) and 25 cities. It is the most populous region in Oregon and the 24th largest metropolitan area in the country. Portland itself is the sixth largest city on the West Coast. Population in the Portland metropolitan region is forecasted to grow to nearly 2 million by 2035 [13].

Vehicle Miles Traveled

In the Portland metropolitan region in 2010, there were 5,074 vehicle miles traveled (VMT) per capita [14]. This was the lowest level of VMT per capita for the region since 1985 [14]. Nevertheless, due to population growth, average daily VMT has continued to grow steadily. Between 1982 and 2010, average daily VMT for the Portland metropolitan region has risen from 15 million miles to over 26 million miles [14].

In addition to population growth, long commute times and above average dependence upon automobiles for drive-alone commuters have contributed to the increase in VMT in the Portland metropolitan region. The average commute time for every county in the region is above the state average (Appendix B, Table 1). Additionally, Clackamas and Washington counties have higher percentages of single passenger auto commuters. Multnomah County is significantly below the state average of single passenger auto commuters; however, when examined at a smaller scale (Appendix B, Table 2) only the City of Portland is below average while more than one-third of Multnomah County's other cities are above average.

Public Transit Travel

Substantial growth in public transit ridership within the Portland Metro region occurred in the late 1990s. From 1997 to 2007, ridership on bus and rail lines increased 45%, nearly twice the growth rate in population [15]. The rate of ridership slowed to 15% between 2002 and 2012, but it is still well over the 10% population growth rate the region experienced in the same decade [16, 17]. Additionally, with a 52-mile MAX light rail system, 79 bus lines, and a 14.7-mile WES Commuter Rail serving 570 square miles, nearly 90% of the region's residents live within one-half mile of a bus stop or a rail platform [15]. In 2004, transit ridership in the Portland metropolitan region was ranked 7th in the U.S. at 70 passenger trips per capita [18]. Since this time, TriMet, the agency overseeing transit services in the Portland metropolitan region, has expanded its transit network. Consequently, in 2009 transit ridership has increased to 73 passenger trips per capita [19]. TriMet currently operates 225 lift vehicles and provides 958,000 annual rides to seniors and people with disabilities. Weekly ridership on buses and MAX rail lines has increased for all but one year in the past 23 years due to recession-related service cuts [16, 17].

Active Transportation Travel

Significant investments to expand bicycle infrastructure throughout the Portland metropolitan region have also occurred over the past two decades. For example, the City of Portland invested more than $12 million between 1991 and 2004 to develop its regional bicycle network which contains more than 300 bikeway miles [15, 20]. In addition, Metro's Regional Flexible Fund Allocation (RFFA) program provided funding for 46 miles of bicycle boulevards, bike lanes, trails and other bicycle projects between 2006 and 2015 [21]. These investments build on RFFA investments that have been made since 1995. Although bicycle data is limited, regional reports and a recently completed travel behavior survey have documented increased bicycle ridership throughout the region [15].

The regional pedestrian network has not seen the same level of expansion as public transit and bicycle facilities. In addition to locally funded pedestrian projects, Metro's RFFA program provided funding for nearly 9 miles of sidewalks in mixed-use centers throughout the Portland metropolitan region. Although nearly 90% of the region's residents live within one-half mile of a bus stop or a rail platform, only 69% of those stops are accessible by sidewalk [15]. Additionally, it was found that the region has 1,230 miles of potential pedestrian facilities located within transit/mixed use corridors and pedestrian districts [15]. In the regional network of corridors and districts, 19% of all streets have no sidewalks, 19% have sidewalks on at least one side of the street and 62 % of all streets had sidewalks on both sides of the street [15, 22].

One in six trips in the Portland metropolitan region are now made using active travel. Comparison of the 1994 and 2011 Oregon Household Activity Survey shows that between 1994-95 and 2011, all trips made by walking, biking and transit increased by 36% (from 13.1% to

17.8% of all trips) while trips made by auto declined by 5.7%. Walking trips increased by 14%, trips by biking increased over 190%, and trips by transit increased by 50% [23].

Lower income, disabled, and people of color make more of their trips using active travel, especially walking and transit, than higher-income, white and non-disabled persons [24]. People with disabilities particularly rely on access to transit for travel. Nearly 7% of the population reports having a disability that affects their ability to travel. People with disabilities drive and bike less and walk and take transit more often than people that reported having no disability that affects their ability to travel [25].

Safety

Making streets safer for people walking and riding bicycles and reducing bicycle and pedestrian crashes is important to protecting the public's health. Feeling and being safe while walking and bicycling is an important factor in the travel choices people make and therefore is a critical part of a complete transportation system. Transportation safety is also an equity issue. Research and data show that people with low incomes and people of color are more likely to live near wide, high-traffic streets and are thus much more likely to be injured by an automobile [26].

Serious pedestrian and bicycle crashes account for 20% of all serious crashes in the region [27]. Serious crashes are those that result in a fatality or an incapacitating injury. While 3.2% of all trips (not counting trips to access transit) take place by bicycle, 8% of all serious crashes involve bicyclists. Pedestrians make 10% of all trips in the Portland metropolitan region (not including trips to access transit); however 12% of all serious and fatal crashes involve a pedestrian.

There were a total of 1,297 pedestrian crashes resulting in injury in the Portland metropolitan region between 2007 and 2010. Of those crashes, 252 resulted in a death or an incapacitating injury. The majority of pedestrian crashes occur while pedestrians are crossing the roadway, either at an intersection or mid-block. Nearly 80% of all serious and fatal pedestrian crashes occur when people are crossing the roadway.

There were a total of 1,503 bicycle crashes resulting in injury in the Portland metropolitan region between 2007 and 2010. Of those crashes, 140 resulted in a death or an incapacitating injury. Most serious and fatal bicycle crashes (73%) occur at intersections.

Major factors contributing to serious crashes include high-traffic streets, streets with multiple lanes, excessive speed, driver impairment due to alcohol or drugs, lack of adequate street lighting and congestion [27].

Air Quality

Overall, air pollution in the Portland metropolitan region has decreased dramatically over the last 30 years [28]. However, air quality remains an environmental justice and equity issue. The Portland Air Toxics Solutions Committee Report mapped census block groups with minority populations above 25% overlaid with total times above benchmarks for all pollutants observed in the study, including emissions from cars and trucks [29]. Visual inspection of the overlay suggests that there is an overlap between high minority and high impact areas in some areas of the study boundary, including Forest Grove, Hillsboro, Aloha, Beaverton, North Portland, East Portland and Gresham.

Vulnerable Populations

Transportation is essential to the health of all the region's residents. Transportation connects people to jobs, schools, parks and recreation facilities, shopping, friends, and essential services like health care. Transportation-related air pollution and a lack of access to affordable, high-quality transportation options negatively impacts health. Certain groups within the region are more likely to be affected by air pollution and lack transit access, such as youth, seniors, low-income residents and communities of color [30, 31]. These groups are also at higher risk for health conditions linked to limited transportation options and transportation-related air pollution, such as asthma, heart disease, and obesity [32, 33].

Age

Older adults make up a smaller portion of the Portland metropolitan region's population compared to Oregon as a whole (Table 1). Comparatively, children and teens comprise a greater share of Clackamas and Washington County's population than Oregon as a whole. Multnomah County has a lower percentage of youth than the state.

Table 1. Portland Metropolitan Region Comparison, County and State - Age

Age Category	Clackamas County	Multnomah County	Washington County	State of Oregon
Under 18 Years Old	23.7%	20.5%	25.6%	22.6%
65 Years or Older	13.6%	10.5%	10%	13.9%

Source: Profile of General Population and Housing Characteristics: 2010 prepared by the U.S. Census Bureau, 2011.

Race and Ethnicity

When examining race and ethnicity within the Portland Metro region, Multnomah and Washington County are similar (Table 2). While white residents make up a large share of both counties' population (approximately 81%), Multnomah and Washington still have higher percentages of residents of color (in all race/ethnicity categories) than Oregon as a whole [34]. Washington County in particular has one of the greatest Hispanic/Latino population in the state [34]. In contrast, Clackamas County's population is primarily white and has smaller populations of communities of color (in all race/ethnicity categories) compared to Oregon as a whole [34].

Table 2. Portland Metropolitan Region Comparison, County and State – Race/Ethnicity

Race/Ethnicity	Clackamas County	Multnomah County	Washington County	State of Oregon
White	91.1%	80.5%	80.4%	87.1%
Black or African American	1.4%	7.1%	2.7%	2.6%
American Indian and Alaska Native	1.9%	2.5%	1.7%	2.9%
Asian	4.8%	8.2%	10.6%	4.9%
Native Hawaiian and Other Pacific Islander	0.5%	0.9%	0.9%	0.7%
Some Other Race	3.7%	5.9%	8.4%	6%
Hispanic or Latino	7.7%	10.9%	15.7%	11.7%

Source: Profile of General Population and Housing Characteristics: 2010 prepared by the U.S. Census Bureau, 2011.

In the Portland metropolitan region, both white and non-white heads of households make the majority of trips by auto. However, non-white householders make a greater percentage of their trips by walking, bicycling and transit than white householders. Non-white householders make 20.5% of all their trips by walking and bicycling and transit, while white householders make 15% of all their trips by walking and bicycling and transit [12].

Income and Poverty

Within Clackamas and Washington counties, the median household income is approximately $62,000, which is higher than the median Oregon household income ($49,260) [35]. Within both counties, fewer than 10% of people had an income in the past 12 months lower than the poverty rate (Table 3) [35]. This was roughly 5% lower than the state as a whole. In comparison, Multnomah County has a median household income that is similar to the median Oregon household income [35]. Also, 16% of Multnomah County residents had an income in the past 12 months lower than the poverty rate [35], a slightly higher percentage than the state as a whole.

Table 3. Metropolitan Region Comparison, County and State – Other Demographics

Category	Clackamas County	Multnomah County	Washington County	State of Oregon
Median Household Income	$62,007	$49,618	$62,574	$49,260
Income in the past 12 months below the poverty level	9%	16%	9.5%	14%
Source: 2006-2010 American Community Survey [Oregon] prepared by the U.S. Census Bureau, 2011.				

Households in the four-county Portland metropolitan region (including Clark County) with lower income levels make more of their trips using active travel modes, especially walking and taking transit. As income rises, more trips are made by auto. For example, for households with income under $15,000, 26% of all trips are made by active modes and 74% of trips are made by auto. This is compared to households with the highest level of income, $150,000 or more, where 11% of trips are made by active modes and 89% of trips are made by auto [12].

For walking trips, 32.8% of all walking trips are made by households with income under $35,000, 32.3% are made by households with income between $35,000 and $75,000, and 35% are made by households with income greater than $75,000. For trips by bicycle, 21.2% of all trips by bicycle are made by households with income under $35,000, 37.1% are made by households with income between $35,000 and $75,000, and 41.8% are made by households with income greater than $75,000 [12].

For transit trips, 44.6% are made by households with income under $35,000, 30% are made by households with income between $35,000 and $75,000 and 24.6% are made by households with income greater than $75,000 [12].

Health Conditions

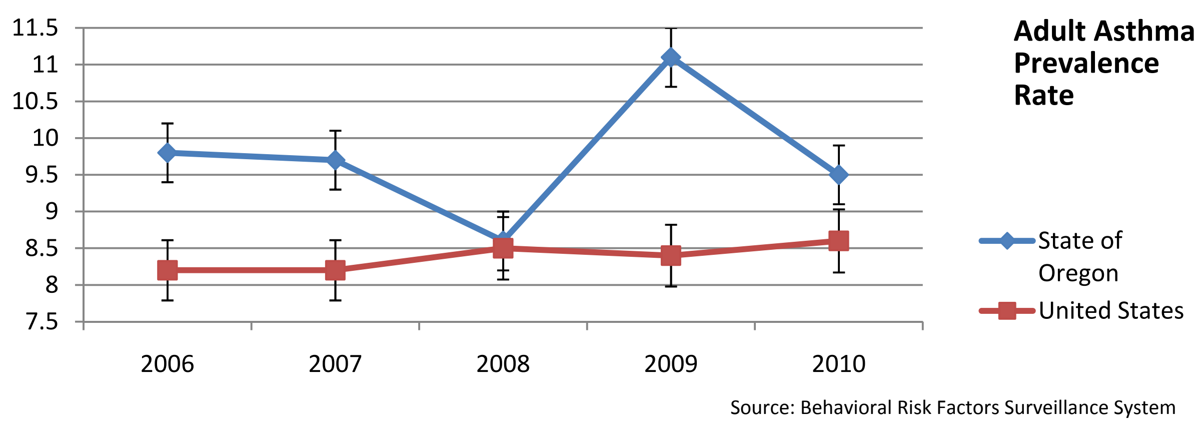
Chronic health diseases such as asthma, diabetes, stroke, heart disease, and cancer, along with factors such as obesity, are significant contributors to illness and death for all Oregon and Portland metropolitan region residents and many of the proposed policies designed to reduce GHG emissions would impact these chronic health conditions. For a tabular comparison of the burden of these illnesses, see Appendix B, Table 3.

Asthma

Asthma is a chronic lung disease that inflames and narrows the airways to cause shortness of breath, coughing, and wheezing [36, 37]. Asthma affects people of all ages, but it is one of the most common long-term chronic diseases of children [38]. Exposure to air pollution increases the risk of developing asthma and can cause those with asthma to experience worsening of symptoms.

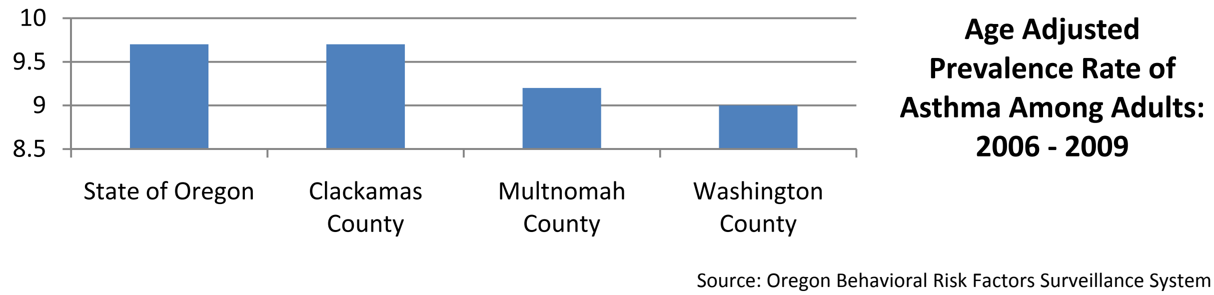
In 2009, approximately 10.2 % (≈300,000) of Oregon adults and 9.5% (≈ 83,000) of children had asthma [36] . As a result, Oregon ranked among the top five states in the nation with the highest percent of adults with asthma (Figure 1) [36, 39]. The most current county-level prevalence data (Figure 2) shows that from 2006 – 2009 the counties of Clackamas (9.7%), Multnomah (9.2%), and Washington (9.0%) fared the same or better than the state average prevalence (9.7%) of adult asthma [40].

Figure 1. Percent of adult population with asthma, Oregon and U.S.



Source for above image: http://www.cdc.gov/asthma/brfss/default.htm#08

Figure 2. Percent of adults with asthma, Oregon and Portland metropolitan region counties



Source for above image: http://public.health.oregon.gov/DiseasesConditions/ChronicDisease/Documents/TableI.pdf

Studies have shown that asthma is distributed unevenly throughout the population. Non-white children and children living in poverty have a significantly higher risk of asthma than do white children [41]. The local patterns of asthma were highlighted in 2002 by a study which showed lower income, more racially and ethnically diverse areas of inner Northeast Portland had higher rates of asthma than the county average and other higher income, less diverse areas within the region (such as Orenco Station in Hillsboro and inner Southeast neighborhoods in Portland) [42, 43].

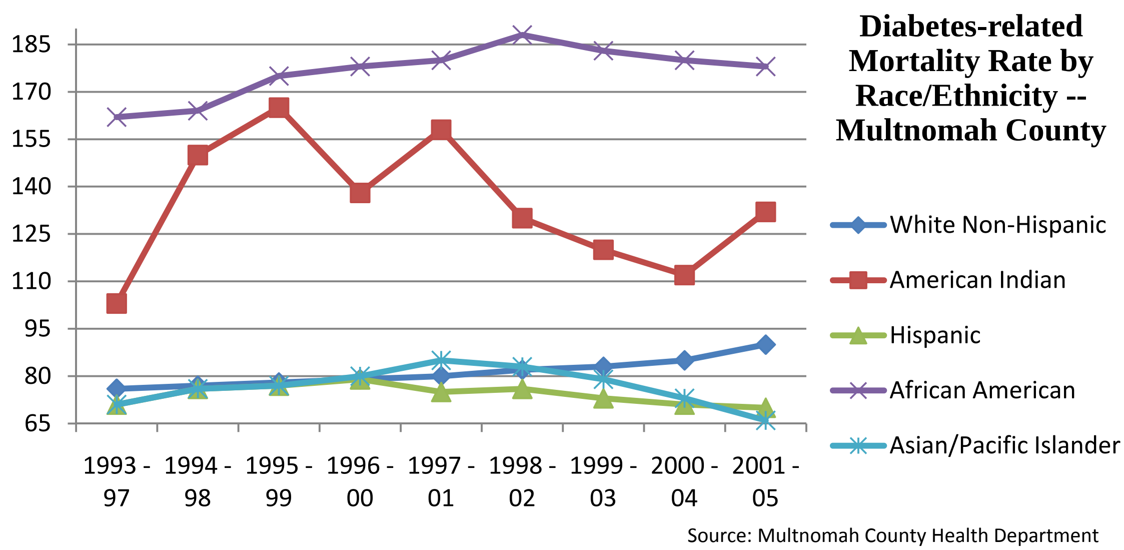
Diabetes

Diabetes is a chronic disease in which blood sugar levels are high and not regulated well, which can lead to serious health complications and premature death [44]. It is the seventh leading cause of death in the United States[45]. Regular physical activity lowers the risk of diabetes.

In 2010, Oregon's diabetes prevalence rate for adults was 7.2%, leading to Oregon's rank among the 10 states with the lowest diabetes rates in the nation [46]. The most current county-level prevalence data shows that from 2006 – 2009 the counties of Clackamas (6.6%), Multnomah (6.2%), and Washington (5.9%) were similar to or slightly better than the state average (6.8%) for adult diabetes [40]. Although the Portland metropolitan region has slightly better diabetes rates than the state average, the rates are still much higher than the 20 per 1,000 population Healthy People 2010 target [47]. Moreover, the most recent data shows that Multnomah County has a higher diabetes mortality rate than the national average [48].

Diabetes predominately affects lower income groups, communities of color, and individuals over the age of 65 [42, 49]. In 2010, diabetes contributed 6.5% of the total deaths for non-white Oregonians, compared to only 3% for white non-Hispanic Oregonians [50]. Figure 3 shows the differences between different races/ethnicities in diabetes-related mortality rates.

Figure 3. Diabetes-related mortality rate, Multnomah County



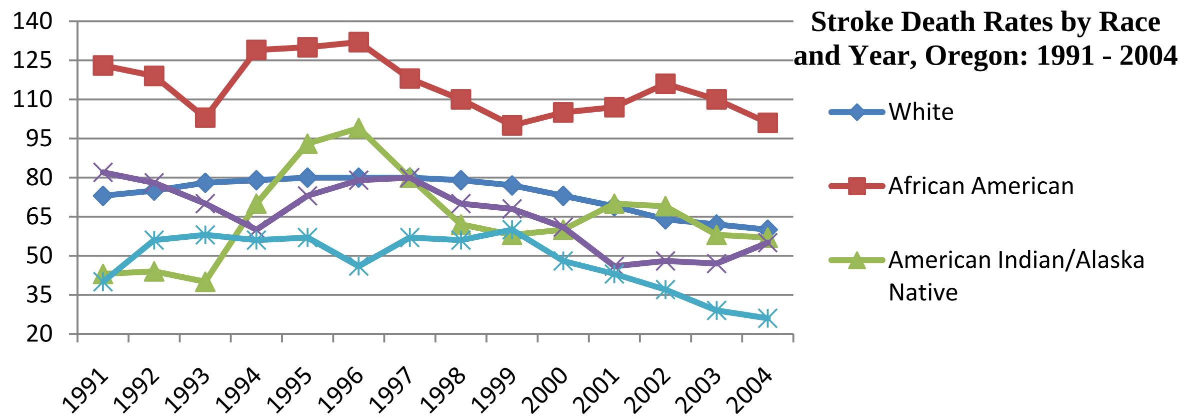
Source for above image: http://web.multco.us/sites/default/files/health/documents/winter2009_diabetes.pdf

Stroke

Stroke is the third leading cause of death in Oregon [51]. In 2010, Oregon's stroke prevalence was 2.2% (1.9 – 2.6) and it ranked among the fifteen states in the nation with the lowest prevalence rate [52]. However, since 1990, Oregon's stroke death rate has been higher than the national average. With a death rate of 49 per 100,000 individuals, Oregon ranks among the top 10 states with the highest stroke death rate in the nation [53, 54]. The most current county-level prevalence data shows that from 2006 – 2009 the counties of Clackamas (2.6%), Multnomah (1.8%), and Washington (1.9%) were similar to the state average (2.3%) of stroke prevalence [53]. Regular physical activity lowers the risk of stroke.

Various studies have shown that in the United States, African-American communities are disproportionately affected by stroke [55]. This disparity also exists in Oregon. Since 1991, the stroke death rates for African Americans living in Oregon have been significantly higher than all other resident races and ethnicities (Figure 4). For example, the African-American death rate from stroke in 2005 was 90.4 per 100,000 [51]. The second closest was the death rate for American Indians/Alaskan Natives which was 69.0 per 100,000 [51]. Figure 4 below shows the differences between different races/ethnicities in stroke-related mortality rates.

Figure 4. Stroke mortality rates by race and year, Oregon



Source: Oregon Heart Disease and Stroke Prevention Program.

Source for above image:
http://public.health.oregon.gov/DiseasesConditions/ChronicDisease/HeartDiseaseStroke/Documents/2007BurdenReport.pdf

Heart Disease

Heart disease refers to several heart conditions, the most common being coronary artery disease, which results when the flow of blood and oxygen to the heart is restricted or cut off [56]. This disease can cause heart attacks and angina. In 2009, more than 168,000 Oregonians (approximately 5.3%) had heart attack, angina, or coronary artery disease [53]. Approximately, 20% of all deaths in Oregon in 2010 were attributed to heart disease [50]. Nevertheless, the most recent Centers for Disease Control and Prevention data highlights that Oregon ranks among the top five states with the lowest heart disease prevalence in the nation [57]. Regular physical activity lowers the risk of heart disease, while exposure to airborne particulate matter increases the risk. The more a scenario promotes physical activity and decreases air pollution, the greater the expected reduction in this disease.

The most current county-level data shows that from 2006 – 2009 the prevalence of angina or heart attack in Clackamas (4.3%), Multnomah (4.6%), and Washington (4.2%) counties was below the state average (5.0%) [53]. Moreover, similar to the State of Oregon, heart disease mortality rates have dropped within the Portland metropolitan region. Nevertheless, heart disease is the second leading cause of death within Clackamas, Multnomah, and Washington counties [42, 58, 59]. While rates of heart disease mortality have dropped within the Portland metropolitan region, there are still populations that experience higher rates of heart disease. In Multnomah County, for example, the rate of coronary heart disease is higher for African-Americans than for other population groups [42]. Over the past 20 years in Oregon, heart disease mortality rates have been statistically higher in rural areas than in urban areas [53].

Cancer

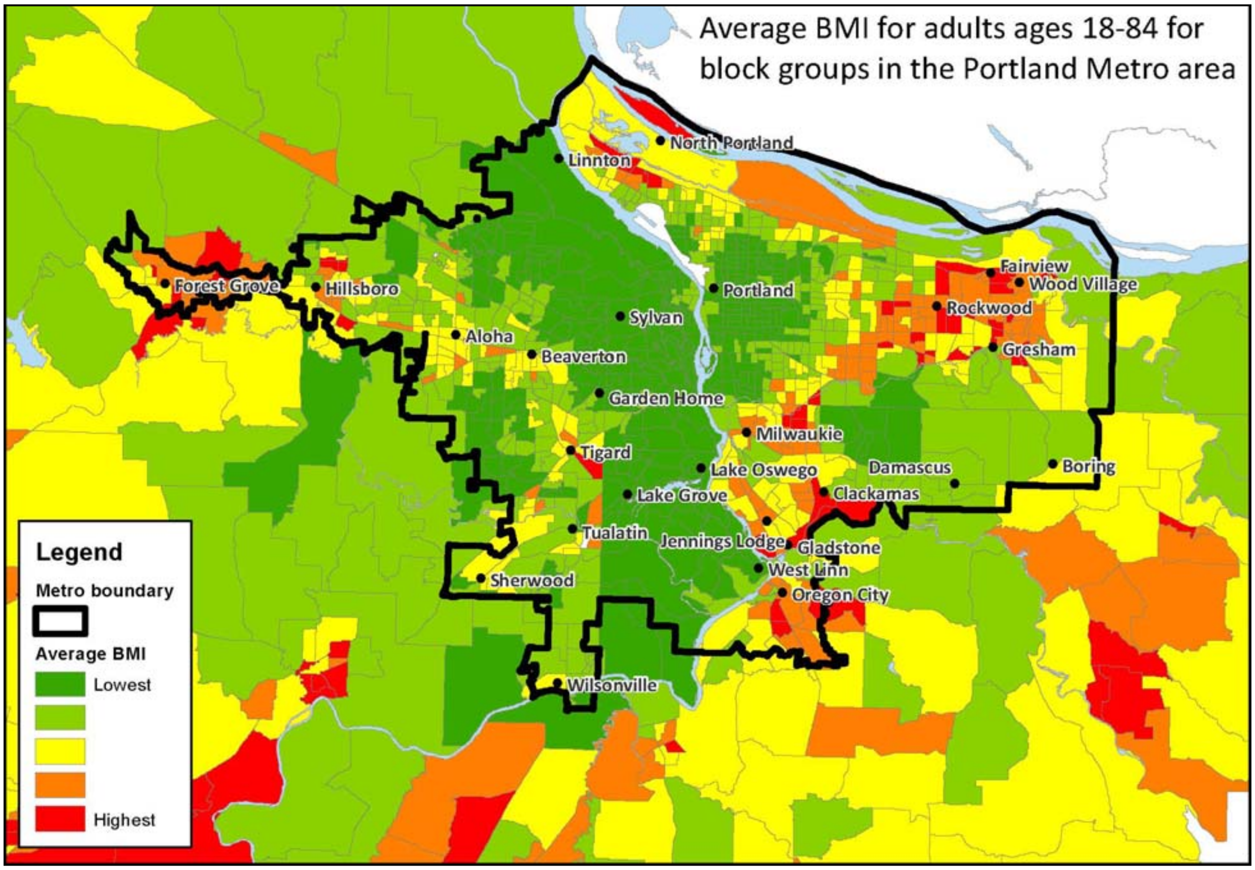
Cancer is the leading cause of death in Oregon and in the Portland metropolitan region [42, 58-60]. With a 2009 death rate of nearly 179 per 100,000 individuals, Oregon ranks in the top quarter of states with the highest cancer death rate in the nation [60, 61]. Additionally, except for lung and colorectal cancer, Oregon has higher incidence rates for all cancer types compared to the national average [62]. Regular physical activity lowers the risk of cancer. Reducing certain transportation-related air pollutants, such as benzene, can also lower cancer risk [29, 63].

Within the Portland metropolitan region, the most current county-level data shows that from 2005 – 2009 the cancer incidence rate for Multnomah County (477 per 100,000) was above the state average (465 per 100,000) while rates in Clackamas (457 per 100,000) and Washington (435) counties were below [64]. Cancer is also the leading cause of years of potential life lost in the region [58].

Obesity

Obesity is increasingly a concern in Oregon and in the Portland metropolitan region [65]. Obesity contributes to the deaths of about 1,400 Oregonians each year, making it second only to tobacco as the state's leading cause of preventable death. More than 60% of Portland metropolitan region residents are overweight or obese, and more than half do not meet physical activity recommendations. Even more worrisome, since those overweight in childhood are more likely to remain so as adults, around one-quarter of Metro region adolescents are overweight or obese. Obesity varies significantly by neighborhood and may be correlated with measures of socio-economic status as well as aspects of the built environment (Figure 5).

Figure 5. Age-adjusted mean Body Mass Index (BMI*) by census block group, Portland metropolitan region, from Department of Motor Vehicles records, 2010



Source: Oregon Health Authority, Environmental Public Health Tracking report: DMV records are valuable for obesity surveillance in Oregon, September 2012

This map shows average body mass index (BMI) for adults ages 18-84, based on self-reported height and weight information on driver licenses and ID cards issued by the State of Oregon from 2003-2010. BMI is expressed in units of kg/m2, is the standard measure used for population-based obesity surveillance. Higher mean values indicate heavier populations. Data are aggregated by block groups based on 2010 Census definitions and age-adjusted to the 2000 U.S. Census standard population. Block groups are classified into quantiles based on all block groups in Oregon.

Literature Review

Methodology

OHA conducted a literature review about the proposed GHG reduction policies and the priority health determinants or impacts within our scope (physical activity, particulate air pollution exposure and road traffic injuries and fatalities).

The CSCS HIA literature review is summarized in Table 4. On the left side there is a list of the policy options that make up the scenarios assessed in Phase One of Metro's scenario planning effort. Metro's scenarios are combinations of the strategies in Table 4 at various levels of proposed change, from a base year representing current conditions (2010) to new policies or more ambitious implementation of current plans (level 3). For example, for the bicycle mode share strategy, the baseline is 10% of the region's single-occupant vehicle tours less than 20 miles round-trip by bike and the most ambitious policy change would increase that to 30%. Detailed descriptions of each strategy and the levels of potential change considered can be found in Metro's Phase One Findings report [66].

To search for available evidence to understand the links between the strategies on the left side and health outcomes on the right (see Table 4), OHA queried multiple online databases using standardized search terms, and included results from PubMed, Google Scholar, Oregon State University library, Human Impact Partners evidence base, and previously published HIAs, in particular the two completed by Upstream Public Health on climate change policy [67, 68]. OHA identified the most relevant publications in each category for inclusion in our evidence base, read and abstracted each article, and rated its quality according to guidelines from the Agency for Healthcare Research and Quality, and summarized the entire evidence base [8] in Table 4 below.

The literature review is represented graphically through pathway diagrams in findings sections of the report below. These diagrams show the connection between the policies and strategies and health outcomes through direct impacts and intermediate outcomes.

Table 4. Climate Smart Communities Scenarios HIA Literature Review - Summary of the Quality of Evidence

Policies (existing conditions - most ambitious scenario)	Physical activity	Air pollution	Crash Injury/ Fatality
Community design			
Mixed use/complete neighborhoods	****	*	**
Bicycle mode share (2% - 30%)	****	**	**
Transit service level (2010 level - 4x RTP level)	***	**	**
Workers/non-work trips pay for parking (13%/8% - 30%/30%)	*	**	*
Average daily parking fee ($5 - $7.25)	*	**	*
Pricing			
Pay as you drive insurance (0% - 100%)	**	**	**
Gas tax ($0.42 - $0.18/cost per gallon^)	**	**	**
Road use fee ($0 - $0.03/cost per mile)	*	*	*
Carbon emissions fee ($0 - $50/cost per ton)	*	**	**
Incentives			
Households participating in eco-driving (0% - 40%)	N	*	*
Households participating in marketing programs (9% - 65%)	*	*	*
Workers in employer-based commuter programs (20% - 40%)	*	*	*
Car-sharing in high density areas (1 - 2 members/100 people)	*	*	*
Car-sharing in medium density areas (1 - 2 members/200 people)	*	*	*
Fleet			
Fleet Mix and turnover rate (light duty vehicles)	N	**	*
Technology			
Fuel economy, Carbon intensity of fuels, electric tech., etc.	N	**	N

^Combined with road use fee - see page 28 of Metro's Phase 1 Findings report for details

Legend
**** 10+ strong studies
*** 5-9 strong studies
** 5 or more studies of weak or moderate quality, or studies have mixed results
* <5 studies and policy-impact link consistent with public health principles
N = No evidence found
For a full explanation of these proposed policies, please see the Metro Climate Smart Communities Phase 1 Findings Report [66].

Integrated Transport and Health Impacts Modeling (ITHIM)

The Integrated Transport and Health Modeling (ITHIM) tool was developed by public health researchers in the UK to assess the potential health impacts of GHG reduction scenarios for London, UK and Delhi, India [9]. The model was later adapted for use in the San Francisco Bay Area and applied to transportation scenarios created to comply with California's GHG reduction goals. OHA further adapted the tool for use in the Portland metropolitan region, including the use of census data for the geography that makes up the Portland metropolitan region governed by Metro.

The purpose of the CSCS Project's Phase One analysis was to understand what level of policies and investments might be needed (beyond current adopted plans and policies) to meet the region's GHG reduction goals. In collaboration with ODOT, Metro staff tested 144 scenarios and found more than 90 scenarios met or exceeded the GHG emissions reduction goals, some by a significant margin. For more detailed information on the CSCS project and methodology please see the CSCS Phase One Report, an essential companion document to this report.

OHA did not assess the health impacts of each of the 144 Phase One scenarios. Instead, OHA used ITHIM to assess 6 sample scenarios in order to provide information about the health impacts of the types of policies and investments decision-makers will consider including as they develop the final three Phase Two scenarios.

Methodology

For the purposes of this HIA, ODOT and Metro staff identified 6 sample scenarios of the 144 scenarios tested in Phase One. OHA also evaluated the current set of policies and investments, named 2010 Base Year, to provide a base year comparison.

The sample scenarios vary primarily with respect to the community design and pricing policy areas tested in Phase One of the CSCS project; differences between each primarily reflect progressively higher levels of transit, bicycle mode share, and pricing strategies as noted by the level 1, level 2 and level 3 labels for each policy area (e.g., community design, pricing).

- Sample scenarios 1 through 3 correspond to community design levels 1 to 3 and pricing level 1.
- Sample 4 through 6 correspond to community design levels 1 through 3 and pricing levels 2 and 3.

More information about the selection of the sample scenarios is available in Appendix D.

The inputs to ITHIM include:

- Information on household vehicle miles traveled (VMT) from the GreenSTEP model [69] developed by the Oregon Department of Transportation (ODOT)
- Monitored particulate matter ($PM_{2.5}$) from DEQ

- 2000 and 2010 census data [13], adjusted for the Portland metropolitan region; household travel data from Metro's Household Activity Survey [70]
- Crash data from ODOT [71]
- Information about the global burden of disease [72]

The outputs to ITHIM include: modeled data on changes in disease, injuries, and deaths. More information about ITHIM is available in Appendix D and in Woodcock et al [73].

Limitations to ITHIM

ITHIM is a unique and reliable tool for modeling and comparing the health impacts of planning scenarios. This is especially true when ITHIM's outputs are considered alongside local health data, such as those described in the existing conditions summary above.

However, ITHIM was developed using global burden of disease data, and OHA did not adapt the tool to use Oregon or Portland metropolitan region health data. Additionally, ITHIM uses particulate air pollution, specifically $PM_{2.5}$, as a proxy for total transportation-related air pollution. Although such assessment is outside of the scope of this HIA, additional analyses on the reduction of toxic air pollutants and ozone precursors from transportation and transportation-specific policies (such as fleet turnover and advances in fuel technology) would likely show additional health benefits [9, 10].

ITHIM detailed results

The CSCS HIA results indicate that all of the GHG reduction scenarios that Metro has evaluated to date could result in net health benefits from increases in active travel and decreases in both air pollution exposure and motor vehicle-related injuries and fatalities (Table 5). There are sample scenarios that are more beneficial to the health of Portland metropolitan region residents than others, and these are discussed in detail below. Additional summary tables are available in appendix C.

A summary of ITHIM's health impact results for sample scenarios 1 through 6 are reported in Table 5, which shows reductions in premature deaths, years of life lost (YLL), years living with disability (YLD), and disability-adjusted life years (DALY) for changes in physical activity, particulate air pollution exposure, and road traffic crashes. DALYs are calculated by adding YLL and YLD across a population. One DALY can be thought of as representing one lost year of healthy life. The sum of DALYs across a population represents the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability [72].

Table 5. ITHIM Results: Annual health co-benefits compared to base year scenario (2010) for sample scenario 1-6 (2035), Portland Metro region

	Counts						Rate per Million Population					
	Sample scenario1	Sample scenario2	Sample scenario3	Sample scenario4	Sample scenario5	Sample scenario6	Sample scenario1	Sample scenario2	Sample scenario3	Sample scenario4	Sample scenario5	Sample scenario6
Physical activity												
Premature deaths	-49	-112	-139	-66	-131	-157	-39	-89	-111	-52	-105	-125
YLL	-492	-1,230	-1,623	-647	-1,403	-1,789	-391	-979	-1,291	-515	-1,116	-1,423
YLD	-201	-528	-710	-216	-526	-703	-160	-420	-565	-172	-419	-560
DALYs	-693	-1,758	-2,333	-863	-1,929	-2,492	-551	-1,398	-1,856	-686	-1,535	-1,983
Particulate air pollution												
Premature deaths	-3	-11	-19	-8	-15	-22	-3	-9	-15	-7	-12	-17
YLL	-42	-140	-236	-105	-189	-271	-34	-111	-188	-83	-151	-215
YLD	0	-1	-1	-1	-1	-1	0	-1	-1	0	-1	-1
DALYs	-42	-141	-237	-105	-190	-272	-34	-112	-189	-84	-151	-216
Road traffic crashes												
Premature deaths	0	-11	-24	-9	-19	-29	0	-7	-16	-6	-13	-20
YLL	-5	-443	-945	-373	-756	-1,181	-3	-299	-637	-252	-510	-796
YLD	-21	-117	-222	-93	-177	-267	-14	-79	-150	-63	-119	-180
DALYs	-25	-560	-1,168	-466	-933	-1,447	-17	-378	-787	-314	-629	-976
Total												
Premature deaths	-53	-134	-182	-83	-165	-208	-42	-106	-142	-65	-129	-162
YLL	-539	-1,813	-2,804	-1,125	-2,348	-3,240	-428	-1,389	-2,116	-850	-1,777	-2,435
YLD	-222	-645	-933	-310	-704	-971	-174	-499	-716	-235	-539	-740
DALYs	-761	-2,458	-3,738	-1,434	-3,052	-4,212	-602	-1,888	-2,832	-1,085	-2,315	-3,175

*YLL, years of life lost; YLD, years living with disability; DALY, disability-adjusted life years (sum of YLL and YLD)

The sample scenarios that represent higher levels of active transportation modes (bicycling, walking and transit), show corresponding reductions in car and light truck travel. The Portland metropolitan area-adapted ITHIM found that with high levels of active transportation compared to the 2010 baseline, as in sample scenarios 3 and 6, the model predicts:

- 5% fewer premature deaths;
- 6% fewer years of life lost for cardiovascular disease, heart attack and stroke; and
- a 4% reduction in diabetes.

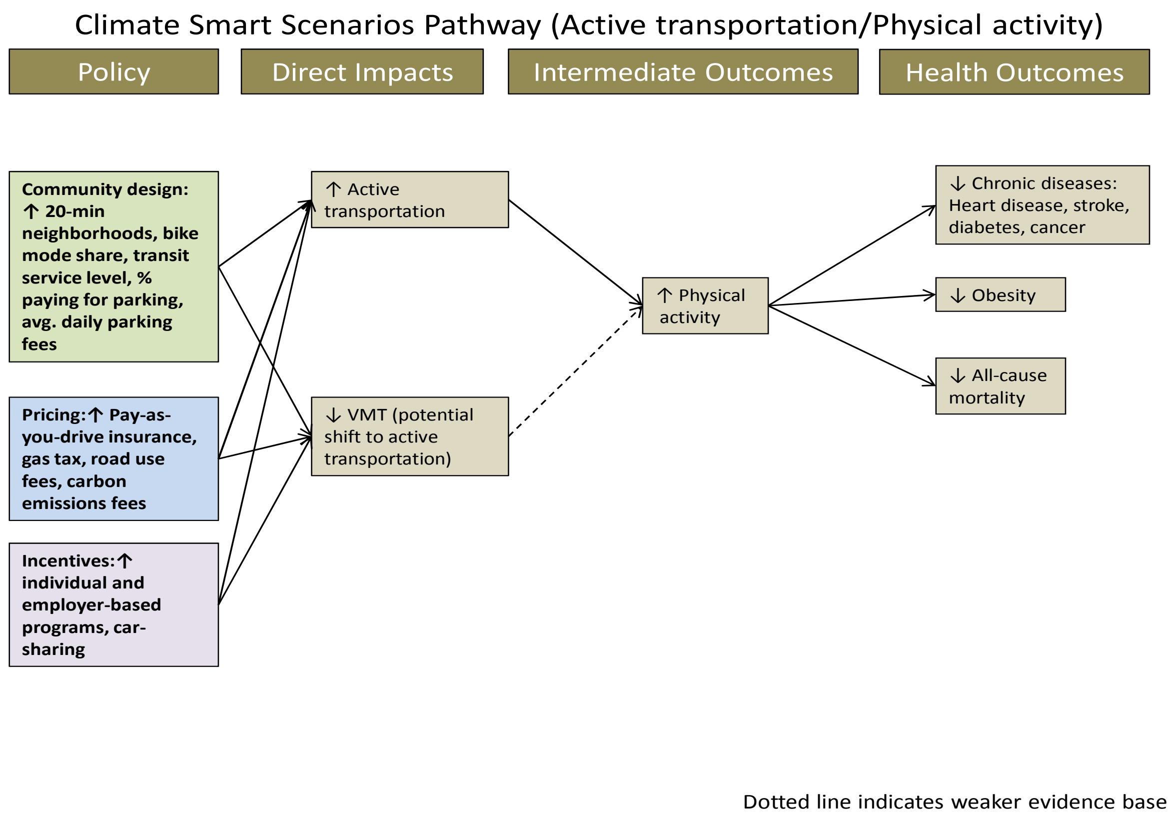
When considering the main health outcome measure (DALYs) between baseline and Scenario 6, the majority (59%) of the health benefit can be accounted for by increased levels of physical activity, followed by decreased road traffic crashes (34%) and decreases in particulate air pollution exposure (7%).

To walk through a specific example from Table 5, under sample scenario 3 the Portland metropolitan region would experience 182 fewer premature deaths in 2035 compared to 2010. In addition 2,804 years of life lost and 933 years living with disability would also be averted. The majority of the health benefits result from increased physical activity, followed by reductions in road traffic crashes and lower exposure to particulate air pollution. Appendix C, Table 2 shows predicted changes in the health of the region's residents due to changes in physical activity under each sample scenario for specific conditions such as heart disease and diabetes.

After accounting for a small increase in the disease burden from fatal and serious traffic injuries to bicyclists (see Appendix C, Table 4), the Portland metropolitan region would still experience 208 fewer premature deaths and 3,240 years of life gained. Strategies for mitigating this increase are discussed in the road traffic injury recommendations below.

Active Transportation and Physical Activity Results

Pathway diagram 1 – Active transportation and physical activity



Pathway 1 was drafted by OHA and refined with information from the advisory committee.

ITHIM findings

Results from the ITHIM model indicate that sample scenarios 3 and 6 have the largest increases in active transportation (Table 5). Averages from these sample scenarios show the largest positive impact on health with reductions of 182-208 premature deaths per year and large reductions in DALYs (scenario 3: 3,738; scenario 6: 4,212). Approximately 60% of the health benefit in these two sample scenarios comes from increased physical activity.

Health equity findings

Decisions about strategies and their implementation can have different impacts on different populations in the Portland metropolitan region. For example, pricing policies that increase costs, including time costs, associated with transportation may disproportionately impact low-income residents. Increased cost burden may lead to increased stress, which negatively affects health [74-76].

Individuals with physical or mental disabilities may experience worse health status than the non-disabled population. In addition they may have more difficulty accessing improvements to active transportation infrastructure or have different needs related to transportation [77-79].

Prioritizing investments and thoughtful implementation of active transportation policies and programs in vulnerable communities could improve inequitable health outcomes for vulnerable populations of the Portland metropolitan region. For example, since African-Americans experience disproportionately higher rates of heart disease, diabetes, and stroke, active transportation investments in predominantly African-American communities may have greater health impacts.

Literature review findings

Policies and investments supporting complete neighborhoods and active modes of travel (walking and biking) best promote physical activity. Public transportation service levels and use also effectively promote physical activity. There is some evidence that pricing policies, such as pay-as-you-drive insurance or a direct tax on gasoline, may reduce VMT and shift trips to active modes of travel. However, these policies may simply reduce the number of driving trips without increasing active transportation, and therefore would not be associated with health benefits associated with physical activity. Policies that lead to reductions in VMT in addition to increases in active transportation will likewise impact the prevalence of chronic disease and mortality.

OHA found the least evidence supporting a positive association between policies in the incentives category and increases in physical activity. There is a need for additional studies about this proposed link. The fleet mix and technology policies as well as the percent of households participating in eco-driving programs are not expected to have an effect on physical activity levels.

It is also worth noting that improvements to active transportation infrastructure may increase leisure time physical activity, along with the accompanying health gains.

Context

When local decision-makers understand the characteristics of their communities that encourage or discourage active transportation, policies and plans can be customized accordingly. For example, a recent HIA in Washington County found a strong preference among residents for bicycle and pedestrian pathways that are separated from traffic, and identified specific barriers to increasing bicycle and pedestrian travel that should be accommodated in local plans and projects [80].

People who commute by walking, bicycling or public transit are more likely to meet physical activity recommendations by engaging in twice as much physical activity (transportation and recreation combined) as those who commute by car [81-88].

Regular, moderate physical activity (at least 30 minutes a day, 5 days a week) provides substantial health benefits, including lower risk of mortality, cardiovascular disease, stroke, cancer, depression, high blood pressure, diabetes, and obesity [89, 90]. Table 6 shows the prevalence of weight-related risk factors and physical activity among adults living in the three counties contributing to the Portland metropolitan region.

Table 6. Age-adjusted prevalence of selected modifiable risk factors among adults by county, 2006-09

Risk factors	Clackamas %	Multnomah %	Washington %	Oregon %
Overweight	35.7	33.8*	36.9	36.1
Obese	23.6	21.8*	23.2	24.5
Met physical activity recommendations	55.6	55.1	53.8	55.8

*Statistically significant difference compared to Oregon

Source: Behavioral Risk Factor Surveillance System, 2006-2009

While obesity is traditionally understood to result from an imbalance between calorie consumption and energy expenditure, it is clear from recent studies that the built environment, transportation infrastructure, access to healthy and nutritious food, and other environmental factors strongly influence physical activity and healthy eating [91-100].

These factors also influence children and adolescents, through commutes to school and other destinations important to youth, like community centers and work locations. Table 7 shows the prevalence of weight-related risk factors and physical activity among 8th and 11th graders living in the three counties contributing to the Portland metropolitan region. Children who walk or bike to school are more likely to meet physical activity recommendations and attain healthier body composition and cardiorespiratory fitness [85, 101-106]. However, just 48% of Oregon children who live within one mile of school walk to school at least 3 days per week, and only 8% bike to school at least 3 days per week.

Table 7. Prevalence of selected modifiable risk factors among 8th and 11th graders by county, 2007-08

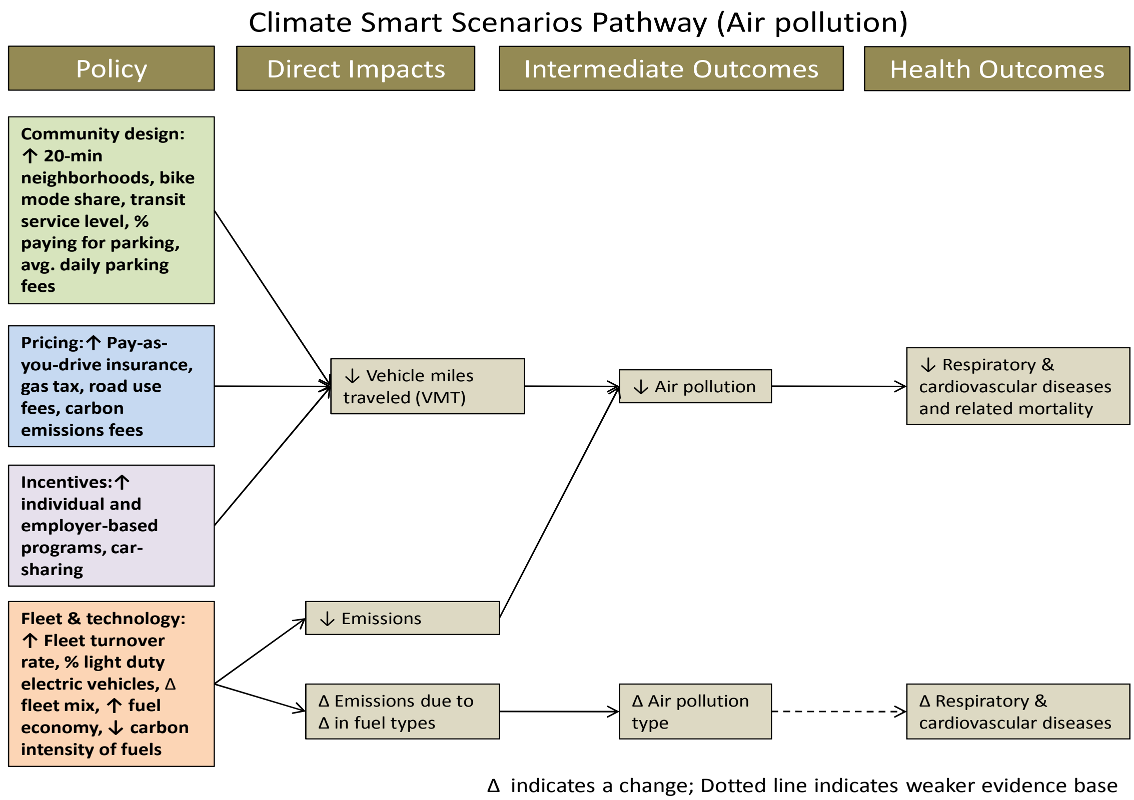
Grade	Risk Factor	Clackamas %	Multnomah %	Washington %	Oregon %
8th	Overweight	14.3	15.4	13.8	15.2
	Obese	9	10.9	10.2	10.7
	Met PA recommendations	53.9*	52.7*	50.8*	57.1
11th	Overweight	13.3	12.8	12.2	14.2
	Obese	9.8	11	10	11.3
	Met PA recommendations	49.8	38.4*	46.2	49.2

*Statistically significant difference compared to Oregon

Source: Oregon Healthy Teens, 2007-2008

Particulate Air Pollution Results

Pathway Diagrams 2 - Particulate air pollution



Pathway 2 was drafted by OHA and refined with information from the advisory committee.

ITHIM findings

Results from the ITHIM model indicate that sample scenarios 3 and 6 have the largest decreases in VMT (Table 5). These scenarios show the largest positive impact on health due to reduced air pollution exposure, with reductions of 19-22 premature deaths per year and reductions in disability adjusted life years (scenario 3: 237; scenario 6: 272). Approximately 6% of the health benefit in these two sample scenarios comes from decreased exposure to $PM_{2.5}$.

Health equity findings

The Oregon Department of Environmental Quality (DEQ) has extensively studied the distribution of air toxics in the Portland metropolitan region. DEQ found that low-income and minority communities are disproportionately impacted by higher concentrations of air toxics compared to mid- to high- income, white communities [29].

Low-income communities and communities of color are more likely to live in close proximity to high-traffic roads, and thus have higher exposures to harmful air pollution. These groups may also live in lower quality housing with poor indoor air quality. Their cumulative exposure to indoor and outdoor air pollution may be significantly higher than other groups.

There is evidence that children, older adults, people with pre-existing cardiopulmonary diseases and people with low incomes are more susceptible to negative health effects from exposure to $PM_{2.5}$ [107].

Children living next to (within 100 meters of) high-traffic roads (>= 10,000 vehicles per day) have worse lung function measures and more respiratory disease symptoms, asthma hospitalizations and doctor visits than children who live further away from high traffic areas [108-110].

Literature review findings

Policies supporting active modes of travel, including public transportation, would reduce levels of air pollution on and near roadways. There is some evidence that the individuals using active modes could increase their air pollution exposure if they are walking or biking next to busy roads.

There is also some evidence that pricing policies, such as a carbon emissions fee or direct tax on gasoline use, may reduce VMT and related air pollution. OHA found more published evidence linking pricing, fleet and technology policies to air pollution levels than incentive policies.

Shifts to lower carbon-intensity fuels and electric vehicles may change the type of emissions from motor vehicle traffic, and consequently affect changes in health conditions, such as asthma and cancer, that result from exposure. Specifically, nitrogen oxides and aldehydes may increase and benzene and 1,3 butadiene may decrease [111]. However, these changes would require large-scale shifts in the types of fuels and vehicles used in the region. While the link between improved air quality and policies related to fleet turnover and fuel technology has been demonstrated [112-114], the link between different types of emissions and changes in health outcomes has not been adequately described.

The CSCS HIA Advisory Committee asked whether an increase in 20-minute neighborhoods might lead to increased congestion and to increased exposure to air pollutants. OHA did not find any evidence to support this link, and in fact found evidence that 20-minute neighborhoods and similar community design policies decrease congestion and are likely to positively influence health [100, 115-117].

There is evidence that drivers and passengers of cars and buses are exposed to air pollution at levels similar to or exceeding those of pedestrians and cyclists [118-120]. There is also evidence that air pollution exposure is higher for pedestrians and bicyclists along busy roadways than next to roads with less traffic. A study underway in Portland has demonstrated that pedestrian exposure on a high-volume roadway is greater than driving exposure, but less than bus exposure. Travel along lower-volume roadways significantly reduced pedestrian exposure [121]. In addition, several studies have demonstrated that the health benefits from physical activity outweigh the negative health impacts of air pollution exposures to pedestrians and cyclists [9, 122, 123].

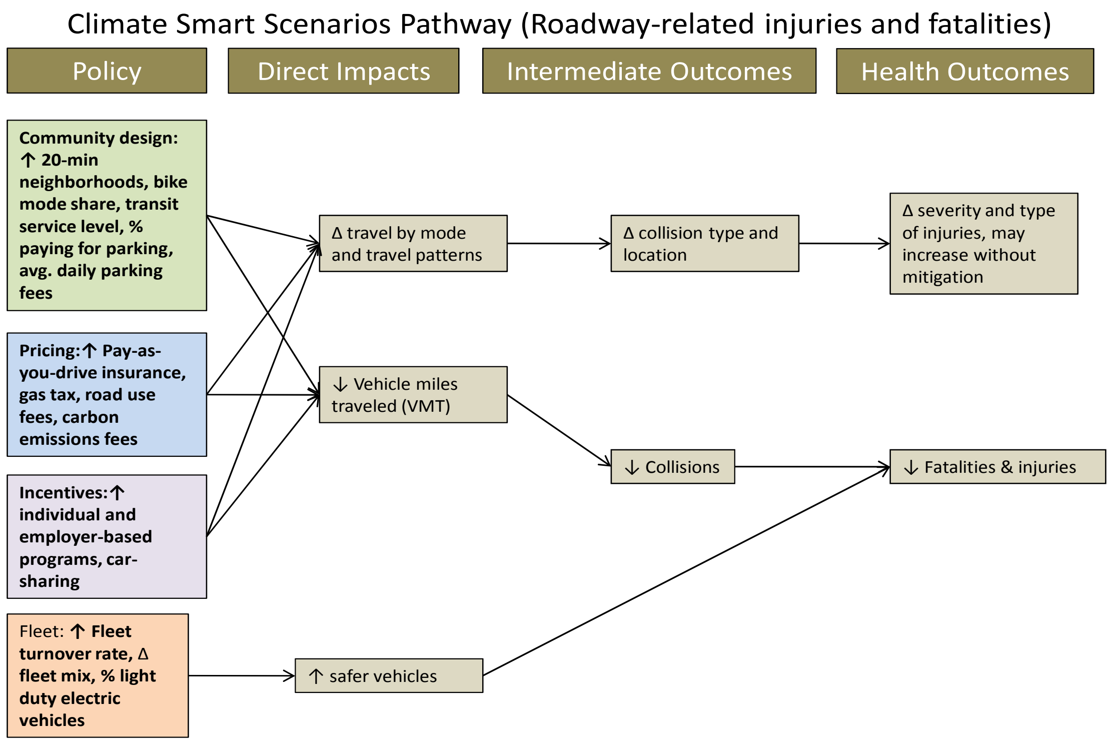
Context

Vehicle emissions contain a mix of particulate matter, nitrogen oxide, diesel exhaust, benzene, and other air toxics. These toxics are harmful to respiratory and cardiovascular health and are associated with increases in mortality and cancer incidence and mortality [32, 124, 125]. There is evidence of a causal relationship between exposure to emissions from motor vehicle traffic and a number of adverse health outcomes, including lung function impairment, asthma incidence, cardiovascular disease, and cardiovascular and overall mortality [125-130]. These adverse health effects may impact drivers and passengers of vehicles, an impact that increases as length of commute time increases. Those outside of cars may also be impacted, including residents of housing less than 300 meters (~1,000 feet) from a major road (more than 10,000 motor vehicles per day), and bicycle and pedestrian commuters along major roads [32, 125, 131].

The literature review and modeling assessment focused on fine particulate matter that is 2.5 micrometers and smaller in diameter ($PM_{2.5}$). The World Health Organization estimates that $PM_{2.5}$ exposure contributes to as many as 800,000 premature deaths each year, making it the 13th leading cause of mortality worldwide [132]. In the U.S., the Environmental Protection Agency estimates that beginning in 2020 approximately 230,000 premature deaths related to $PM_{2.5}$and ozone exposure could be avoided due to implementation of Clean Air Act Amendments [133].

Road Traffic Injuries and Fatalities Results

Pathway Diagrams 3 - Roadway-related injuries and fatalities



Pathway 3 was drafted by OHA and refined with information from the advisory committee.

ITHIM findings

Results from the ITHIM model indicate that sample scenarios 3 and 6 have the largest decreases in VMT (Table 5). These scenarios are associated with the largest positive impact on health due to decreased road traffic crashes, with reductions of 24-29 premature deaths per year and reductions in disability adjusted life years (scenario 3: 1,168; scenario 6: 1,447). Approximately 1/3 of the health benefits from these two sample scenarios come from reductions in motor vehicle crashes. With increased rates of biking, negative health impacts from increased bike injuries and deaths may arise.

Health equity findings

Children between 5 and 9 years have the highest pedestrian-motor vehicle injury rates [134]. Older adult pedestrians are more likely to die as a result of a motor-vehicle pedestrian crash than younger pedestrians [135].

There is a correlation between lower socioeconomic status and the risk of road traffic injury death for child pedestrians [136]. These socioeconomic differences may result from environmental factors or behavioral differences, or a combination of the two.

Literature review findings

Policies and investments supporting complete neighborhoods with safer infrastructure, active modes of travel, including public transportation, as well as pricing policies that reduce VMT would best reduce roadway-related injuries and fatalities. There is the least amount of evidence to support a link between incentives and fleet policies and road-related injuries and fatalities. However, fleet policies could have an impact if fleet turnover increases the number of newer and safer vehicles being driven in the region. Technology policies were not found to have an impact on crash injuries and fatalities. While crash-avoidance technologies such as sensory systems that stop a car before a collision, may reduce crash events, currently this technology is still fairly new and has yet to be directly linked to population-level impacts [112-114, 137, 138].

Risks of traffic injury and death vary by age, with higher injury rates for children and youth and higher fatality rates for older adults. Features of the built environment and transportation infrastructure contribute to the risk of motor vehicle, pedestrian and bicycle crashes. One study found that crosswalk markings without signals or stop signs are associated with increased risk of pedestrian-motor vehicle crashes for older pedestrians [135]. There is evidence of a significant positive relationship between traffic volume and the rate of vehicle collisions involving pedestrians [139-141]. One review and analysis found that the highest risk of severe or fatal crashes occurs in areas with low street network density, and that safety outcomes improve as intersection density increases [140].

One researcher has found that for bike and pedestrian crashes, there is safety in numbers; as the number of bicyclists and pedestrians increases, severe and fatal crashes decrease [142]. However, other studies have shown that higher pedestrian and bike activity does not result in increased safety. These studies suggest that other factors such as vehicle volume, speed, and roadway design are the most important contributors to bicycle and pedestrian motor vehicle crashes [139, 143].

Pedestrian and bicycle injuries are typically underestimated. Non-fatal crashes with motor vehicles and bicycle-only injuries are less likely to result in a police report, and therefore end up in official crash statistics. A Portland study found that 20% of bicycle commuters surveyed had experienced a traumatic event and 5% required medical attention during one year of commuting [144]. A San Francisco study found that over 50% of bicycle injuries treated at one hospital were not associated with a police report [137].

Context

Motor vehicle crashes are the leading cause of injury death in the United States and the second leading cause in Oregon [145, 146]. Motor vehicle crashes are the leading cause of death for individuals between the ages of 5 and 24 [147]. In 2010, the State of Oregon's rate of traffic fatalities per 100 million VMT was .94 [148]. In 2010, the State of Oregon's rate of 1.2 [149]. This was below the national rate of 1.10 and the highest injury rate of 1.2 [148, 149]. Oregon's rate of traffic injuries per 100 million VMT in 2010 was higher than the national MSA average of 8.2 [149, 150].

In 2009, the Portland metropolitan region ranked in the top 15 metropolitan statistical areas (MSA) nationally for lowest annual rate of traffic fatalities per 100,000, with a rate of 6.2 compared to the national MSA average of 8.2 [150]. When injury and fatality data are combined, both Clackamas County (5.2) and Washington County (5.25) had better rates than the statewide (5.51) fatal and injury crash rate per 1,000 [151, 152]. Conversely, Multnomah County was significantly worse (8.03) [153, 154]. Nevertheless, all three counties fared better than the state rate of crash-related deaths for individuals between the ages of 15 and 24 [155]. OHA has set a goal to decrease statewide motor vehicle fatalities by 17% below the 2007 rate of 12.1 per 100,000.

In the Portland metropolitan region, streets with more lanes and higher speeds (arterials such as SE 82nd Ave, SE McLoughlin Boulevard, and SW Beaverton-Hillsdale Highway) have higher serious crash rates, especially for pedestrians. About 40% of all vehicle travel in the Portland metropolitan region between 2007 and 2009 was on arterials. Arterials were the location of 57% of the serious auto crashes, 67% of the serious pedestrian crashes, and 52% of the serious bike crashes [11]. Serious pedestrian and bicycle crashes disproportionately occurred after dark on unlit streets. Travel by transit is relatively safe in the region, with a rate of 0.23 deaths involving a transit vehicle per 100 million transit-passenger-miles, compared to the rate of 0.42 for all traffic [11].

Conclusion and Recommendations

Significant shifts in the climate are already happening and as the climate continues to warm the impacts to public health will become more apparent. We can expect exposure to more frequent heat waves, an increase in asthma, changes in disease patterns and diminishing water quality and quantity. Curbing climate change is a pressing public health issue, and the Public Health Division strongly supports efforts across the state to reduce greenhouse gas emissions. Reducing greenhouse gas emissions will have In addition to the inevitable health benefits for Oregonians by slowing down climate change and improving air quality.

The changes required to reduce GHG emissions represent a significant investment of resources, many of which have the potential to impact health. To maximize the health benefits of these investments and minimize any potential health risks, OHA makes the following recommendations.

Findings and Recommendations

Air quality

Findings:
All scenarios that meet GHG reduction goals have potential positive impacts on human health. The most health-promoting scenarios evaluated in this assessment had similar elements:

- The most ambitious levels of community design policies,
- Intermediate and ambitious levels of pricing and incentives,
- Highest levels of active transportation (including transit),
- Lowest levels of single occupancy vehicle driving, and
- Lowest levels of particulate air pollution.

In addition, air pollution has several health equity impacts of concern, such as:

- Children, older adults, people with pre-existing cardiopulmonary diseases and people with low incomes are more susceptible to negative health effects from exposure to $PM_{2.5}$.
- Low-income communities and communities of color are more likely to live in close proximity to high-traffic roads, and thus have higher exposures to harmful air pollution. These groups may also live in lower quality housing with poor indoor air quality. Their cumulative exposure to indoor and outdoor air pollution may be significantly higher than other groups.

Recommendation:
Develop and implement a preferred scenario that meets or surpasses the greenhouse gas emissions reduction target set for the region. Further:

- Prioritize strategies that lead to decreases in air pollution exposure for all populations in the region; in particular for low income communities, children, seniors, people with low incomes, and people with chronic health conditions or disabilities. An example strategy may be creating and promoting walking and biking routes adjacent to low-traffic roads specifically in lower income neighborhoods).
- Follow through with implementation of the recommendations identified in the Portland Air Toxics Solutions Report**.** The report identifies a number of recommendations that will reduce air pollution from light vehicles and have also been linked to reducing GHG emissions.

Physical activity

Findings:

Scenarios that meet GHG reduction goals by decreasing vehicle miles traveled (VMT) will have the most positive impacts on health. In the most health-promoting scenarios assessed, the majority of the health benefits result from increased physical activity (60%), followed by reductions in road traffic crashes (approximately 33%) and lower exposure to particulate matter in the air (6%).

Recommendation:

To maximize public health benefits and meet the state target, emphasize the types of strategies that best increase active transportation and physical activity: community design, pricing and incentives. Further:

- Implement active transportation strategies with an understanding of existing local health conditions and inequities.
    a. Increasing the number of people biking and walking could cause a small increase in injuries and deaths from collisions. Therefore Metro and partners should implement strategies in ways that do not worsen these health conditions and inequities, such as planning for necessary safety infrastructure.
    b. Portland metropolitan region residents do not all have equal access to active transportation opportunities. An effort should be made to improve access for all communities.
- Prioritize strategies that lead to increases in active travel for all populations in the region, in particular for children, seniors, people with low incomes, communities of color, and people with chronic health conditions or disabilities. Example strategies include marketing and incentive programs targeted to these populations, improved active travel infrastructure on routes to schools, and improved public transportation service in areas where these populations live.

Collisions

Findings:

The modeling tool used in this assessment shows positive health impacts due to reductions in motor vehicle crashes and potential negative impacts from increased bike injuries.

- Children are more likely to experience pedestrian-motor vehicle injuries and older adult pedestrians are more likely to die as a result of motor-vehicle pedestrian crashes.
- Child pedestrians from lower income families are at higher risk of dying from a road traffic injury.

Recommendation:

Include strategies, such as community design, that can lead to decreases in road traffic injuries and fatalities for all populations in the region, in particular for children. Further:

- Prioritize strategies that lead to decreases in road traffic injuries and fatalities for all populations in the region; in particular for children and older adults. The community design, pricing and incentives strategies that lead to reductions in VMT may also increase safety in the region.
- Mitigate potential increases in pedestrian and bicyclist injuries and fatalities through proven design strategies, such as increasing the visibility of vulnerable road users; separate facilities like sidewalks, bike boulevards or cycle tracks; and traffic calming or speed control measures [134, 156]. The feeling of safety given by these mitigations may also expand the percentage of the population willing to bike and walk.

Further assessment

Carry out additional quantitative health impact assessment of the three scenarios that are identified in spring 2013 to further inform development and adoption of a final preferred scenario. OHA recommends the use of ITHIM or a similar health impacts model for this future assessment. Further:

- OHA recommends that when the CSCS Project develops the preferred scenario in 2013-14, health stakeholders (in particular, local health departments) be consulted in order to incorporate local health expertise and to continue building relationships between public health and planning professionals and policymakers.
- OHA recommends that future related HIAs include consideration of land use, housing affordability, location relative to employment, gentrification and displacement, or air pollution other than $PM_{2.5}$.

Appendix A. List of Climate Smart Communities Scenarios HIA Advisory Committee members

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Appendix B. Population travel and health characteristics of Portland Metro region

Table 1. Metropolitan Region Travel Characteristics Comparison, County and State

Travel Characteristic	Clackamas County	Multnomah County	Washington County	State of Oregon
Commute to Work – Drove Alone	76%	62.9%	73.9%	72%
Commute to Work – Carpooled	9.6%	9.8%	10.2%	10.8%
Commute to Work – Public Transportation	3.2%	11%	5.7%	4.2%
Commute to Work – Walked	2.4%	4.8%	2.9%	3.9%
Commute to Work – Other Means	1.2%	5.4%	2.1%	3.1%
Average Commute Time (minutes)	26	24.3	24.1	22.1
Source: 2006-2010 American Community Survey - Oregon, U.S. Census Bureau, 2011.				

Table 2. Multnomah County Travel Characteristics Comparison, Cities

Travel Characteristic	Fairview	Gresham	Lake Oswego	Maywood	Milwaukie	Portland	Troutdale	Wood Village	State of Oregon
Commute to Work Drove Alone (%)	73	73.5	76.7	79.4	74.8	60.4	76.7	74.7	72
Commute to Work Carpooled (%)	10.3	12.2	6	13.2	8.9	9.4	13.7	6.8	10.8
Commute to Work Public Transport (%)	4.8	7.4	3.8	1.5	8.1	12	3.3	12.2	4.2
Commute to Work Walked (%)	4.5	2.5	1.7	1	2.5	5.4	0.5	2.4	3.9
Commute to Work Other Means (%)	0.6	1.1	1.5	2.2	1.3	6.4	2.1	0.9	3.1
Average Commute Time (minutes)	22.1	26.2	21.5	24.8	24.3	23.9	27.3	26.2	22.1

Yellow = **Positively** different from state average Pink = **Negatively** different from state average

Source: 2006-2010 American Community Survey - Oregon, U.S. Census Bureau, 2011.

Table 3. Portland Metropolitan Region Health Conditions Comparison, 2006 – 2009

Health Condition	Clackamas County	Multnomah County	Washington County	State of Oregon
Asthma Prevalence	9.7%	9.2%	9.0%	9.7%
Diabetes Prevalence	6.6%	6.2%	5.9%	6.8%
Stroke Prevalence	2.6%	1.8%	1.9%	2.3%
Heart Attack Prevalence	2.5%	2.9%	2.5%	3.3%
Obesity Prevalence	23.6%	21.8%	23.2%	24.5%
Meets CDC Physical Activity Recommendation	55.6%	55.1%	53.8%	55.8%
Fatal/Injury Crash Rate (per 1,000 population)	5.2	8.03	5.25	5.51
Source: 2006-2009 BRFSS County Combined Dataset				

Appendix C. Integrated transport and health modeling (ITHIM) results, detailed tables

Table 1. GreenSTEP model inputs for Base Year (2010) and Scenario Clusters 1-6 (2035)

	Walk Trips Per Person Per Week	Bike Miles Per Person Per Week	Household Vehicle Miles Per Person Per Week	Roadway Light Duty Vehicle Miles Per Person Per Week	Bus Revenue Miles Per Person Per Week	Rail Revenue Miles Per Person Per Week
Base Year (2010)	2.81	2.24	129.36	139.03	0.32	0.23
Scenario Cluster 1	3.53	2.16	122.41	131.56	0.44	0.11
Scenario Cluster 2	3.69	3.71	99.00	106.48	0.66	0.66
Scenario Cluster 3	3.90	4.57	76.77	82.61	1.10	1.10
Scenario Cluster 4	3.53	2.16	107.99	116.08	0.44	0.11
Scenario Cluster 5	3.69	3.71	87.49	94.13	0.66	0.66
Scenario Cluster 6	3.90	4.57	68.65	73.90	1.10	1.10

Table 2. Premature deaths, years of life lost, and attributable fractions* due to increased physical activity, Scenario Clusters 1-6, Portland metropolitan region

	Burden of Disease						Attributable Fraction, Percent					
Item by Cause	Scenario Cluster 1	Scenario Cluster 2	Scenario Cluster 3	Scenario Cluster 4	Scenario Cluster 5	Scenario Cluster 6	Scenario Cluster 1	Scenario Cluster 2	Scenario Cluster 3	Scenario Cluster 4	Scenario Cluster 5	Scenario Cluster 6
Premature Deaths												
Ischemic Heart Disease	-25	-58	-73	-34	-69	-82	-1.6%	-3.8%	-4.8%	-2.2%	-4.5%	-5.4%
Hypertensive Heart Disease	-5	-11	-14	-7	-13	-16	-1.7%	-3.8%	-4.8%	-2.3%	-4.5%	-5.5%
Stroke	-12	-27	-33	-16	-31	-37	-1.7%	-3.8%	-4.7%	-2.3%	-4.5%	-5.3%
Diabetes	-3	-8	-9	-4	-9	-11	-1.4%	-3.2%	-3.7%	-1.6%	-3.6%	-4.2%
Dementia	-3	-5	-6	-4	-6	-7	-0.7%	-1.3%	-1.6%	-0.9%	-1.6%	-1.8%
Breast Cancer	0	-1	-2	0	-1	-2	-0.3%	-0.8%	-1.0%	-0.2%	-0.6%	-0.9%
Colon Cancer	-1	-2	-2	-1	-2	-2	-0.4%	-0.9%	-1.1%	-0.5%	-0.9%	-1.1%
Depression	0	0	0	0	0	0	-0.6%	-1.1%	-1.3%	-0.6%	-1.1%	-1.2%
Total	-49	-112	-139	-66	-131	-157	-1.4%	-3.2%	-3.9%	-1.9%	-3.7%	-4.4%
Years Life Lost												
Ischemic Heart Disease	-247	-617	-820	-335	-717	-915	-1.6%	-3.9%	-5.2%	-2.1%	-4.6%	-5.8%
Hypertensive Heart Disease	-53	-134	-187	-73	-156	-208	-1.5%	-3.8%	-5.3%	-2.1%	-4.4%	-5.9%
Stroke	-109	-275	-354	-147	-320	-395	-1.6%	-4.0%	-5.1%	-2.1%	-4.6%	-5.7%
Diabetes	-47	-118	-149	-55	-133	-165	-1.3%	-3.2%	-4.1%	-1.5%	-3.6%	-4.5%
Dementia	-18	-37	-43	-21	-40	-46	-0.7%	-1.4%	-1.7%	-0.8%	-1.5%	-1.8%
Breast Cancer	-10	-28	-43	-8	-20	-37	-0.3%	-0.8%	-1.3%	-0.2%	-0.6%	-1.1%
Colon Cancer	-7	-19	-26	-7	-17	-24	-0.3%	-0.8%	-1.1%	-0.3%	-0.7%	-1.0%
Depression	0	0	0	0	0	0	-0.5%	-1.1%	-1.5%	-0.5%	-1.0%	-1.3%
Total	-492	-1230	-1623	-647	-1403	-1789	-1.3%	-3.2%	-4.3%	-1.7%	-3.7%	-4.7%

Years Living With Disability												
Ischemic Heart Disease	-18	-44	-56	-21	-49	-61	-1.4%	-3.4%	-4.3%	-1.6%	-3.8%	-4.7%
Hypertensive Heart Disease	-7	-15	-17	-9	-17	-19	-1.5%	-2.9%	-3.4%	-1.8%	-3.4%	-3.9%
Stroke	-41	-107	-142	-48	-118	-155	-1.3%	-3.4%	-4.5%	-1.5%	-3.7%	-4.9%
Diabetes	-49	-137	-182	-57	-152	-200	-1.1%	-3.1%	-4.2%	-1.3%	-3.5%	-4.6%
Dementia	-47	-109	-127	-53	-110	-128	-0.6%	-1.5%	-1.7%	-0.7%	-1.5%	-1.7%
Breast Cancer	-3	-7	-11	-2	-5	-10	-0.3%	-0.8%	-1.3%	-0.2%	-0.6%	-1.1%
Colon Cancer	-2	-4	-6	-2	-4	-6	-0.3%	-0.8%	-1.1%	-0.3%	-0.7%	-1.1%
Depression	-33	-104	-168	-24	-70	-124	-0.2%	-0.7%	-1.1%	-0.2%	-0.5%	-0.8%
Total	-201	-528	-710	-216	-526	-703	-0.6%	-1.6%	-2.1%	-0.6%	-1.6%	-2.1%
DALYs												
Ischemic Heart Disease	-265	-661	-876	-356	-766	-976	-1.6%	-3.9%	-5.2%	-2.1%	-4.5%	-5.8%
Hypertensive Heart Disease	-61	-149	-204	-82	-173	-228	-1.5%	-3.7%	-5.1%	-2.0%	-4.3%	-5.6%
Stroke	-150	-382	-496	-195	-438	-550	-1.5%	-3.8%	-4.9%	-1.9%	-4.4%	-5.5%
Diabetes	-96	-255	-332	-112	-285	-365	-1.2%	-3.2%	-4.1%	-1.4%	-3.6%	-4.5%
Dementia	-65	-146	-170	-75	-150	-174	-0.6%	-1.5%	-1.7%	-0.7%	-1.5%	-1.7%
Breast Cancer	-13	-36	-54	-10	-25	-46	-0.3%	-0.8%	-1.3%	-0.2%	-0.6%	-1.1%
Colon Cancer	-9	-24	-32	-9	-21	-29	-0.3%	-0.8%	-1.1%	-0.3%	-0.7%	-1.0%
Depression	-34	-104	-168	-24	-70	-125	-0.2%	-0.7%	-1.1%	-0.2%	-0.5%	-0.8%
Total	-693	-1758	-2333	-863	-1929	-2492	-1.0%	-2.5%	-3.3%	-1.2%	-2.7%	-3.5%

*The attributable fraction (AF) is the proportional reduction in population disease or mortality that would occur if exposure to a risk factor were reduced to an alternative ideal exposure scenario. Many diseases are caused by multiple risk factors, and individual risk factors may interact in their impact on overall risk of disease. As a result, AFs for individual risk factors often overlap and add up to more than 100 percent.

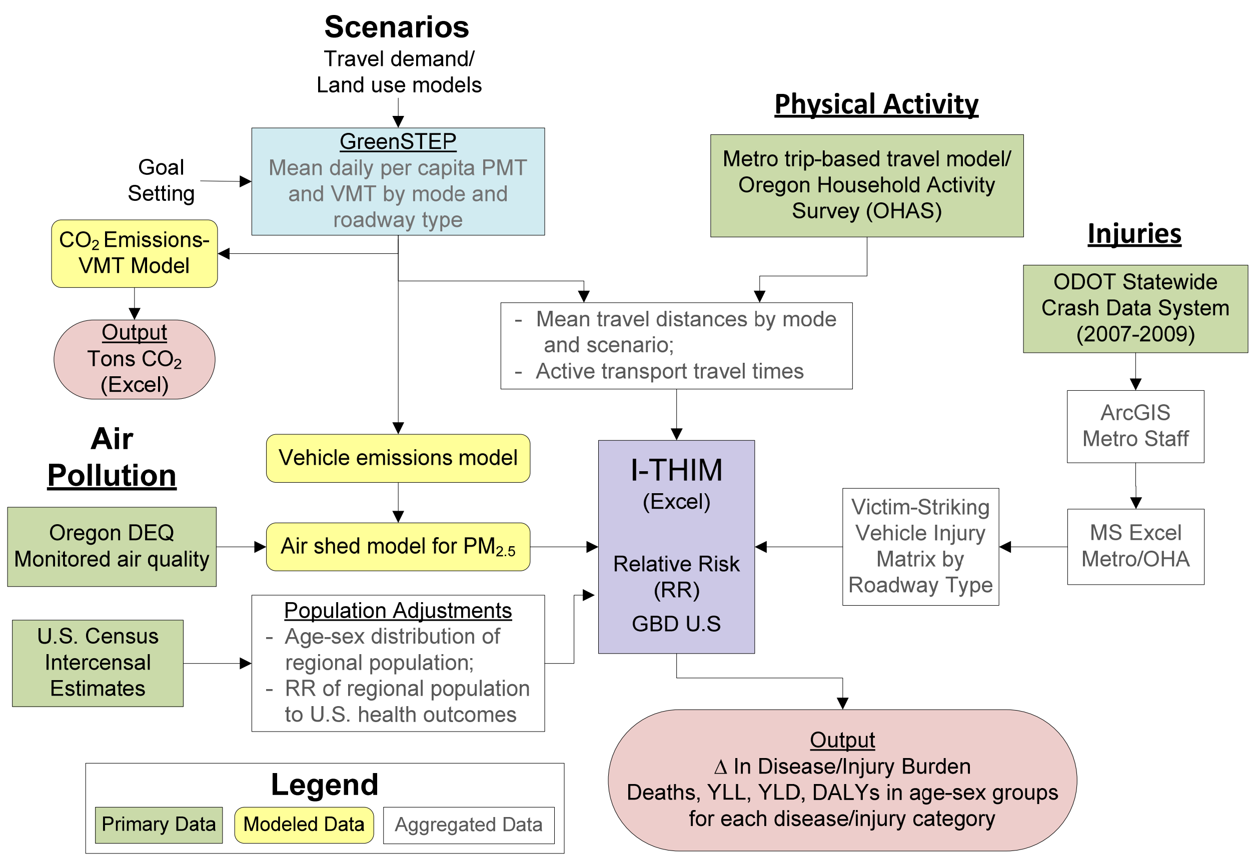
Table 3. Annual mean miles traveled per person by mode and percent mode share for Base Year (2010) and Scenario Clusters 1-6 (2035)

Scenario	Units	Automobile/ Light Truck	Bus	Rail	Bicycle	Walk	Total
Base Year	Miles	6,727	17	12	116	70	6,942
	%	96.9	0.2	0.2	1.7	1.0	100.0
Scenario Cluster 1	Miles	6,365	23	6	112	88	6,594
	%	96.5	0.3	0.1	1.7	1.3	100.0
Scenario Cluster 2	Miles	5,148	34	34	193	92	5,501
	%	93.6	0.6	0.6	3.5	1.7	100.0
Scenario Cluster 3	Miles	3,992	57	57	238	97	4,442
	%	89.9	1.3	1.3	5.4	2.2	100.0
Scenario Cluster 4	Miles	5,616	23	6	112	88	5,844
	%	96.1	0.4	0.1	1.9	1.5	100.0
Scenario Cluster 5	Miles	4,549	34	34	193	92	4,903
	%	92.8	0.7	0.7	3.9	1.9	100.0
Scenario Cluster 6	Miles	3,570	57	57	238	97	4,020
	%	88.8	1.4	1.4	5.9	2.4	100.0

Table 4. Total injuries and fatalities by roadway and mode of travel for Scenario Clusters 1-6, Portland Metropolitan ITHIM model

Roadway/Victim	Baseline	Scenario Cluster 1	Scenario Cluster 2	Scenario Cluster 3	Scenario Cluster 4	Scenario Cluster 5	Scenario Cluster 6
1. Highway							
Walk	0.7	0.7	0.7	0.6	0.7	0.6	0.6
Bicycle	0.3	0.3	0.4	0.4	0.3	0.3	0.3
Bus	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Car	26.3	24.9	20.2	15.8	22.0	17.9	14.1
Truck	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Motorcycle	6.3	6.3	6.2	6.2	6.3	6.2	6.1
2. Arterial							
Walk	39.0	42.8	39.8	36.8	40.3	37.6	35.0
Bicycle	10.3	9.9	12.0	12.1	9.4	11.3	11.6
Bus	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Car	128.0	121.2	98.5	76.7	107.2	87.2	68.7
Truck	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Motorcycle	11.0	10.8	10.2	9.6	10.5	9.9	9.4
3. Local street							
Walk	17.7	19.3	17.8	16.3	18.2	16.8	15.5
Bicycle	18.3	17.5	20.7	20.3	16.5	19.5	19.2
Bus	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Car	61.7	58.4	47.4	36.9	51.6	42.0	33.1
Truck	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Motorcycle	12.0	11.8	11.2	10.5	11.5	10.9	10.3
Total	332.6	325.1	286.2	243.2	295.4	261.4	224.8

Appendix D. ITHIM diagram and data inputs



Data inputs

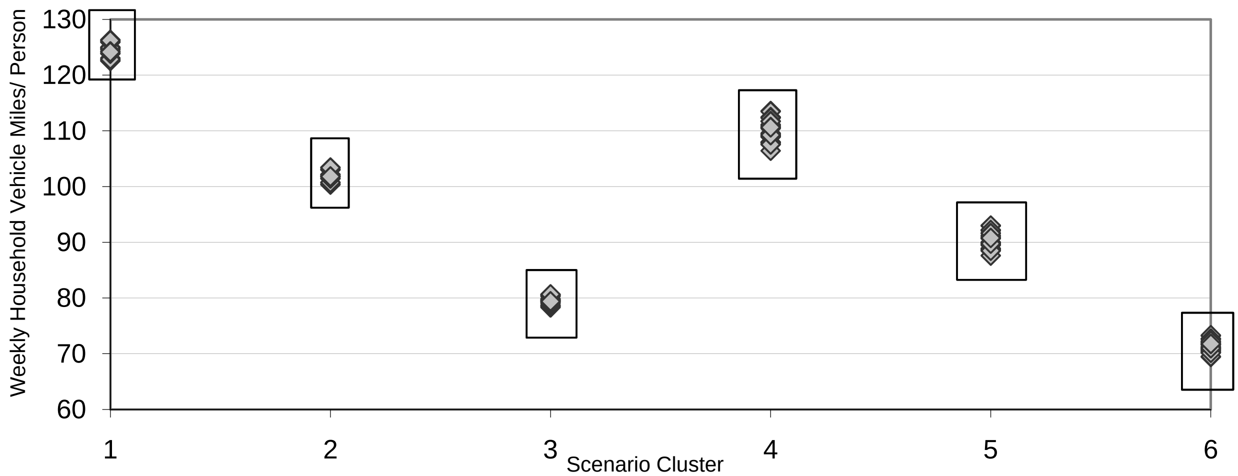
OHA obtained data from various sources for the ITHIM data inputs. These sources and more detailed descriptions of the data follow.

Selection of sample scenarios for assessment in ITHIM

During Phase One of the Climate Smart Communities Scenarios Planning effort, Metro estimated the GHG-reducing properties of 144 specific scenarios. OHA did not assess the health impacts of each of the Phase One scenarios. Instead, 6 sample scenarios were assessed to provide information about the health impacts of the types of policies and investments decision-makers will consider including as they develop the final three Phase Two scenarios.

The sample scenarios are actually averages of 6 clusters of scenarios for the Portland metropolitan region in 2035 and the 2010 base year. The clusters were identified based on similarities in household travel and emissions characteristics as shown in the figure below and in Appendix C, Table 1.

Figure Household Vehicle Travel By Scenario Cluster



The distinguishing features of the sample scenarios are detailed below:

- Scenario Cluster 1 includes all community design level 1 and pricing level 1 scenarios.
- Scenario Cluster 2 includes all community design level 2 and pricing level 1 scenarios.
- Scenario Cluster 3 includes all community design level 3 and pricing level 1 scenarios.
- Scenario Cluster 4 includes all community design level 1 and pricing level 2 and level 3 scenarios.
- Scenario Cluster 5 includes all community design level 2 and pricing level 2 and level 3 scenarios.
- Scenario Cluster 6 includes all community design level 3 and pricing level 2 and level 3 scenarios.

More detailed descriptions of the scenario assumptions for each policy area level can be found in the Phase One Findings Report [66].

Road Traffic Injuries

In 2011, Metro extracted three years of collision data between 2007 and 2009 from Oregon Department of Transportation's (ODOT) statewide crash data system for use in the Metro State of Safety Report. Metro formatted ODOT's crash data to show injury severity by travel mode (motorized vehicles, bicyclists, pedestrians) of injured parties and roadway type where the collision occurred for state of safety report. OHA averaged serious injuries and fatalities for the three years of data used in the report by road type and travel mode of injured parties and applied it in ITHIM's baseline injuries module. Fatal injuries are deaths occurring within 30 days of the collision. Serious injuries are injuries that the victim is not able to walk away from.

Air Pollution

Estimates of average, annual airborne concentration of fine particulate matter (aerodynamic diameter of 2.5 microns, $PM_{2.5}$) were based on two sources. Mobile $PM_{2.5}$ from light duty vehicles was calculated inside ODOT's Greenhouse Gas Statewide Transportation Emissions Planning Model (GreenSTEP) from estimated household vehicle travel, fuel consumption by fuel type and emission rates for each scenario. Fluctuations in emissions from heavy vehicle travel were not included in GreenSTEP scenario outputs.

Annual mean ambient $PM_{2.5}$ concentration was calculated from monitors distributed around the Washington and Multnomah Counties. Most $PM_{2.5}$ monitors measure air quality every sixth day, some every third day and a few measure every day. Monitored $PM_{2.5}$ data was not available for Clackamas County, but it is assumed that air pollution is similar to Multnomah County based on input from DEQ. Mobile emissions calculated for existing conditions in GreenSTEP were treated as a percentage of the total annual mean ambient $PM_{2.5}$ concentration and subtracted from the total to estimate stationary $PM_{2.5}$ for the alternative scenarios. Stationary $PM_{2.5}$ was held constant for the alternative scenarios and only mobile emissions fluctuated.

Census

US Census data were used to create the demographic profile of the three counties in the Metro region. The 2004 population was estimated from the 2000 and 2010 census population growth trend for populations inside Metro's Urban Growth Boundary geography. Relative risk factors were applied in ITHIM to describe risk reduction for several diseases from physical exercise associated with active travel. Age group and sex determine relative risk factors. Population distribution was also used to adjust U.S. health outcomes from the Global Burden of Disease database for the Metro region.

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Article 1. General Provisions - California Education Code Section 17213

Legal Research Home > California Laws > Education Code > Article 1. General Provisions - California Education Code Section 17213

17213. The governing board of a school district may not
approve a
project involving the acquisition of a schoolsite by a school
district, unless all of the following occur:
(a) The school district, as the lead agency, as defined in
Section
21067 of the Public Resources Code, determines that the
property
purchased or to be built upon is not any of the following:
(1) The site of a current or former hazardous waste
disposal site
or solid waste disposal site, unless if the site was a former
solid
waste disposal site, the governing board of the school
district
concludes that the wastes have been removed.
(2) A hazardous substance release site identified by the
Department of Toxic Substances Control in a current list
adopted
pursuant to Section 25356 of the Health and Safety Code for
removal
or remedial action pursuant to Chapter 6.8 (commencing with
Section
25300) of Division 20 of the Health and Safety Code.
(3) A site that contains one or more pipelines, situated
underground or aboveground, that carries hazardous substances,
extremely hazardous substances, or hazardous wastes, unless
the
pipeline is a natural gas line that is used only to supply
natural
gas to that school or neighborhood.
(b) The school district, as the lead agency, as defined in
Section
21067 of the Public Resources Code, in preparing the
environmental
impact report or negative declaration has consulted with the
administering agency in which the proposed schoolsite is
located,
pursuant to Section 2735.3 of Title 19 of the California Code
of
Regulations, and with any air pollution control district or
air

June 8, 2015

Los Angeles City Council
200 North Spring Street, Room 360
Los Angeles, CA 90012
Attn: Herb J, Wesson, Jr., President
Cc: Michael Espinosa, Office of the City Clerk

RE: Glendale-Hyperion Complex Improvement Project (CF #05-0173)

Honorable Councilmembers,
I write to voice concerns regarding the lack of compliance with Federal Americans with Disabilities Act regulations ("ADA") in the proposed design for the Glendale-Hyperion Bridge Complex Improvement Project (CF #05-0173).

Overview:

The proposed design calls for removal of the sidewalk on the South side of the Hyperion Avenue Viaduct ("Hyperion") portion of the project. In removing this sidewalk, it is explained that the proposed design improves upon the existing condition by providing a single path accessible to those who utilize a wheelchair on the North side of Hyperion. The proposed design, however, results in a condition in which able-bodied persons are provided a more direct, convenient, and less time-consuming route; while persons with disabilities are not afforded *equivalent facilitation*.

In providing a prioritized route for able-bodied people that does not accommodate those of limited abilities, the proposed design discriminates against people with disabilities. The proposed design is not compliant with ADA regulations and California Civil Code, and as such, creates an unacceptable financial liability for the City of Los Angeles and its taxpayers for the cost of a judgment against the City and/or subsequent retrofit to comply with ADA.

Legal Requirement to Eliminate ADA Barriers in Hyperion Bridge:

It is noted in a technical memorandum prepared by project structural engineer, Psomas, dated May 28, 2015, "Sidewalks exist on both sides of the Hyperion Bridge over I-5, and over the L.A. River." These sidewalks are acknowledged to be non-ADA compliant due, in part, to a pinch point at the Waverly Drive underpass that causes the sidewalk to reduce to a 2'-0" section.

Under ADA and Section 504 of the U.S. Rehabilitation Act of 1973, an alteration project is required to remove barriers from public facilities that would provide discrimination against persons with disabilities. ADA [28 C.F.R. § 35.151 (b)] states:

> (1) Each facility or part of a facility altered by, on behalf of, or for the use of a public entity in a manner that affects or could affect the usability of the facility or part of the facility shall, to the maximum extent feasible, be altered in such manner that the altered portion of the facility is readily accessible to and usable by individuals with disabilities, if the alteration was commenced after January 26, 1992.
>
> (3)
> (i) Alterations to historic properties shall comply, to the maximum extent feasible, with the provisions applicable to historic properties in the design standards specified in § 35.151(c).

> (ii) If it is not feasible to provide physical access to an historic property in a manner that will not threaten or destroy the historic significance of the building or facility, alternative methods of access shall be provided pursuant to the requirements of § 35.150.

No reasoning for non-compliance with ADA has been provided for the proposed project, however the City's Bureau of Engineering has argued that adjustment to the roadway configuration would have impacts to vehicle Level Of Service ("LOS") on the road that may require further study to mitigate under California law. Because vehicle LOS is not an aspect of *historic significance*, this claimed requirement for further study under state law does not absolve the City's requirement to provide for the civil rights of users with disabilities by complying with Federal ADA Law.

These requirements to provide equal access for users of all abilities is mirrored in California Civil Code Section 54:

> 54. (a) Individuals with disabilities or medical conditions have the same right as the general public to the full and free use of the streets, highways, sidewalks, walkways, public buildings, medical facilities, including hospitals, clinics, and physicians' offices, public facilities, and other public places.
>
> 54.1 (3) "Full and equal access," for purposes of this section in its application to transportation, means access that meets the standards of Titles II and III of the Americans with Disabilities Act of 1990 (Public Law 101-336) and federal regulations adopted pursuant thereto, except that, if the laws of this state prescribe higher standards, it shall mean access that meets those higher standards.

<u>Option 3 is the Only Design Provided that Complies with ADA:</u>

In August 2014, the Bureau of Engineering provided three (3) feasible design alternatives for review by a Citizen's Advisory Committee, convened by Los Angeles City Councilmembers Mitch O'Farrell and Tom LaBonge. Design Option 3 ("Exhibit 3") provided a design with two sidewalks on Hyperion, by widening existing non-compliant sidewalks. This option provides a path for users between the Silver Lake and Atwater Village communities on the South side of the bridge complex that accommodates not only able-bodied persons, but also persons with disabilities.

Because Exhibit 3 represents an option "readily accessible" to all users without requirement of detour for people with disabilities, it is evidence that Options 1, 1A, and 2 <u>do not</u> meet the requirement under ADA for alterations to comply with ADA design guidelines "to the maximum extent feasible." Exhibit 3 shows dimensional ability to incorporate widened sidewalks compliant with ADA design guidelines. Exhibit 3 further shows that no *structural impracticability* or *impracticability with regard to historic significance* exists to exempt the alteration project from the requirements of ADA.

The Bureau of Engineering has stated that further study in the form of an Environmental Impact Report ("EIR") of Exhibit 3 is required in order to comply with California Environmental Quality Act ("CEQA") provisions. Because an EIR is required by state law for projects that may have impacts on the environment, such a study and time required to perform does not represent an unreasonable hardship in eliminating a discriminatory condition and complying with ADA.

<u>Discrimination Against People with Disabilities Detailed in Technical Memorandum:</u>

The May 28, 2015 Technical Memorandum prepared by Psomas provides an Appendix detailing the routes available to users for the proposed design. Although this Appendix obfuscates the condition of unequal access by showing a destination on the North side of Hyperion from a starting point on the South side (as well as inaccurate distance and time calculations), the Appendix clearly shows evidence of a discriminatory lack of equivalent facilitation for those with disabilities.

The first diagram shows the existing pathway and ADA compliant path (the document misstates the accessible path from Ferncroft Road to Hyperion's south sidewalk as 1,260 feet, when it is actually 660 feet). This graphic shows the convenient and accessible path that would be provided to all users in design option, Exhibit 3.

The second diagram of the Appendix shows a new pathway provided to able-bodied persons via a new bridge constructed over the former Red Car right of way. It estimates that this path provided to able-bodied persons adds 310 feet from the path that would be provided were design option Exhibit 3 selected.

The third and final diagram of the Appendix shows the required path for people with disabilities under the proposed design. This path for users with disabilities – fully separated from those provided to able-bodied users – is estimated, under Psomas' own calculations to add a significant distance and time only to users with disabilities. Psomas notes, "Compared to shortest ADA route on south side adds 1,550 ft." and that the proposed design "adds 7.4 minutes walking time" only for users with disabilities. These distances would be even greater and longer in duration if a destination on the south side of Hyperion were considered, and if waiting time for the four traffic lights on the selected route was incorporated.

This Appendix details discriminatory design in the project proposal against users with disabilities by forcing such users to take a separate and unequal pathway to cross the Los Angeles River and I-5 Freeway from that which is provided to able-bodied users.

<u>Summary:</u>

In its proposed design and in its consultant's documentation, the City of Los Angeles appears to attempt only to reduce – rather than eliminate – discrimination faced by people with disabilities in traversing over the Los Angeles River at Hyperion Avenue from the bridge's current condition. This objective, however, is inconsistent with the Americans with Disabilities Act, because it does not *minimize* discrimination, per § 35.151, "to the maximum extent feasible" in making the bridge complex "readily accessible to and usable by individuals with disabilities."

In light of the recent $1.4 billion ADA sidewalk settlement, *Willits v. City of Los Angeles*, it is imperative that the City of Los Angeles perform new and alteration to infrastructure projects in compliance with California and Federal law with regards to the civil rights of users with disabilities. **By providing a design that is discriminatory towards users with disabilities, the City's proposed option for the Glendale-Hyperion Bridge Improvement Project fails to comply with ADA, and places a significant financial liability on its taxpayers.**

Thank you,

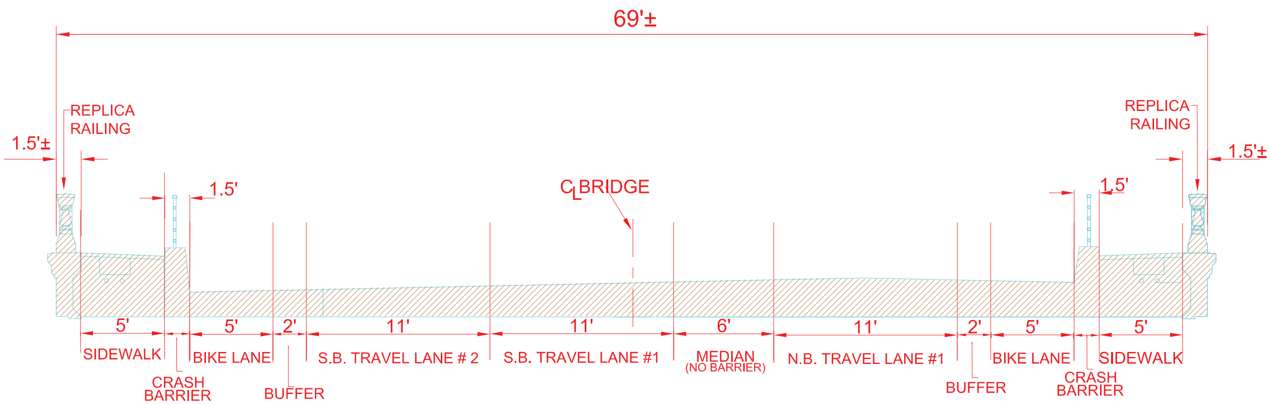
Michael MacDonald
Architect, NCARB, LEED AP BD&C
michael.s.macdonald@gmail.com

BUREAU OF ENGINEERING PROVIDED DESIGN OPTION 3

EXHIBIT 3

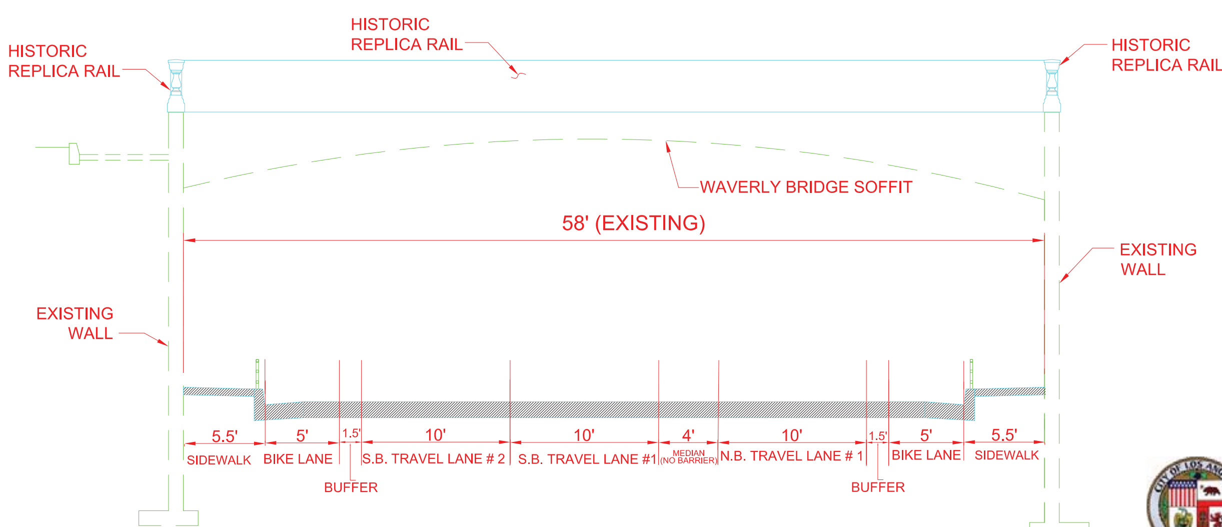
HYPERION AVENUE BRIDGE OVER I-5, RIVERSIDE DRIVE AND LA RIVER (LOOKING NORTH)

1) THREE-11 FT. LANES (ONE LANE DOWNHILL; TWO LANES UPHILL)
2) SIDEWALK AND BUFFER ON BOTH SIDES
3) 6 FT. MEDIAN (NO BARRIER)



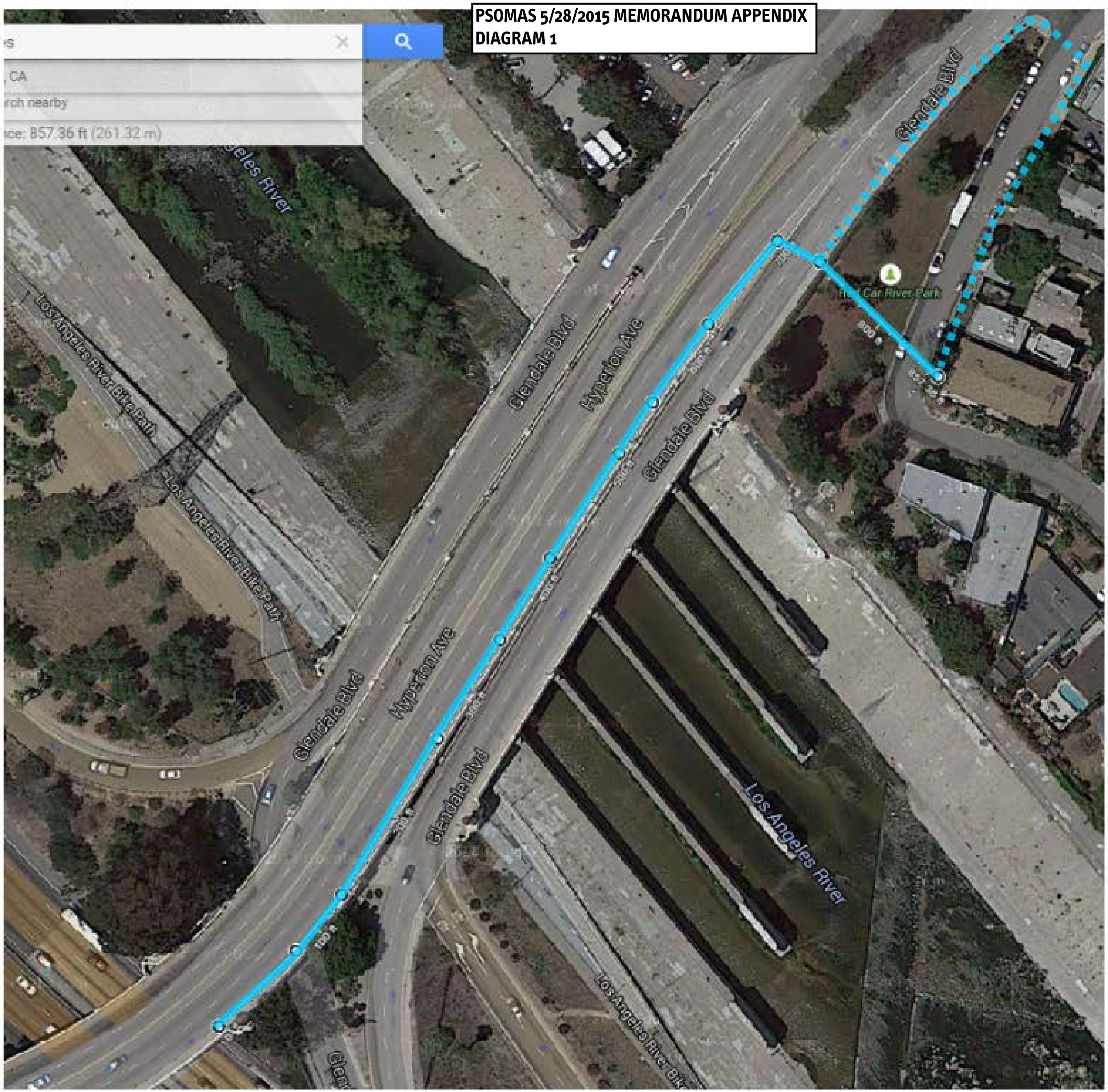
HYPERION AVENUE AT WAVERLY DRIVE (LOOKING NORTH)

1) THREE-10 FT. LANES (ONE LANE DOWNHILL ; TWO LANES UPHILL)
2) SIDEWALK AND BUFFER ON BOTH SIDES
3) 4 FT. MEDIAN (NO BARRIER)



This Exhibit is strictly a preliminary design alternative under consideration, and does not represent the final design of the bridge.

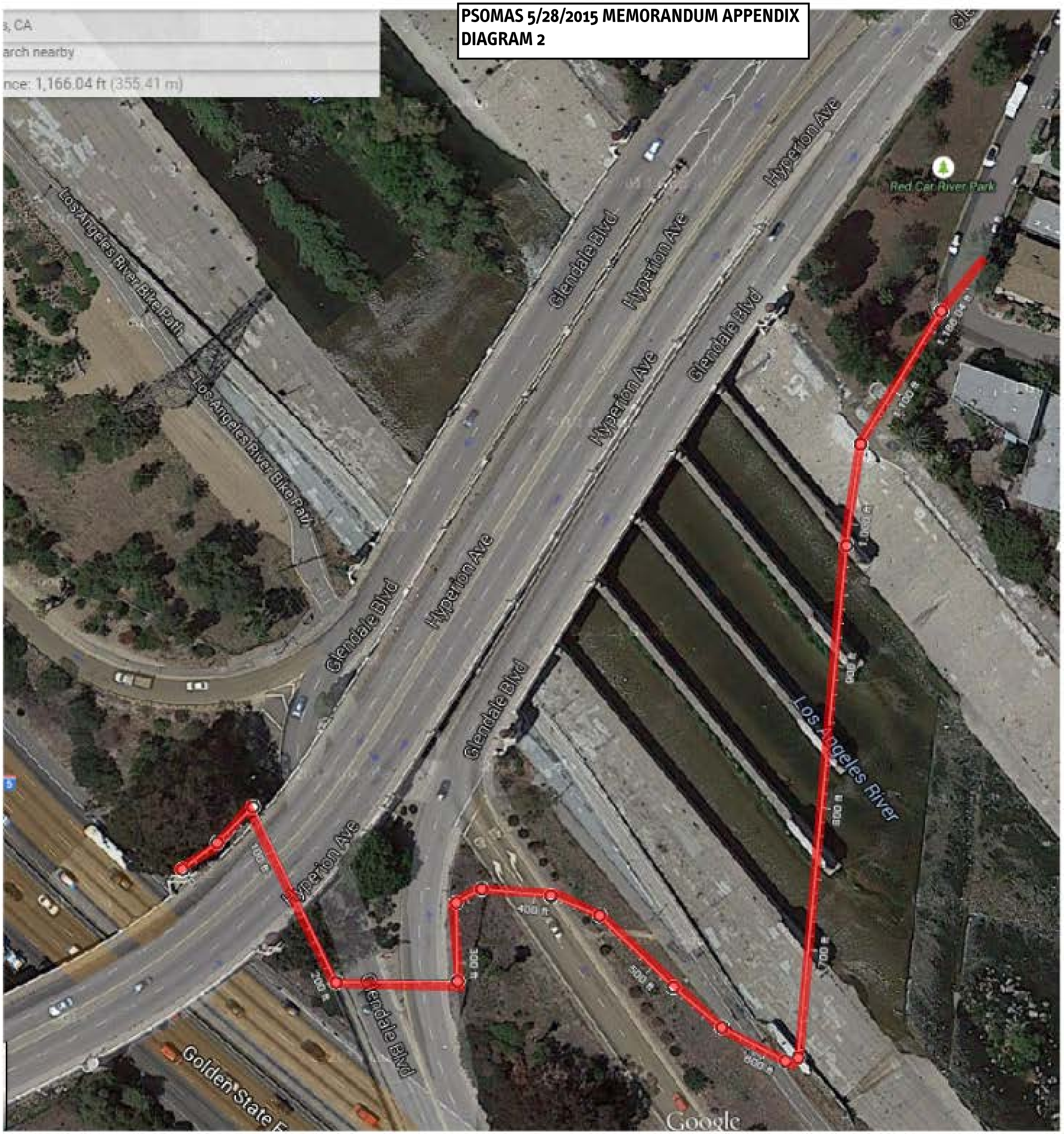
PSOMAS 5/28/2015 MEMORANDUM APPENDIX
DIAGRAM 1



Sidewalk on south side of bridge - 860 ft (non-ADA compliant, uses slope)

If ADA compliant (going to Greensward and coming back, dashed line) would be 1,260 ft.

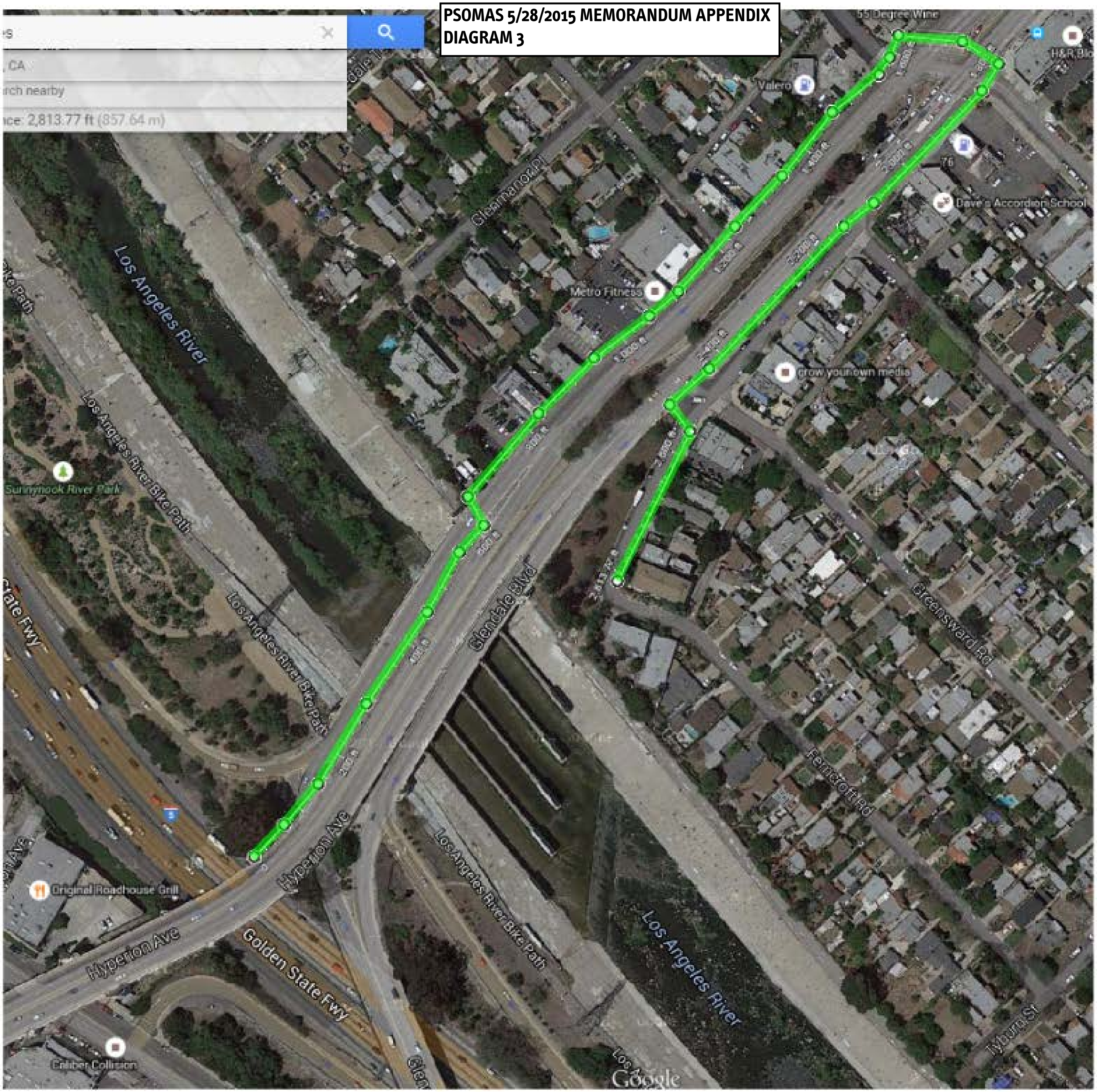
PSOMAS 5/28/2015 MEMORANDUM APPENDIX DIAGRAM 2



Using stair and Red Car pedestrian bridge - 1,170 ft (non-ADA compliant at stairs).

Additional 310 ft at 3.5 ft/s walking speed = 1.5 min additional walking time.

PSOMAS 5/28/2015 MEMORANDUM APPENDIX DIAGRAM 3



Using sidewalk on west side of bridge then crossing at Glenfeliz - 2,810 ft (ADA compliant)

Compared to shortest ADA route on south side (1,260 ft) adds 1,550 ft.

At 3.5 ft/s walking speed adds 7.4 minutes walking time